IMPACT OF CROP-MANAGEMENT HISTORY ON ORGANICALLY FERTILIZED SWEET CORN (*Zea mays* L.)

By

KIMBERLY A. SEAMAN

A THESIS PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE

UNIVERSITY OF FLORIDA

2005

To my parents, Jeffrey and Karen Seaman

ACKNOWLEDGMENTS

I would like to extend my greatest thanks, acknowledgements, and praise to Dr. R. N. Gallaher, my major professor, for his extensive instruction, guidance, support, and friendship during my studies at the University of Florida. I would also like to thank Dr. R. McSorley for all of his support and editorial assistance. I would like to acknowledge Dr. E. Whitty and Dr. R. Gilbert for their editing and advice. Special thanks are given to Dr. K-H. Wang, Mr. J. Chichester, and Mr. H. Palmer for all of their assistance in the laboratory and in the field. I would also like to acknowledge the providers of the USDA-CREES grant entitled, 'Effects of Management Practices on Pests, Pathogens, and Beneficials in Soil Ecosystems' which has supported my research and education.

My deepest thanks and love are given to my parents, Jeffrey and Karen Seaman, and my sister, Kelly. Their support and advice have been constant and I never could have completed such a task without them. I would also like to specially thank Ms. Belkys Bracho for her friendship and advice throughout my studies in Gainesville. Finally, I want to thank all of my friends for their unending support and confidence.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Abstract of Thesis Presented to the Graduate School
of the University of Florida in Partial Fulfillment of the
Requirements for the Degree of Master of Science

IMPACT OF CROP-MANAGEMENT HISTORY ON ORGANICALLY FERTILIZED SWEET CORN (*Zea mays* L.)

By

Kimberly A. Seaman

May 2005

Chair: R.N. Gallaher
Major Department: Agronomy

Farmers make decisions daily that impact the environment. Multiple cropping, no-tillage management, and organic fertilizers are all agronomic techniques that promote sustainable agriculture and benefit the environment and farmer alike.

Research was conducted to investigate the effects of no-tillage multiple cropping systems on organically fertilized sweet corn (*Zea mays* L.). A split-split plot experiment was conducted to examine cropping history, N source, and N rate. Production, in terms of yield and quality, and plant nutrient concentrations were determined. Sweet corn yield was not affected by cropping history; but was affected by N source, with the inorganic source producing significantly higher yields than organic sources (5.2, 5.2, and 6.0 ears m^{-2} for lupine (*Lupinus angustifolius* L.), vetch (*Vicia villosa* L. Roth), and ammonium nitrate, respectively) ($p \leq 0.05$). Diagnostic leaf N concentration was affected by cropping history and N source ($p \leq 0.05$). Equal response of sweet corn to organic and inorganic N sources may be achieved by choosing appropriate rates of organic N.

Crops within the systems were also examined. An experiment was conducted to investigate applied N management, yield, and plant mineral concentrations of sweet corn hybrids. Nitrogen treatments had a minor effect on measured variables compared to hybrids, with ‘Silver Queen’ and ‘8102R’ proving to be the best hybrids for fall production in Florida.

Cowpea (*Vigna unguiculata* (L.) Walp.) and lima bean (*Phaseolus lunatus* L.) were also examined for yield and plant mineral content. For production in Florida in a cropping system or for use as an organic mulch, ‘Iron Clay’ cowpea was the best candidate, while ‘California Blackeye #5’ was the best for consumption. The lima bean hybrid ‘Fordhook’ was the top choice for food crop production.

Sunn hemp (*Crotalaria juncea* L.) was also investigated, to determine the effects of plant height and population on yield and mineral concentration. Plants grown at densities of 18 and 30 plants m^{-2} and maintained at heights of 0.4 and 0.8 m produced highest yields and highest mineral concentrations. The effect of previous crops on Austrian winter pea (*Pisum arvense* L.) was also investigated, with N concentration in dry matter highest (4.4% N) following sweet corn. Plant-parasitic nematode populations were also examined following each crop, and were found to be lowest following sunn hemp and Austrian winter pea.

CHAPTER 1
INTRODUCTION

Multiple Cropping

Multiple cropping is an agronomic practice used by farmers for thousands of years. The practice of harvesting more than one crop from the same land over the course of a year is especially successful in areas with tropical or subtropical climates. Florida's climate is suitable for the production of multiple crops in 1 yr, and as many as 3 or more sequential crops can be harvested. Multiple cropping used in conjunction with no-tillage cropping can increase the success of crop production (Gallaher, 1980). No-tillage practices are defined as any tillage and planting system that maintains at least 30% of the soil surface covered by residue after planting in order to decrease soil erosion by water (Gallaher and Ferrer, 1987). The characteristics of Florida's climate are conducive to the implementation of both of these practices, the high temperatures and humidity helping to rapidly break down crop residues and avoid over-accumulation.

Multiple cropping also offers many benefits when crops such as legumes are included in the system. Legumes have the capacity to fix N, which reduces the need for added N fertilizers. The use of legumes in a cropping system can increase the amount of N in the soil and the N that is available to subsequent crops, decreasing the need for added inorganic fertilizers. Specific legume species have also been found to aid in nematode control, possessing suppressive qualities that reduce nematode populations, which can be very destructive especially in the Southeast (Davis et al., 1991).

No-Tillage Cropping

The utilization of both multiple cropping and no-tillage cropping can be very beneficial. No-tillage cropping greatly reduces soil-bed preparation, which can contribute to timely planting over more land area. Less labor is required, and also less equipment and fuel use, which can help reduce maintenance and upkeep costs (Gallaher, 1980). Less tillage also greatly helps to improve soil health by reducing erosion and maintaining soil moisture. The organic matter of soil can also be greatly increased by no-tillage practices. In a 6-yr study conducted in Florida, soil 0 to 5 cm in depth was found to be 36% higher in organic matter than that in conventional cropping systems (Gallaher and Ferrer, 1987).

Cropping History

Diversified cropping histories also influence the supply of nutrients to growing crops. Crops differ considerably in the amount of N, one of the most important nutrients for crop growth, returned in residue for use by subsequent crops because N supplied depends on volume of residue as well as N concentration of the residue (Grant et al., 2002). Varying crop species and nutrient management of those species will affect the nutrient content of crop residues and the amount of nutrients that will become available for subsequent crops. The inclusion of crops such as legumes into cropping histories can increase available N for (and also reduce inorganic N requirements of) subsequent non-legume crops.

Phosphorus and N availability are necessary to optimize crop yield and quality and efficiency of crop production (Grant et al., 1996). Cropping history can also influence P levels in soil. A history of crops high in P produced in a no-tillage system can greatly benefit subsequent crops. Increased availability of P can occur through biocycling of crop residue and litter.

Another important nutrient for crop health and productivity is K. Approximately 80% of plant K is located in stubble (Whitbread et al., 1998) and the potential for return to the soil for use by succeeding crops is greatly influenced by residue management. Crops containing higher levels of K would be more suited for inclusion in a cropping history managed with no-tillage practices, potentially supplying more K for later crops through residue.

Careful consideration must be paid to what crops should be chosen for inclusion in cropping systems. Variations in cropping history influence many aspects of crop production, especially soil properties. Diversification of cropping systems affects physical, chemical, and microbiological characteristics of soil. Increasing crop production can increase the amount of plant biomass produced and returned to the soil as residue and root material (Grant et al., 2002). As a result, soil organic matter content may increase (Wood et al., 1990) and this can improve the stability and structure of the soil (Campbell and Zentner, 1993) as well as nutrient cycling. Cropping history can impact soil respiration, microbial biomass, and soil microbiological diversity (Lupwayi et al., 1999).

Organic Mulches

The use of organic mulches and fertilizers is another agricultural technique often used in conjunction with multiple cropping and no-tillage practices. Organic mulches bring many benefits to cropping systems, especially to the soil. Legumes can add N to soil, especially in the form of a mulch. Other nutrients are also made available to subsequent crops by using organic mulches, the most important of which include P, K, Ca, and Mg. Applying mulches can reduce soil erosion, conserve soil moisture, and prevent weed infestation. Also, the structure of the soil can be improved with the addition of organic matter from the breakdown of the organic mulch.

Crop yield and quality, including nutrient production, can be improved with the proper utilization of multiple cropping and no-tillage cropping systems. Nitrogen management is also important for achieving high yields of healthy crops. An efficient cropping system will balance crop demands for N with timing and rate of N supply so that crop yield is maximized while N is neither depleted from the soil nor accumulated (potentially contaminating ground or surface waters) (Grant et al., 2002). The source, rate, and timing of applied fertilizer can be determined to meet these goals.

A 2-yr investigation that integrated these agronomic principles was conducted from the fall of 2002 to the spring of 2004. Three different multiple cropping systems were established each year and maintained using no-tillage techniques (Table 1-1). The first history included sweet corn (*Zea mays* L.), followed by Austrian winter pea (*Pisum arvense* L.), followed by sweet corn. This same sequence of crops was repeated during both years of the study for the first history. The second cropping history included cowpea (*Vigna unguiculata* (L.) Walp.), followed by Austrian winter pea, followed by sweet corn for the first year of the study. In the second year, lima bean (*Phaseolus lunatus* L.) replaced cowpea, and the remainder of the history was repeated. The third history included sunn hemp (*Crotalaria* juncea L.), followed by Austrian winter pea, followed by sweet corn. The same sequence of crops was grown for both years of the study for the third cropping history. The investigation focused on the final sweet corn crop of each year of the study and the impact that each multiple cropping history had on the sweet corn. Different rates and sources of N were also examined during the final sweet corn crop. The individual crops within each history were also examined. The specific objectives of this research were as follows:

- Evaluate yield and plant nutrition of sweet corn due to varying N management treatments and varieties.
- Evaluate yield and plant nutrition of cowpea and lima bean varieties.
- Analyze sunn hemp for mineral concentration to determine mineral content and find the best clipping height and population for maximum yield and N content.
- Compare three cropping histories for their effect on yield of an Austrian winter pea cover crop and analyze the legume for mineral concentration to compare mineral content across three cropping histories.
- Evaluate yield and plant nutrition of sweet corn due to varying cropping histories, N sources (organic and inorganic), and N rates.
- Determine which cropping histories resulted in low nematode population densities.

Table 1-1. Cropping histories from fall 2002 to spring 2004.

	Cropping histories		
Season	1	2	3
Fall 2002	Sweet corn	Cowpea	Sunn hemp
Winter 2003	Austrian winter pea	Austrian winter pea	Austrian winter pea
Spring 2003	Sweet corn	Sweet corn	Sweet corn
Fall 2003	Sweet corn	Lima bean	Sunn hemp
Winter 2004	Austrian winter pea	Austrian winter pea	Austrian winter pea
Spring 2004	Sweet corn	Sweet corn	Sweet corn

CHAPTER 2
YIELD AND PLANT NUTRITION FOR NINE SWEET CORN HYBRIDS RECEIVING THREE NITROGEN MANAGEMENT TREATMENTS

Introduction

Sweet corn (*Zea mays* L.) is an economically important crop for Florida. The Florida climate provides a suitable environment for sweet corn production at a time when most of the US is too cold for corn growth (Gallaher and McSorley, 1998). Florida is the major source of sweet corn during the winter and early spring, with harvesting most active from November to June (Florida Commodities, 2002). In 1998, Florida was the top ranking state in gross receipts from sweet corn production (Orzolek et. al., 2003). Over 15,900 ha of sweet corn were planted in Florida in the 2002-03 season, yielding over 16,100 kg ha^{-1} of fresh produce and bringing in well over $89 million to the state's economy (Florida Agricultural Statistics Service, 2004).

The recommended amount of N fertilizer for sweet corn in Florida is 224 kg ha^{-1} (Hochmuth et al., 1996). In a study conducted from 1992-95 in Iowa, sweet corn grown in cropping systems following rye (*Secale cereale* L.) exhibited a linear response in yield to increasing rates of N fertilizer, with affects peaking at an N rate of 156 kg N ha^{-1} (Griffin et al., 2000). In a study in Minnesota, sweet corn (var. Rugosa Bonaf.) silage waste was applied to a crop of field corn (*Zea* mays L.) and was found to significantly increase in-season and post-harvest soil N concentrations and to optimize grain yield and N uptake of the field corn (Fritz et al., 2001). These studies illustrate the variation and importance of N management in corn production.

Sweet corn can provide farmers with a very viable option for multiple cropping systems. The cultivation of sweet corn following strawberry (*Fragaria x Ananassa*) in a cropping system cultivated in Taiwan was found to be effective in utilizing the high residual N after the strawberry harvest (Lian, 1991). Conversely, production of sweet corn, which was chosen for its high N requirement and early maturity, in Quebec was found to benefit from the use of cover crops that absorbed excess fertilizers following harvest (Isse et al., 1999). Sweet corn can be a beneficial component of cropping systems because succeeding crops can absorb residual soil N, reducing the need for applied N, as well as minimize losses of fertilizer to leaching (Isse et al., 1999). The use of sweet corn in cropping systems, especially after several years of a cover crop such as alfalfa (*Medicago sativa* L.), was also found to reduce weed pressure during the year the sweet corn was produced (Delahaut and Thiede, 2002).

Due to increasing interest in the reduction of nutrient leaching and the more precise application of fertilizers, a 2-yr experiment was conducted to investigate applied N management on 9 different varieties of sweet corn. This test was also part of a larger study (see Chapter 6) conducted to investigate the effects of cropping histories on no-till sweet corn. This particular portion of the overall study comprised the first of 3 cropping histories tested. The objectives of this study were to evaluate the yield and plant nutrition of sweet corn due to varying N management treatments and varieties.

Materials and Methods

For this study, a split-plot experiment was conducted from August to November of 2002 and 2003. Main effects were 3 N application treatments (4, 3, and 2 equal split applications) of ammonium nitrate (AN), each totaling the recommended 224 kg N ha^{-1} (IFAS Extension Soil Testing Laboratory, 2002). The main effects allowed us to determine the optimum N management for sweet corn. Sub-effects were 5 different hybrids of sweet corn ('Merritt', 'Silver Queen', 'Golden Queen', 'Florida Stay Sweet', and 'Peaches and Cream' in 2002), ('Silver Queen', '8100R', 'Prime Plus', '8102R', and 'Big Time' in 2003). Throughout both years of the study, corn was irrigated to ensure at least 3 cm of water per week, and weeded both mechanically and manually. Data from each year was analyzed separately, because with the exception of 'Silver Queen', hybrids differed each year.

The split-plot design is specifically suited for a 2-factor experiment that has more treatments than a randomized complete block design can accommodate (Gomez and Gomez, 1984). In this design, the precision for the measurement of the effects of the main-plot factor is sacrificed to improve that of the subplot factor. The randomization process in this design is performed separately for each effect.

Nitrogen Application

In order to more precisely examine applied N fertilizer and any subsequent nutrient leaching, we evaluated the effects of varying N management treatments on a crop of sweet corn. Three different management plans were implemented and the null hypothesis stated that the various plans would not affect final sweet corn yield or nutrient concentration in diagnostic leaf samples.

Sweet corn was planted on 29 August of 2002 and on 25 August of 2003. Each plot contained four 0.76 m wide rows and measured 2 m by 3 m. Varieties were planted by hand at a rate of 10 seeds m^{-2} into Millhopper fine sand (loamy siliceous semiactive hyperthermic Grossarenic Paleodults [USDA-NRCS, 2003]). Plants were thinned by hand to approximately 6 plants m^{-2} during both years of the study.

The N treatments were all applied by hand during both years of the study. Treatment 1 was split into 4 equal applications of AN at 56 kg N ha^{-1}. Application began 1 week after planting and continued every 12 days following until the total recommended N had been applied. Treatment 2 was split into 3 equal AN applications at 75 kg N ha^{-1}. Application began 1 week following planting and continued every 16 days following until the total recommended N had been applied. Treatment 3 was split into 2 equal applications of AN at 112 kg N ha^{-1}. The initial application took place 1 week following planting and a second 24 days later to complete the total recommended N.

Sweet Corn Varieties

Five different varieties of sweet corn were tested during the first year of the study. Four additional varieties were tested during the second year of the study in conjunction with the highest yielding variety from the first year. New varieties were tested during the second year in order to increase the number of hybrids tested. Also, during the first year of the study, some hybrids did not grow tall enough to avoid damage from rodents and taller-growing hybrids were needed. Each crop of sweet corn was analyzed separately for yield and nutrient concentrations. Soil samples were taken from a depth of 20 cm directly following harvest.

Nitrogen Analysis

Five diagnostic leaves, or the fifth leaf from the top of each plant, were obtained during early tassel stage from each plot during both years of the experiment for analysis (Mills and Jones, 1996). Sample leaves were combined from each plot and analyzed for leaf area with a LI 3100 Area Meter (LI-COR, Inc., Lincoln, NE), weighed for fresh matter yield, dried in a forced air oven at 70°C, and weighed again for dry matter yield.

Leaf samples were then ground in a Wiley mill to pass a 2-mm stainless steel screen. The samples were then stored in plastic sample bags before analysis.

Nitrogen analysis of the diagnostic leaf samples was performed using a modified micro-Kjedahl procedure. A mixture of 0.100 g of each leaf sample, 3.2 g salt-catalyst (9:1 K_2SO_4:$CuSO_4$), 2 to 3 glass boiling beads and 10 mL of H_2SO_4 were vortexed in a 100 mL test tube. In order to reduce frothing, 2 mL 30% H_2O_2 were added in 1 mL increments and tubes were then digested in an aluminum block digester at 370 C for 3.5 hours (Gallaher et al., 1975). Cool digested solutions were brought to 75 mL volume and were filtered to remove the boiling beads. Solutions were then transferred to square Nalgene storage bottles, sealed, mixed, and stored. Nitrogen trapped as $(NH_4)_2SO_4$ was analyzed on an automatic solution sampler and a proportioning pump. A plant standard with a known N concentration value was subjected to the same procedure as the leaf samples and used as a check (Multiple Cropping Agronomy Lab, University of Florida). Fresh matter, dry matter, and nutrient concentrations were recorded for each crop of sweet corn.

Mineral Analysis

For mineral analysis, 1.0 g from each leaf sample was weighed into 50 mL beakers and ashed in a muffle furnace at 480°C for 6 h. The samples were then cooled to room temperature and moistened with de-ionized water. Twenty mL of de-ionized water and 2 mL of concentrated HCl were added to each beaker, which were then placed on a hot plate and slowly boiled to dryness before being removed. An additional 20 mL of de-ionized water and 2 mL concentrated HCl were then added and small watch glasses were used to cover the beakers for reflux. They were brought to a vigorous boil and then removed from the hot plate and again allowed to cool to room temperature. The samples were then brought to volume in 100 mL flasks and mixed. The flasks were set aside overnight to allow the Si to settle. The solutions were decanted into 20 mL scintillation vials for analysis. Phosphorus was analyzed by colorimetry, K and Na by flame emission, and Ca, Mg, Cu, Fe, Mn, and Zn by atomic adsorption spectrometry (AA). Data from each year were analyzed by ANOVA for a split-plot experimental design using MSTAT 4.0 (1985). Means were separated by least significant difference (LSD) at the 0.05 level of probability (Gomez and Gomez, 1984).

Yield

For both years of the experiment, the ears from each plot were hand collected before being graded and separated into >15.2 cm, 12.7 to 15.2 cm, 10.2 to 12.7 cm, and <10.2 cm length categories (USDA, 1954). The ears were then counted and weighed in order to obtain fresh weights.

Soil Analysis

During both years of the study, soil samples were obtained from the top 20 cm of soil directly following harvest. Samples were air-dried in open paper bags, then screened through a 2.0-mm stainless steel sieve to remove any rocks or debris and stored for further analysis.

The samples were then analyzed for N, mineral concentrations, pH, buffer pH (BpH), organic matter (OM), and cation exchange capacity (CEC). For soil N, a mixture of 2.0 g of each soil sample, 3.2 g of salt catalyst (9:1 K_2SO_4:$CuSO_4$), and 10 mL of H_2SO_4 were subjected to the same procedures for N analysis as leaf tissue was, except that boiling beads were not used because the particles of soil served the same purpose. A soil sample of known N concentration was also analyzed and used as a check. For soil mineral analysis, a Mehlich I (Mehlich, 1953), extraction method was used. Five g of each soil sample were weighed and extracted with 20 mL of a combination of 0.025 N H_2SO_4 and 0.05 N HCl. Using an Eberach shaker at 240 oscillations minute^{-1}, mixtures were shaken for 5 min. The mixtures were then filtered using Schleischer and Schuell 620 (11 cm) filter paper and poured into scintillation vials. The remaining solutions were then subjected to analysis of P, K, Ca, Mg, Na, Cu, Fe, Mn, and Zn in the same manner as described for leaf tissue analysis.

Soil pH was found using a 1:2 soil to water volume ratio using a glass electrode pH meter (Peech, 1965). Buffer pH was found using Adams/Evans buffered solution (Adams and Evans, 1962). Cation exchange capacity was estimated by the summation of relevant cations (Hesse, 1972; Jackson, 1958). Estimated soil CEC was calculated by summing the milliequivalents of the determined bases of Ca, Mg, K, and Na (where applicable) and adding them to exchangeable H^+ expressed in milliequivalents per 100 grams (meq 100 g^{-1} or cmol kg^{-1}) (Hesse, 1972). For the determination of OM, a modified version of the Walkley Black method was used, in which 1.0 g of soil was weighed into a 500-mL Earlenmeyer flask, and 10 mL of 1 N $K_2Cr_2O_7$ solution was then pipetted into the flask. Twenty mL of concentrated H_2SO_4 was added and mixed by gentle rotation for 1 min using care to avoid throwing soil up onto the sides of the flask. The flask was then left to stand for 30 min, and then diluted to 200 mL with de-ionized water. Five drops of indicator were added, and the solution was titrated with 0.5 N ferrous sulfate solution until the color sharply changed from a dull green to a reddish brown color. A flask without soil was prepared in the same manner and titrated to determine the blank titrant, along with a flask containing a check soil with a known amount of OM. Percent OM was determined using the equation: percent OM = (1-T/S) x

6.8, where S is blank-titration in mL of ferrous ammonium sulfate solution, and T is sample titration in mL ferrous ammonium sulfate solution (Walkley, 1935; Allison, 1965).

Statistical Analysis

Data was recorded in Quattro Pro (Anonymous, 1987) spreadsheets and transferred to MSTAT 4.0 (Anonymous, 1985) for analysis of variance using the appropriate model for the experimental design (Tables 2-1 to 2-7). Mean separation was performed using fixed LSD at the 0.05 level of probability (Gomez and Gomez, 1984).

Results

Data for 2002

The number of sweet corn ears measuring >15.2 cm in length for 2002 displayed no significant ($p>0.05$) differences among N management treatments (Table 2-8). Significant ($p\leq0.05$) differences occurred among sweet corn hybrids, with 'Silver Queen' producing the highest number of top grade ears (Table 2-8). Ears measuring 12.7 to 15.2 cm in length did not differ ($p>0.05$) among N management treatments, but again, differences ($p\leq0.05$) were found among hybrids (Table 2-8). Number of ears measuring 10.2 to 12.7 cm did not differ ($p>0.05$) among N management treatments, but differences ($p\leq0.05$) were found among hybrids (Table 2-8). The lowest grade ears differed ($p>0.05$) among N management treatments as well as among sweet corn hybrids (Table 2-8). Total ears produced in 2002 also differed ($p\leq0.05$) among N management treatments and hybrids, with 4 N splits yielding highest and 'Silver Queen' as the top-producing hybrid (Table 2-8). In summary, 'Silver Queen' produced the highest number of total ears as well as the highest number of top grade ears.

The fresh weight of ears >15.2 cm in length produced in 2002 exhibited no significant (p>0.05) differences among N management treatments (Table 2-9). Significant ($p \leq 0.05$) differences occurred among sweet corn hybrids for the weight of top grade ears, with 'Silver Queen' as the top-producing hybrid (Table 2-9). Fresh weight of ears measuring 12.7 to 15.2 cm were not statistically different (p>0.05) among N management treatments, but differed among hybrids (Table 2-9). Weights of sweet corn ears 10.2 to 12.7 cm in length were not statistically different (p>0.05) among N management treatments, but displayed significant differences ($p \leq 0.05$) among hybrids (Table 2-9). Fresh weight of ears measuring <10.2 cm in length exhibited significant ($p \leq 0.05$) differences among both N management treatments and hybrids (Table 2-9). No statistical differences (p>0.05) were demonstrated among N management treatments for total ear weight produced, while significant ($p \leq 0.05$) differences occurred among sweet corn hybrids, again with 'Silver Queen' as top-producing hybrid (Table 2-9). 'Silver Queen' produced not only the most total ear weight, but also the most top grade ear weight in 2002.

The fresh weights of the fifth leaf, or diagnostic leaf, harvested in 2002 were found to exhibit no significant (p>0.05) differences among N management treatments (Table 2-10). Statistical differences ($p \leq 0.05$) were found among sweet corn hybrids, with 'Silver Queen' producing the heaviest leaves (Table 2-10). The dry weights of the fifth leaves were not statistically different (p>0.05) among N management treatments, but were among hybrids with 'Silver Queen' producing the heaviest leaves (Table 2-10). The leaf area index did not display any significant (p>0.05) differences among N management treatments, but did among hybrids, with 'Peaches and Cream' producing the largest leaves (Table 2-10).

Percent seed emergence of sweet corn in 2002 displayed an interaction between N management treatments and the sweet corn hybrids (Table 2-11). Both plant and ear height of sweet corn for 2002 did not exhibit significant (p>0.05) differences among N management treatments, while both did exhibit differences (p≤0.05) among corn hybrids (Table 2-12). 'Silver Queen' and 'Golden Queen' hybrids produced the tallest plants and highest ears on the stalk.

Among the macronutrients in the diagnostic leaf in 2002, only Ca, P, and N were not significantly (p≥0.05) different among N management treatments (Table 2-13). The N management treatments were statistically different (p≤0.05) for Mg, K, and Na (Table 2-13). While interactions were present in Mg and Na between N management treatments and hybrids, K and P displayed statistical differences (p≤0.05) among sweet corn hybrids (Table 2-13). Among the micronutrients, interactions between N management treatments and hybrids were present in Cu, Mn, and Zn (Table 2-13). Significant (p≤0.05) differences were displayed among N management treatments as well as among sweet corn hybrids for Fe (Table 2-13).

For soil macro- and micro- nutrients, no significant (p>0.05) differences were exhibited, either among N management treatments or among sweet corn hybrids (Table 2-14). Soil pH was not statistically different (p>0.05) among N management treatments, but was among hybrids (Table 2-14). Soil BpH displayed an interaction between N management treatments and hybrids (Table 2-14). Soil CEC was not statistically different (p>0.05) among N treatments or hybrids (Table 2-14). Soil OM displayed significant ($p \leq 0.05$) differences among N management treatments, but not among hybrids (Table 2-14).

Data for 2003

The number of sweet corn ears produced in 2003 measuring >15.2 cm in length were not statistically different ($p > 0.05$) among N management treatments, but were among sweet corn hybrids (Table 2-15). Hybrid '8102R' was the top producer for the highest-grade ears (Table 2-15). The numbers of ears 12.7 to 15.2 cm in length were statistically different ($p \leq 0.05$) among N management treatments as well as among hybrids (Table 2-15). Ears measuring 10.2 to 12.7 cm were not significantly ($p \geq 0.05$) different among N management treatments, but were among corn hybrids (Table 2-15). Ears <10.2 cm were also not significantly ($p \geq 0.05$) different among N management treatments, but were among hybrids (Table 2-15). The total ears produced in 2003 did not differ ($p \geq 0.05$) among N management treatments, but did among sweet corn hybrids (Table 2-15). 'Silver Queen', '8100R', and '8102R' were all top-producing hybrids in 2003 (Table 2-15).

The fresh weights of ears >15.2 cm produced in 2003 did not display significant ($p > 0.05$) differences among N management treatments, but did among corn hybrids (Table 2-16). Hybrid '8102R' produced the highest number of top-grade ears (Table 2-16). An interaction was displayed between N management treatments and hybrids in ears measuring 12.7 to 15.3 cm (Table 2-16). No statistical differences ($p > 0.05$) were exhibited among N management treatments in ears 10.2 to 12.7 cm, while sweet corn hybrids were statistically different ($p \leq 0.05$) (Table 2-16). Ears <10.2 cm were significantly ($p \leq 0.05$) different among N management treatments as well as among hybrids (Table 2-9). Fresh weights of total ears produced were not statistically different

($p>0.05$) among N management treatments, but differed ($p\leq0.05$) among hybrids (Table 2-16). Hybrid ‘8102R’ was the highest producing hybrid in 2003 (Table 2-16).

Fresh weights of fifth leaves from 2003 displayed statistical differences ($p\leq0.05$) among both N management treatments and corn hybrids (Table 2-17). Dry weights also were not significantly ($p>0.05$) different among N management treatments but were among sweet corn hybrids (Table 2-17). No statistical differences ($p>0.05$) were displayed among N management treatments for leaf area index, but differences ($p\leq0.05$) occurred among hybrids (Table 2-17). Plant emergence of sweet corn in 2003 was not statistically different ($p>0.05$) among N management treatments, but was among sweet corn hybrids, with ‘8102R’ having highest emergence (Table 2-18).

Among the macronutrients in the diagnostic leaves sampled in 2003, only Mg and N displayed significant ($p\leq0.05$) differences among N management treatments (Table 2-19). Significant ($p\leq0.05$) differences among sweet corn hybrids were only exhibited in Ca, K, and N (Table 2-19). Among micronutrients, statistical differences ($p\leq0.05$) among N management treatments were only demonstrated in Mn (Table 2-19). Significant ($p\leq0.05$) differences among sweet corn hybrids were displayed for Fe, Mn and Zn, but not Cu (Table 2-19).

Soil mineral analysis for 2003 did not exhibit any significant ($p\geq0.05$) differences among N management treatments for any minerals (Table 2-20). In addition, no statistical differences ($p>0.05$) were found among N management treatments for soil pH, BpH, or CEC (Table 2-21). Soil OM was greatest ($p\leq0.05$) when N was applied in 4 splits.

Discussion and Conclusion

Data for 2002

The objectives of this study were to investigate yield and plant nutrition due to N management treatments and sweet corn hybrids. The varying N treatments were found to have a minor effect on the measured variables in comparison to the hybrids, which had a much more significant effect. In 2002, 'Silver Queen' was the highest producing hybrid of top grade and total ears. 'Silver Queen' produced the heaviest, but not largest diagnostic leaves. This hybrid also produced some of the tallest plants and highest ears from the ground. From our 2002 data, for fall sweet corn production in central Florida, 'Silver Queen' was the best hybrid choice for high yields in combination with split applications of N.

The cause for the interaction in seed emergence between N management and sweet corn hybrids is not known. It is most likely due to germination differences among hybrids and possible differences in N requirements. The seedlings were receiving varying amounts of N during seedling emergence, which may have affected some hybrids differently.

Mineral analysis of the diagnostic leaf indicated that all macronutrients were well within sufficiency ranges appropriate for sweet corn during the tasseling stage (Hochmuth et al., 1991; Mills and Jones, 1996). The N levels in 'Silver Queen' were not found to be the highest among the hybrids. This could be due to a dilution effect since this hybrid did produce the largest plants. All of the micronutrients were found to be sufficient for sweet corn (Hochmuth et al., 1991; Mills and Jones, 1996).

The interactions between N splits and hybrids found for several minerals may be due to a timing of N splits in relation to hybrid maturity. A lessening of N split effect with the 4-split management treatment may have occurred, with the fourth split being applied too late to give any real benefit to the plants. Also, the 2-split treatment may have not been as effective. The first of the 2 applications may have occurred too early, leaving only half of the recommended N to be applied to the plants throughout the experiment. If any adverse weather, such as a heavy rain, occurred, the N may have been leached away before the plants could benefit from it.

Soil mineral analysis displayed no hybrid effects and only one N management treatment effect. The mineral that was affected by N treatments was Ca. Plant uptake of this mineral can be depressed by ammonium (Mills and Jones, 1996), which is the form of the N used here, but there is no significant evidence of this occurrence. The pH of the soil was in an acceptable range for nutrient availability and the high nutrient levels were demonstrated by OM and CEC (Brady and Buckman, 1969).

Data for 2003

In 2003, sweet corn hybrids were again found to have more significant effects than the N management treatments. Hybrid '8102R' was the highest producer of top grade ears as well as total ears. The hybrid also produced some of the heaviest and largest diagnostic leaves and also had the best plant emergence. Hybrid '8102R' would be another possible choice for fall production of sweet corn in central Florida with applied N split into at least 2 applications. The cause of the interactions between N splits and hybrids in ear production are unknown.

Mineral analysis of the diagnostic leaves demonstrated that all of the macronutrients were within suggested sufficiency ranges for sweet corn during tasseling (Hochmuth et al., 1991; Mills and Jones, 1996). The interaction in N levels between N managements and hybrids could be due to problems with N availability with early and late application. Micronutrients were all found to be within suggested sufficiency ranges as well (Hochmuth et al., 1991, Mills and Jones, 1996).

Mineral analysis of the soil samples again demonstrated no effects due to N management treatments or to hybrids. Soil was not a variable in hybrid response. Levels of N, P, and K were found to be slightly elevated. These elevated levels could be due to the application of organic amendments in this same test area during the prior growing season. Soil pH was in good range for nutrient availability (Brady and Buckman, 1969). Soil OM was the only characteristic to be affected by N treatments.

Both ‘Silver Queen’ and ‘8102R’ were found to be superior hybrid choices for fall production of sweet corn in central Florida. However, greater yield potential would likely occur from earlier planting dates than occurred in this study. A particular number of N splits cannot be suggested, although the management of N fertilizer for sweet corn should be split into at least 2 applications, in order to diminish the effects of sandy soils and possible leaching. The number of split applications should be economically based.

Table 2-1. Sweet corn ear yield for N management treatments and sweet corn hybrids for 2002 analysis of variance.

		>15.2 cm‡	15.2–12.7 cm	12.7–10.2 cm	<10.2 cm	Total ears	>15.2 cm	15.2–12.7 cm	12.7–10.2 cm	<10.2 cm	Total ears
Source of variation	df	No. of ears					Fresh weight of ears				
Replications	4	—	—	—	—	—	—	—	—	—	—
N splits (N)	2	ns†	ns	ns	**	*	ns	ns	ns	**	ns
Error	8	—	—	—	—	—	—	—	—	—	—
Hybrids (H)	4	***	***	***	***	***	***	***	***	***	***
N x H	8	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Error	48	—	—	—	—	—	—	—	—	—	—
Total	74	—	—	—	—	—	—	—	—	—	—

* Significant at the 0.05 level.
** Significant at the 0.01 level.
*** Significant at the 0.001 level.
†ns = not significant.
‡Sweet corn ear lengths, according to USDA standards (USDA, 1954).

Table 2-2. Sweet corn diagnostic leaf yield, seed emergence, and plant and ear height for N management treatments and sweet corn hybrids for 2002 analysis of variance.

Source of variation	df	Leaf fresh weight	Leaf dry weight	Leaf area index	% Seed emergence	Plant height	Ear height
Replications	4	—	—	—	—	—	—
N splits (N)	2	ns†	ns	ns	ns	ns	ns
Error	8	—	—	—	—	—	—
Hybrids (H)	4	***	***	***	**	***	***
N x H	8	ns	ns	ns	***	ns	ns
Error	48	—	—	—	—	—	—
Total	74	—	—	—	—	—	—

** Significant at the 0.01 level.
*** Significant at the 0.001 level.
†ns = not significant.

Table 2-3. Sweet corn diagnostic leaf mineral concentrations for N management treatments and sweet corn hybrids for 2002 analysis of variance.

Source of variation	df	Ca	Mg	K	N	P	Na	Cu	Fe	Mn	Zn
Replications	4	—	—	—	—	—	—	—	—	—	—
N splits (N)	2	ns†	**	*	ns	ns	***	ns	*	ns	ns
Error	8	—	—	—	—	—	—	—	—	—	—
Hybrids (H)	4	***	**	***	***	***	**	ns	***	ns	***
N x H	8	ns	*	ns	ns	ns	***	***	ns	***	*
Error	48	—	—	—	—	—	—	—	—	—	—
Total	74	—	—	—	—	—	—	—	—	—	—

* Significant at the 0.05 level.
** Significant at the 0.0 level.
*** Significant at the 0.001 level.
†ns = not significant.

Table 2-4. Soil mineral concentrations and characteristics for N management treatments and sweet corn hybrids for 2002 analysis of variance.

Source of variation	df	Ca	Mg	K	N	P	Na	Cu	Fe	Mn	Zn	pH	BpH	OM	CEC
Replications	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—
N splits (N)	2	ns†	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	**	ns
Error	8	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Hybrids (H)	4	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	***	**	ns	ns
N x H	8	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	*	ns	ns
Error	48	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	74	—	—	—	—	—	—	—	—	—	—	—	—	—	—

* Significant at the 0.05 level.
** Significant at the 0.01 level.
*** Significant at the 0.001 level.
†ns = not significant.

Table 2-5. Sweet corn ear yield for N management treatments and sweet corn hybrids for 2003 analysis of variance.

Source of variaion	df	>15.2 cm‡	15.2–12.7 cm	12.7–10.2 cm	<10.2 cm	Total ears	>15.2 cm	15.2–12.7 cm	12.7–10.2 cm	<10.2 cm	Total ears
		No. of ears					Fresh weight of ears				
Replications	4	—	—	—	—	—	—	—	—	—	—
N splits (N)	2	ns†	ns	ns	ns	ns	ns	*	ns	*	ns
Error	8	—	—	—	—	—	—	—	—	—	—
Hybrids (H)	4	***	***	***	***	***	***	***	***	***	***
N x H	8	ns	*	ns	ns	ns	ns	*	ns	ns	ns
Error	48	—	—	—	—	—	—	—	—	—	—
Total	74	—	—	—	—	—	—	—	—	—	—

* Significant at the 0.05 level.
*** Significant at the 0.001 level.
†ns = not significant.
‡Sweet corn ear lengths, according to USDA standards (USDA, 1954).

Table 2-6. Sweet corn diagnostic leaf yield, leaf area index, seed emergence for N management treatments and sweet corn hybrids for 2003 analysis of variance.

Source of variation	df	Leaf fresh weight	Leaf dry weight	Leaf area index	Seed emergence
Replications	4	—	—	—	—
N splits (N)	2	*	ns†	ns	ns
Error	8	—	—	—	—
Hybrids (H)	4	***	***	***	***
N x H	8	ns	ns	ns	ns
Error	48	—	—	—	—
Total	74	—	—	—	—

* Significant at the 0.05 level.
*** Significant at the 0.001 level.
†ns = not significant.

Table 2-7. Soil mineral concentrations and characteristics for N management of sweet corn for 2003 analysis of variance.

Source of variation	df	Ca	Mg	K	N	P	Na	Cu	Fe	Mn	Zn	pH	BpH	OM	CEC
Replications	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—
N splits	2	ns†	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Error	8	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	14	—	—	—	—	—	—	—	—	—	—	—	—	—	—

†ns = not significant at $p \leq 0.05$.

Table 2-8. Number of ears for different grades of sweet corn for three nitrogen management treatments and five hybrids, fall 2002.

Hybrid	Nitrogen management: Two splits	Three splits	Four splits	$\overline{X}$
	No ears ha^{-1}			
		Ears > 15.2 cm		
Silver Queen	13000	20667	15667	16444 a†
Golden Queen	6667	6667	5000	6111 bc
Meritt	6667	8667	11667	9000 b
Florida Stay Sweet	3667	3667	4333	3889 c
Peaches & Cream	0	0	0	0 d
$\overline{X}$	6000 x‡	7933 x	7333 x	
LSD at $p \leq 0.05$ for nitrogen management = ns				
LSD at $p \leq 0.05$ for sweet corn hybrids = 3880				
		Ears 12.7–15.2 cm		
Silver Queen	24000	20667	17000	20556 b
Golden Queen	8000	10334	7333	85556 a
Meritt	2000	4333	4333	3556 cd
Florida Stay Sweet	8000	7667	4667	6778 c
Peaches & Cream	333	1333	667	778 d
$\overline{X}$	8467 x	8867 x	6800 x	
LSD at $p \leq 0.05$ for nitrogen management = ns				
LSD at $p \leq 0.05$ for sweet corn hybrids = 3568				
		Ears 10.2–12.7 cm		
Silver Queen	16334	15333	16000	15889 a
Golden Queen	7000	10000	9333	8778 b
Meritt	2667	3000	4333	3333 cd
Florida Stay Sweet	5334	3667	6333	5111 c
Peaches & Cream	4000	1667	667	2111 d
$\overline{X}$	7067 x	6733 x	7333 x	
LSD at $p \leq 0.05$ for nitrogen management = ns				
LSD at $p \leq 0.05$ for sweet corn hybrids = 2793				
		Ears < 10.2 cm		
Silver Queen	43667	32667	53333	43222 b
Golden Queen	53667	67333	79000	66667 a
Meritt	37667	42333	44333	41444 b
Florida Stay Sweet	36000	41333	41000	39445 b
Peaches & Cream	36667	33667	36333	35556 b
$\overline{X}$	41533 x	43467 y	50800 y	
LSD at $p \leq 0.05$ for nitrogen management = 4696				
LSD at $p \leq 0.05$ for sweet corn hybrids = 11736				
		Total ears		
Silver Queen	97000	89334	102000	96111 a
Golden Queen	75333	94334	100667	90111 ab
Meritt	49000	58333	64667	57333 bc
Florida Stay Sweet	53000	56333	56333	55222 c

Table 2-8. Continued.

Hybrid	Nitrogen management: Two splits	Three splits	Four splits	Average
			Total ears	
Peaches & Cream	41000	36667	37667	38444 c
$\overline{X}$	63067 y	67000 xy	72267 x	

LSD at $p \leq 0.05$ for nitrogen management = 5526
LSD at $p \leq 0.05$ for sweet corn hybrids = 3401

†Values in columns (a,b,c) not followed by the same letter are significantly different ($p \leq 0.05$) according to LSD.
‡Values in rows (x, y, z) not followed by the same letter are significantly different ($p \leq 0.05$) according to LSD.
`

Table 2-9. Fresh weight of ears for different grades of sweet corn for three nitrogen management treatments and five hybrids, fall 2002.

Hybrid	Nitrogen management: Two splits	Three splits	Four splits	$\overline{X}$
	Fresh weight, kg ha^{-1}			
		Ears > 15.2 cm		
Silver Queen	2354	3599	2702	2885 a†
Golden Queen	1203	1239	896	1113 bc
Meritt	1122	1420	2101	1548 b
Florida Stay Sweet	603	535	700	612 cd
Peaches & Cream	0	0	0	0 d
$\overline{X}$	1056 x‡	1359 x	1280 x	
LSD at $p \leq 0.05$ for nitrogen management = ns				
LSD at $p \leq 0.05$ for sweet corn hybrids = 733				
		Ears 12.7–15.2 cm		
Silver Queen	2983	2560	2186	2576 a
Golden Queen	1023	1458	1041	1174 b
Meritt	244	554	571	456 cd
Florida Stay Sweet	859	842	516	739 bc
Peaches & Cream	43	136	69	83 d
$\overline{X}$	1031 x	1110 x	877 x	
LSD at $p \leq 0.05$ for nitrogen management = ns				
LSD at $p \leq 0.05$ for sweet corn hybrids = 450				
		Ears 10.2–12.7 cm		
Silver Queen	1751	1426	1672	1616 a
Golden Queen	657	1069	1122	949 b
Meritt	260	308	454	341 cd
Florida Stay Sweet	432	323	516	424 c
Peaches & Cream	358	153	56	189 d
$\overline{X}$	692 x	656 x	764 x	
LSD at $p \leq 0.05$ for nitrogen management = ns				
LSD at $p \leq 0.05$ for sweet corn hybrids = 213				
		Ears < 10.2 cm		
Silver Queen	2318	1578	2636	2177 b
Golden Queen	2814	3738	4114	3555 a
Meritt	993	1110	1608	1237 c
Florida Stay Sweet	1278	1306	1501	1362 c
Peaches & Cream	891	816	921	876 c
$\overline{X}$	1659 y	1710 y	2156 x	
LSD at $p \leq 0.05$ for nitrogen management = 305				
LSD at $p \leq 0.05$ for sweet corn hybrids = 504				
		Total ears		
Silver Queen	9407	9163	9195	9255 a
Golden Queen	5697	7503	7173	6791 b
Meritt	2619	3392	4733	3581 c
Florida Stay Sweet	3172	3006	3233	3137 c

Table 2-9. Continued.

	Nitrogen management			
	Two splits	Two splits	Two splits	Average
			Total ears	
Peaches & Cream	1292	1105	1046	1148 d
$\overline{X}$	4437 x	4834 x	5076 x	
LSD at $p \leq 0.05$ for nitrogen management = ns				
LSD at $p \leq 0.05$ for sweet corn hybrids = 1072				

†Values in columns (a,b,c) not followed by the same letter are significantly different ($p \leq 0.05$) according to LSD.

‡Values in rows (x,y,z) not followed by the same letter are significantly different ($p \leq 0.05$) according to LSD.

Table 2-10. Yield of 5th leaf for sweet corn for three nitrogen management treatments and five hybrids, fall 2002.

Hybrid	Nitrogen management: Two splits	Three splits	Four splits	$\overline{X}$
	kg ha^{-1}			
	Fresh weight			
Silver Queen	1268	1190	1221	1226 a†
Golden Queen	1049	1058	1066	1058 b
Meritt	878	854	860	864 d
Florida Stay Sweet	1047	989	906	981 c
Peaches & Cream	755	646	698	700 e
$\overline{X}$	999 x‡	947 x	950 x	
LSD at $p \leq 0.05$ for nitrogen management = ns				
LSD at $p \leq 0.05$ for sweet corn hybrids = 66				
	Dry weight			
Silver Queen	246	235	240	241 a
Golden Queen	202	210	217	210 b
Meritt	197	193	198	196 c
Florida Stay Sweet	209	196	184	196 c
Peaches & Cream	131	117	131	126 d
$\overline{X}$	197 x	190 x	194 x	
LSD at $p \leq 0.05$ for nitrogen management = ns				
LSD at $p \leq 0.05$ for sweet corn hybrids = 11				
	Leaf area index, cm^{2} leaf^{-1} cm^{-2} ground area			
Silver Queen	0.378	0.376	0.364	0.373 b
Golden Queen	0.328	0.334	0.342	0.335 c
Meritt	0.368	0.372	0.372	0.371 b
Florida Stay Sweet	0.426	0.424	0.390	0.413 a
Peaches & Cream	0.226	0.198	0.208	0.211 d
$\overline{X}$	0.345 x	0.341 x	0.335 x	
LSD at $p \leq 0.05$ for nitrogen management = ns				
LSD at $p \leq 0.05$ for sweet corn hybrids = 0.02				

†Values in columns (a,b,c) not followed by the same letter are significantly different ($p \leq 0.05$) according to LSD.

‡Values in rows (x,y,z) not followed by the same letter are significantly different ($p \leq 0.05$) according to LSD.

Table 2-11. Percent seed emergence of sweet corn for three nitrogen management treatments and five hybrids, fall 2002.

Hybrid	Nitrogen management: Two splits	Three splits	Four splits	$\overline{X}$
	Emergence, %			
Silver Queen	79 b† y‡	86 ab x	87 a x	84
Golden Queen	84 a x	84 b x	78 b y	82
Meritt	85 a x	86 ab x	79 b y	83
Florida Stay Sweet	85 a x	88 a x	88 a x	87
Peaches & Cream	83 a x	72 c y	85 a x	80
$\overline{X}$	83	83	83	
LSD at $p \leq 0.05$ for nitrogen management = 3.5				
LSD at $p \leq 0.05$ for sweet corn hybrids = 3.5				

†Values in columns (a,b,c) not followed by the same letter are significantly different ($p \leq 0.05$) according to LSD.

‡Values in rows (x,y,z) not followed by the same letter are significantly different ($p \leq 0.05$) according to LSD.

Table 2-12. Plant and ear height of sweet corn for three nitrogen management treatments and five hybrids, fall 2002.

Hybrid	Nitrogen management: Two splits	Three splits	Four splits	$\overline{X}$
	Height, m			
			Plant height	
Silver Queen	1.99	1.90	2.14	2.01 a†
Golden Queen	1.91	2.02	2.10	2.01 a
Meritt	1.87	1.84	1.92	1.87 b
Florida Stay Sweet	1.63	1.60	1.55	1.60 c
Peaches & Cream	1.77	1.63	1.63	1.67 c
$\overline{X}$	1.83 x‡	1.79 x	1.87 x	
LSD at $p \leq 0.05$ for nitrogen management = ns				
LSD at $p \leq 0.05$ for sweet corn hybrids = 0.10				
			Ear height	
Silver Queen	0.51	0.60	0.69	0.60 a
Golden Queen	0.57	0.56	0.67	0.60 a
Meritt	0.57	0.56	0.57	0.56 ab
Florida Stay Sweet	0.50	0.49	0.51	0.50 b
Peaches & Cream	0.40	0.35	0.39	0.38 c
$\overline{X}$	0.51 x	0.51 x	0.57 x	
LSD at $p \leq 0.05$ for nitrogen management = ns				
LSD at $p \leq 0.05$ for sweet corn hybrids = 0.06				

†Values in columns (a,b,c) not followed by the same letter are significantly different ($p \leq 0.05$) according to LSD.

‡Values in rows (x, y, z) not followed by the same letter are significantly different ($p \leq 0.05$) according to LSD.

Table 2-13. Mineral analysis for 5th leaf of sweet corn for three nitrogen management treatments and five hybrids, fall 2002.

	Nitrogen management			
Hybrid	Two splits	Three splits	Four splits	$\overline{X}$
	Mineral concentration, g kg^{-1}			
			Ca	
Silver Queen	5.9	5.9	5.9	5.9 a†
Golden Queen	4.6	5.1	4.9	4.9 cd
Meritt	4.9	5.5	5.1	5.2 bc
Florida Stay Sweet	4.1	4.4	4.8	4.5 d
Peaches & Cream	5.4	6.4	5.4	5.7 ab
$\overline{X}$	5.0 x‡	5.5 x	5.2 x	
LSD at $p \leq 0.05$ for nitrogen management = ns				
LSD at $p \leq 0.05$ for sweet corn hybrids = 0.58				
			Mg	
Silver Queen	2.8 c x	2.7 c x	2.4 b y	2.6
Golden Queen	3.2 ab y	3.9 a x	2.6 b z	3.2
Meritt	3.3 a x	3.54a x	2.5 b y	3.1
Florida Stay Sweet	3.0 abc x	2.7 c x	2.7 b x	2.8
Peaches & Cream	2.9 bc x	3.1 b x	3.1 a x	3.0
$\overline{X}$	3.00	3.2	2.7	
LSD at $p \leq 0.05$ for nitrogen management = 0.28				
LSD at $p \leq 0.05$ for sweet corn hybrids = 0.35				
			K	
Silver Queen	15.6	15.1	17.6	16. c
Golden Queen	16.8	17.2	20.4	18.13 b
Meritt	18.3	17.1	22.4	19.3 b
Florida Stay Sweet	18.1	18.4	17.8	18.1 b
Peaches & Cream	24.7	22.0	22.8	23.2 a
$\overline{X}$	18.7 xy	18.0 y	20.2 x	
LSD at $p \leq 0.05$ for nitrogen management = 1.7				
LSD at $p \leq 0.05$ for sweet corn hybrids = 1.9				
			P	
Silver Queen	3.9	3.7	3.7	3.8 d
Golden Queen	4.7	4.3	4.3	4.4 b
Meritt	4.9	4.4	4.7	4.7 a
Florida Stay Sweet	4.2	4.2	4.1	4.2 c
Peaches & Cream	4.1	4.1	4.2	4.1 c
$\overline{X}$	4.4 x	4.1 x	4.20 x	
LSD at $p \leq 0.05$ for nitrogen management = ns				
LSD at $p \leq 0.05$ for sweet corn hybrids = 0.21				
			N	
Silver Queen	26.8	28.5	28.5	28.0 c
Golden Queen	29.1	30.9	29.7	29.9 a
Meritt	29.3	29.9	30.3	29.8 ab
Florida Stay Sweet	28.7	28.2	28.5	28.5 bc

Table 2-13. Continued.

Hybrid	Nitrogen management: Two splits	Three splits	Four splits	$\overline{X}$
	Mineral concentration, g kg^{-1}			
			N	
Peaches & Cream	30.4	31.4	31.8	31.2 a
$\overline{X}$	28.8 x	29.8 x	29.8 x	
LSD at $p \leq 0.05$ for nitrogen management = ns				
LSD at $p \leq 0.05$ for sweet corn hybrids = 1.4				
			Na	
Silver Queen	0.6 c y	0.9 a x	0.5 a y	0.7
Golden Queen	0.8 b x	0.6 b y	0.5 a z	0.6
Meritt	0.8 b x	0.3 d z	0.4 ab y	0.5
Florida Stay Sweet	0.8 ab x	0.3 d y	0.3 b y	0.5
Peaches & Cream	0.9 a x	0.5 c y	0.5 a y	0.6
$\overline{X}$	0.8	0.5	0.5	
LSD at $p \leq 0.05$ for nitrogen management = 0.08				
LSD at $p \leq 0.05$ for sweet corn hybrids = 0.11				
	Mineral concentration, mg kg^{-1}			
			Cu	
Silver Queen	6.00 ab y	3.20 d z	7.00 a x	5.40
Golden Queen	6.20 a x	4.20 c z	5.20 c y	5.20
Meritt	5.60 ab y	6.40 ab x	5.40 c y	5.80
Florida Stay Sweet	5.40 b x	5.80 b x	5.40 c y	5.53
Peaches & Cream	5.80 ab x	6.80 a x	6.20 b xy	6.27
$\overline{X}$	5.80	5.28	5.84	
LSD at $p \leq 0.05$ for nitrogen management = 0.63				
LSD at $p \leq 0.05$ for sweet corn hybrids = 0.80				
			Fe	
Silver Queen	96.00	94.00	98.00	96.00 c
Golden Queen	84.00	92.00	98.00	91.33 c
Meritt	94.00	90.00	94.00	92.67 c
Florida Stay Sweet	98.00	106.00	106.00	103.33 b
Peaches & Cream	108.00	122.00	114.00	114.67 a
$\overline{X}$	96.00 y	100.80 xy	102.00 x	
LSD at $p \leq 0.05$ for nitrogen management = 5.9				
LSD at $p \leq 0.05$ for sweet corn hybrids = 6.8				
			Mn	
Silver Queen	23.00 a x	19.60 b y	20.60 b y	21.07
Golden Queen	18.80 b y	25.00 a x	17.20 c y	20.33
Meritt	16.20 bc z	24.20 a x	19.20 bc y	19.87
Florida Stay Sweet	18.00 b y	20.60 b x	18.20 bc y	18.93
Peaches & Cream	13.60 c z	24.40 a y	30.20 a x	22.73
$\overline{X}$	17.92	22.76	21.08	

Table 2-13. Continued.

Hybrid	Nitrogen management: Two splits	Three splits	Four splits	$\overline{X}$
	Mineral concentration, mg kg^{-1}			
			Mn	
LSD at $p \leq 0.05$ for nitrogen management = 2.3				
LSD at $p \leq 0.05$ for sweet corn hybrids = 3.4				
			Zn	
Silver Queen	23.20 a y	23.80 b y	27.40 a x	24.80
Golden Queen	24.60 a x	21.20 b y	24.20 b x	23.33
Meritt	22.60 a y	27.00 a x	22.80 b y	24.13
Florida Stay Sweet	19.40 b y	21.80 b x	18.60 c y	19.93
Peaches & Cream	16.40 c z	21.40 b x	18.60 c y	18.80
$\overline{X}$	21.24	23.04	22.32	
LSD @ 0.05 for nitrogen management = 1.9				
LSD @ 0.05 for sweet corn hybrids = 2.6				

†Values in columns (a,b,c) not followed by the same letter are significantly different ($p \leq 0.05$) according to LSD.

‡Values in rows (x,y,z) not followed by the same letter are significantly different ($p \leq 0.05$) according to LSD.

Table 2-14. Mineral analysis for soil samples following sweet corn, fall 2002.

Hybrid	Nitrogen management: Two splits	Three splits	Four splits	$\overline{X}$
	Mineral concentration, mg kg^{-1}			
		Ca		
Silver Queen	673.8	641.6	688.0	667.5 a†
Golden Queen	700.0	656.0	755.2	704.7 a
Meritt	603.2	746.4	838.4	729.3 a
Florida Stay Sweet	678.4	751.2	668.8	699.5 a
Peaches & Cream	745.6	821.6	704.0	757.1 a
$\overline{X}$	680.0 x‡	723.4 x	730.9 x	
LSD at $p \leq 0.05$ for nitrogen management = 109				
LSD at $p \leq 0.05$ for sweet corn hybrids = ns				
		Mg		
Silver Queen	54.2	51.4	53.0	52.8 a
Golden Queen	52.8	52.0	54.4	53.1 a
Meritt	47.8	57.2	59.6	54.9 a
Florida Stay Sweet	60.0	55.4	50.6	55.3 a
Peaches & Cream	56.6	51.0	52.6	53.4 a
$\overline{X}$	54.3 x	53.4 x	54.0 x	
LSD at $p \leq 0.05$ for nitrogen management = ns				
LSD at $p \leq 0.05$ for sweet corn hybrids = ns				
		K		
Silver Queen	25.0	26.6	25.8	25.8 a
Golden Queen	23.6	22.6	25.8	24.0 a
Meritt	22.4	26.4	27.2	25.3 a
Florida Stay Sweet	29.0	25.8	24.0	26.3 a
Peaches & Cream	33.6	24.8	27.4	28.6 a
$\overline{X}$	26.7 x	25.2 x	26.0 x	
LSD at $p \leq 0.05$ for nitrogen management = ns				
LSD at $p \leq 0.05$ for sweet corn hybrids = ns				
		P		
Silver Queen	50.0	54.4	58.2	54.2 a
Golden Queen	65.0	43.6	55.0	54.5 a
Meritt	43.8	35.0	46.2	41.7 a
Florida Stay Sweet	27.8	52.8	46.4	45.7 a
Peaches & Cream	58.6	48.8	53.2	53.5 a
$\overline{X}$	51.0 x	46.9 x	51.8 x	
LSD at $p \leq 0.05$ for nitrogen management = ns				
LSD at $p \leq 0.05$ for sweet corn hybrids = ns				
		N		
Silver Queen	379.0	401.0	412.2	397.4 a
Golden Queen	406.2	407.0	426.0	413.1 a
Meritt	365.6	454.0	430.4	416.7 a
Florida Stay Sweet	395.8	444.6	411.0	417.1 a
Peaches & Cream	438.2	472.8	447.4	452.8 a

Table 2-14. Continued.

Hybrid	Nitrogen management: Two splits	Three splits	Four splits	Average
	Mineral concentration, mg kg^{-1}			
			N	
$\overline{X}$	397.0 x	435.9 x	425.4 x	
LSD at $p \leq 0.05$ for nitrogen management = ns				
LSD at $p \leq 0.05$ for sweet corn hybrids = ns				
			Na	
Silver Queen	15.0	15.6	14.4	15.0 a
Golden Queen	16.8	15.4	15.4	15.9 a
Meritt	15.2	14.4	15.0	14.9 a
Florida Stay Sweet	15.8	15.2	14.8	15.3 a
Peaches & Cream	15.8	15.6	14.6	15.3 a
$\overline{X}$	15.7 x	15.2 x	14.8 x	
LSD at $p \leq 0.05$ for nitrogen management = ns				
LSD at $p \leq 0.05$ for sweet corn hybrids = ns				
			Cu	
Silver Queen	0.18	0.15	0.32	0.22 a
Golden Queen	0.18	0.18	0.17	0.18 a
Meritt	0.17	0.14	0.15	0.15 a
Florida Stay Sweet	0.16	0.14	0.22	0.17 a
Peaches & Cream	0.17	0.16	0.18	0.17 a
$\overline{X}$	0.17 x	0.15 x	0.21 x	
LSD at $p \leq 0.05$ for nitrogen management = ns				
LSD at $p \leq 0.05$ for sweet corn hybrids = ns				
			Fe	
Silver Queen	9.12	9.52	9.68	9.44 a
Golden Queen	8.88	6.88	9.44	8.40 a
Meritt	6.4	8.16	8.8	7.79 a
Florida Stay Sweet	10.0	8.48	7.6	8.69 a
Peaches & Cream	9.68	8.4	9.12	9.07 a
$\overline{X}$	8.82 x	8.29 x	8.93 x	
LSD at $p \leq 0.05$ for nitrogen management = ns				
LSD at $p \leq 0.05$ for sweet corn hybrids = ns				
			Mn	
Silver Queen	3.92	3.66	3.42	3.67 a
Golden Queen	3.82	3.06	3.52	3.47 a
Meritt	3.2	3.80	4.24	3.75 a
Florida Stay Sweet	3.32	3.78	2.88	3.33 a
Peaches & Cream	4.12	3.82	3.36	3.77 a
$\overline{X}$	3.68 x	3.62 x	3.48 x	
LSD at $p \leq 0.05$ for nitrogen management = ns				
LSD at $p \leq 0.05$ for sweet corn hybrids = ns				

Table 2-14. Continued.

Hybrid	Nitrogen management Two splits	Three splits	Four splits	Average
	Mineral concentration, mg kg^{-1}			
			Zn	
Silver Queen	3.8	3.9	2.86	3.52 a
Golden Queen	2.82	2.46	4.86	3.38 a
Meritt	3.48	5.04	5.54	4.69 a
Florida Stay Sweet	3.04	5.02	4.94	4.33 a
Peaches & Cream	4.80	5.42	2.86	4.36 a
$\overline{X}$	3.59 x	4.37 x	4.21 x	
LSD at $p \leq 0.05$ for nitrogen management = ns				
LSD at $p \leq 0.05$ for sweet corn hybrids = ns				
	pH			
Silver Queen	6.5	6.8	6.5	6.6 d
Golden Queen	6.6	6.7	6.6	6.7 cd
Meritt	6.6	6.7	6.7	6.7 bc
Florida Stay Sweet	6.7	6.9	6.7	6.8 ab
Peaches & Cream	6.8	6.8	6.8	6.8 a
$\overline{X}$	6.6 x	6.8 x	6.7 x	
LSD at $p \leq 0.05$ for nitrogen management = ns				
LSD at $p \leq 0.05$ for sweet corn hybrids = 0.08				
	BpH			
Silver Queen	7.84 d z	7.86 ab x	7.85 b y	7.85
Golden Queen	7.87 bc x	7.85 bc z	7.86 b y	7.86
Meritt	7.89 a x	7.84 c z	7.85 b y	7.86
Florida Stay Sweet	7.88 ab y	7.86 ab z	7.89 a x	7.88
Peaches & Cream	7.86 c z	7.87 a y	7.88 a x	7.87
$\overline{X}$	7.87	7.86	7.87	
LSD at $p \leq 0.05$ for nitrogen management = 0.0005				
LSD at $p \leq 0.05$ for sweet corn hybrids = 0.01				
	CEC, meq 100 g^{-1} (cmol kg^{-1})			
Silver Queen	9.26	8.77	9.16	9.06
Golden Queen	9.11	8.91	9.54	9.19
Meritt	8.04	9.95	10.5	9.49
Florida Stay Sweet	9.47	9.57	8.57	9.21
Peaches & Cream	9.74	9.52	9.01	9.42
$\overline{X}$	9.12	9.35	9.35	
LSD at $p \leq 0.05$ for nitrogen management = ns				
LSD at $p \leq 0.05$ for sweet corn hybrids = ns				
	OM, %			
Silver Queen	0.98	1.01	1.09	1.03
Golden Queen	0.91	0.95	1.18	1.02
Meritt	0.91	1.05	1.28	1.08
Florida Stay Sweet	1.13	0.86	1.14	1.04
Peaches & Cream	0.98	1.11	1.39	1.16

Table 2-14. Continued.

Hybrid	Nitrogen management			Average
	Two splits	Three splits	Four splits	
	OM, %			
$\overline{X}$	0.98 y	1.0 y	1.22 x	
LSD at $p \leq 0.05$ for nitrogen management = 0.1				
LSD at $p \leq 0.05$ for sweet corn hybrids = ns				

†Values in columns (a,b,c) not followed by the same letter are significantly different ($p \leq 0.05$) according to LSD.

‡Values in rows (x,y,z) not followed by the same letter are significantly different ($p \leq 0.05$) according to LSD.

Table 2-15. Number of ears for different grades of sweet corn for three nitrogen management treatments and five hybrids, fall 2003.

Hybrid	Nitrogen management: Two splits	Three splits	Four splits	$\overline{X}$
	No ears ha^{-1}			
		Ears > 15.2 cm		
Silver Queen	21333	14333	16667	1744 c†
8100R	17333	14333	18667	16778 b
Prime Plus	0	667	667	444 c
8102R	21333	29667	19667	23556 a
Big Time	333	0	333	223 c
$\overline{X}$	12067 x‡	11800 x	11200 x	
LSD at $p \leq 0.05$ for nitrogen management = ns				
LSD at $p \leq 0.05$ for sweet corn hybrids = 4832				
		Ears 12.7–15.2 cm		
Silver Queen	18333 a x	18667 a x	9667 b y	15556
8100R	20667 a x	17000 a y	12667 a z	16778
Prime Plus	333 b x	1333 b x	1667 c x	1111
8102R	19667 a x	17333 a y	12000 ab z	16333
Big Time	1000 b x	333 b x	0 c x	445
$\overline{X}$	12000	10933	7200	
LSD at $p \leq 0.05$ for nitrogen management = 1994				
LSD at $p \leq 0.05$ for sweet corn hybrids = 2855				
		Ears 10.2–12.7 cm		
Silver Queen	13333	15000	15667	14667 a
8100R	12667	12666	13667	13000 a
Prime Plus	6333	5667	5333	5778 b
8102R	10667	11667	16667	13000 a
Big Time	3333	4667	4667	4222 b
$\overline{X}$	9267 x	9933 x	11200 x	
LSD at $p \leq 0.05$ for nitrogen management = ns				
LSD at $p \leq 0.05$ for sweet corn hybrids = 3525				
		Ears < 10.2 cm		
Silver Queen	13333	18667	26000	19333 b
8100R	12667	16333	17000	15333 bc
Prime Plus	32000	28333	33000	31111 a
8102R	12667	5667	14333	10889 c
Big Time	33667	36000	36333	35333 a
$\overline{X}$	20867 x	21000 x	25333 x	
LSD at $p \leq 0.05$ for nitrogen management = ns				
LSD at $p \leq 0.05$ for sweet corn hybrids = 6074				
		Total ears		
Silver Queen	66333	66667	68000	67000 a
8100R	63333	60333	62000	61889 a
Prime Plus	38667	36000	40667	38445 b
8102R	64333	64333	62666	63778 a

Table 2-15. Continued.

Hybrid	Nitrogen management: Two splits	Three splits	Four splits	Average
	No ears ha^{-1}			
			Total ears	
Big Time	38333	41000	41333	40222 b
$\overline{X}$	54200 x	53667 x	54933 x	
LSD at $p \leq 0.05$ for nitrogen management = ns				
LSD at $p \leq 0.05$ for sweet corn hybrids = 5684				

†Values in columns (a,b,c) not followed by the same letter are significantly different ($p \leq 0.05$) according to LSD.

‡Values in rows (x,y,z) not followed by the same letter are significantly different ($p \leq 0.05$) according to LSD.

Table 2-16. Fresh weight of ears for different grades of sweet corn for three nitrogen management treatments and five hybrids, fall 2003.

	Nitrogen management			
Hybrid	Two splits	Three splits	Four splits	$\overline{X}$
	Ear weight, kg ha^{-1}			
		Ears > 15.2 cm		
Silver Queen	4169	2927	3218	3438 ab†
8100R	2804	2461	3230	2832 b
Prime Plus	0	109	131	80 c
8102R	3767	5260	3893	4307 a
Big Time	72	0	52	41 c
$\overline{X}$	2162 x‡	2151 x	2105 x	
LSD at $p \leq 0.05$ for nitrogen management = ns				
LSD at $p \leq 0.05$ for sweet corn hybrids = 916				
		Ears 12.7–15.2 cm		
Silver Queen	2573 a x	2736 a x	1485 a y	2264
8100R	2317a x	2099 b x	1539 a y	1985
Prime Plus	35 b x	148 c x	183 b x	122
8102R	2427 a x	2098 b x	1553 a z	2026
Big Time	113 b x	46 c x	0B x	53
$\overline{X}$	1493	1425	952	
LSD at $p \leq 0.05$ for nitrogen management = 264				
LSD at $p \leq 0.05$ for sweet corn hybrids = 362				
		Ears 10.2–12.7cm		
Silver Queen	1483	1741	1817	1680 a
8100R	1038	1159	1473	1224 b
Prime Plus	655	578	481	571 c
8102R	931	1229	1584	1248 b
Big Time	322	432	400	385 c
$\overline{X}$	886 x	1028 x	1151 x	
LSD at $p \leq 0.05$ for nitrogen management = ns				
LSD at $p \leq 0.05$ for sweet corn hybrids = 369				
		Ears < 10.2 cm		
Silver Queen	901	1273	1693	1289 a
8100R	529	858	912	766 b
Prime Plus	1463	1211	1307	1327 a
8102R	705	313	753	590 b
Big Time	995	1418	1525	1313 a
$\overline{X}$	918 y	1015 y	1238 x	
LSD at $p \leq 0.05$ for nitrogen management = 223				
LSD at $p \leq 0.05$ for sweet corn hybrids = 325				
		Total ears		
Silver Queen	9125	8676	8212	8671 a
8100R	6689	6577	7154	6807 b
Prime Plus	2153	2046	2102	2100 c

Table 2-16. Continued.

Hybrid	Nitrogen management: Two splits	Three splits	Four splits	$\overline{X}$
	Ear weight, kg ha^{-1}			
			Total ears	
8102R	7829	8900	7784	8171 a
Big Time	1503	1896	1978	1792 c
$\overline{X}$	5460 x	5619 x	5446 x	

LSD at $p \leq 0.05$ for nitrogen management = ns
LSD at $p \leq 0.05$ for sweet corn hybrids = 674

†Values in columns (a,b,c) not followed by the same letter are significantly different ($p \leq 0.05$) according to LSD.
‡Values in rows (x,y,z) not followed by the same letter are significantly different ($p \leq 0.05$) according to LSD.

Table 2-17. Yield of 5th leaf of sweet corn for three nitrogen management treatments and five hybrids, fall 2003.

Hybrid	Nitrogen management: Two splits	Three splits	Four splits	$\overline{X}$
	Leaf weight, kg ha^{-1}			
			Fresh weight	
Silver Queen	1289	1470	1477	1412 a†
8100R	1174	1067	1128	1123 bc
Prime Plus	976	1063	1002	1014 c
8102R	1317	1502	1497	1439 a
Big Time	1110	1241	1114	1155 b
$\overline{X}$	1173 y‡	1269 x	1244 xy	
LSD at $p \leq 0.05$ for nitrogen management = 89				
LSD at $p \leq 0.05$ for sweet corn hybrids = 129				
			Dry weight	
Silver Queen	251	275	238	260 a
8100R	215	200	210	209 b
Prime Plus	168	177	171	172 c
8102R	145	280	275	267 a
Big Time	187	208	189	195 b
$\overline{X}$	214 x	228 x	220 x	
LSD at $p \leq 0.05$ for nitrogen management = ns				
LSD at $p \leq 0.05$ for sweet corn hybrids = 22				
	Leaf area index, cm^{2} leaf^{-1} cm^{-2}ground area			
Silver Queen	0.442	0.485	0.461	0.463 b
8100R	0.447	0.411	0.443	0.434 bc
Prime Plus	0.340	0.358	0.353	0.350 d
8102R	0.513	0.567	0.576	0.552 a
Big Time	0.390	0.457	0.387	0.411 c
$\overline{X}$	0.426 x	0.456 x	0.444 x	
LSD at $p \leq 0.05$ for nitrogen management = ns				
LSD at $p \leq 0.05$ for sweet corn hybrids = 0.04				

†Values in columns (a,b,c) not followed by the same letter are significantly different ($p \leq 0.05$) according to LSD.

‡Values in rows (x,y,z) not followed by the same letter are significantly different ($p \leq 0.05$) according to LSD.

Table 2-18. Plants emerged for sweet corn for three nitrogen management treatments and five hybrids, fall 2003.

	Nitrogen management			
Hybrid	Two splits	Three splits	Four splits	$\overline{X}$
	Plants m^{-2}			
Silver Queen	9.6	10.2	9.8	9.9 b†
8100R	10.1	8.9	9.7	9.6 b
Prime Plus	7.9	8.2	8.3	8.1 c
8102R	10.6	11.0	11.3	11.0 a
Big Time	9.3	11.0	8.9	9.7 b
$\overline{X}$	9.5 x‡	9.9 x	9.6 x	

LSD at $p \leq 0.05$ for nitrogen management = ns
LSD at $p \leq 0.05$ for sweet corn hybrids = 0.83

†Values in columns (a,b,c) not followed by the same letter are significantly different ($p \leq 0.05$) according to LSD.
‡Values in rows (x,y,z) not followed by the same letter are significantly different ($p \leq 0.05$) according to LSD.

Table 2-19. Mineral analysis for 5th leaf of sweet corn for three nitrogen management treatments and five hybrids, fall 2003.

Hybrid	Nitrogen management: Two splits	Three splits	Four splits	$\overline{X}$
	Mineral concentration, g kg^{-1}			
			Ca	
Silver Queen	4.7	4.5	4.8	4.7 a†
8100R	3.5	4.1	4.1	3.9 b
Prime Plus	4.7	5.2	5.2	5.0 a
8102R	3.6	4.0	3.9	3.9 b
Big Time	4.6	4.2	4.9	4.6 a
$\overline{X}$	4.2 x‡	4.4 x	4.6 x	
LSD at $p \leq 0.05$ for nitrogen management = ns				
LSD at $p \leq 0.05$ for sweet corn hybrids = 0.41				
			Mg	
Silver Queen	2.8	2.9	3.4	3.1 a
8100R	2.3	2.6	2.9	2.6 a
Prime Plus	2.7	2.9	3.2	2.9 a
8102R	2.3	3.1	3.3	2.9 a
Big Time	2.7	2.7	3.0	2.8 a
$\overline{X}$	2.6 y	2.9 xy	3.2 x	
LSD at $p \leq 0.05$ for nitrogen management = 0.38				
LSD at $p \leq 0.05$ for sweet corn hybrids = ns				
			K	
Silver Queen	23.0	23.4	23.6	23.3 b
8100R	23.9	24.3	22.6	23.6 b
Prime Plus	26.9	28.4	26.2	27.2 a
8102R	23.6	24.2	21.7	23.2 b
Big Time	27.0	27.0	29.4	27.8 a
$\overline{X}$	24.9 x	25.5 x	24.7 x	
LSD at $p \leq 0.05$ for nitrogen management = ns				
LSD at $p \leq 0.05$ for sweet corn hybrids = 1.7				
			P	
Silver Queen	3.9	3.9	4.0	3.9 ab
8100R	4.0	4.1	3.8	4.0 a
Prime Plus	3.8	3.8	3.8	3.8 bc
8102R	3.8	4.2	4.0	4.0 a
Big Time	3.8	3.7	3.8	3.7 c
$\overline{X}$	3.9 x	3.9 x	3.9 x	
LSD at $p \leq 0.05$ for nitrogen management = ns				
LSD at $p \leq 0.05$ for sweet corn hybrids = 0.17				
			N	
Silver Queen	30.1 a x	29.8 b x	28.1 ab y	29.3
8100R	28.8 a y	32.3 a x	27.1 b z	29.4
Prime Plus	30.8 a x	29.2 b y	27.1 b z	29.0

Table 2-19. Continued.

Hybrid	Nitrogen management: Two splits	Three splits	Four splits	$\overline{X}$
	Mineral concentration, g kg^{-1}			
			N	
8102R	28.9 a x	29.3 b x	29.0 ab x	29.1
Big Time	28.7 a x	26.1 c y	30.0 a x	28.3
$\overline{X}$	29.5	29.4	28.3	
LSD at $p \leq 0.05$ for nitrogen management = 1.5				
LSD at $p \leq 0.05$ for sweet corn hybrids = 2.2				
			Na	
Silver Queen	0.3	0.3	0.4	0.3 a
8100R	0.2	0.8	0.4	0.5 a
Prime Plus	0.3	0.3	0.5	0.4 a
8102R	0.3	0.3	0.4	0.3 a
Big Time	0.4	0.4	0.3	0.4 a
$\overline{X}$	0.3 x	0.4 x	0.4 x	
LSD at $p \leq 0.05$ for nitrogen management = ns				
LSD at $p \leq 0.05$ for sweet corn hybrids = ns				
	Mineral concentration, mg kg^{-1}			
			Cu	
Silver Queen	4.0	2.8	3.4	3.4 a
8100R	4.8	3.2	2.8	3.6 a
Prime Plus	3.6	6.0	3.2	4.3 a
8102R	4.0	3.2	2.6	3.3 a
Big Time	3.4	2.6	4.4	3.5 a
$\overline{X}$	4.0 x	3.6 x	3.3 x	
LSD at $p \leq 0.05$ for nitrogen management = ns				
LSD at $p \leq 0.05$ for sweet corn hybrids = ns				
			Fe	
Silver Queen	100.0	114.0	104.0	106.0 b
8100R	106.0	124.0	118.0	116.0 a
Prime Plus	104.0	116.0	106.0	108.7 b
8102R	108.0	110.0	108.0	108.7 b
Big Time	106.0	100.0	102.0	102.7 b
$\overline{X}$	104.8 x	112.8 x	107.6 x	
LSD at $p \leq 0.05$ for nitrogen management = ns				
LSD at $p \leq 0.05$ for sweet corn hybrids = 6.2				
			Mn	
Silver Queen	17.8	20.2	32.2	23.4 a
8100R	15.0	18.0	22.4	18.5 bc
Prime Plus	18.8	17.4	25.6	20.6 ab
8102R	13.6	17.2	14.2	15.0 c
Big Time	17.6	21.2	26.2	21.7 ab
$\overline{X}$	16.6 x	18.8 x	24.1 y	

Table 2-19. Continued.

Hybrid	Nitrogen management: Two splits	Three splits	Four splits	$\overline{X}$
	Mineral concentration, mg kg^{-1}			
			Mn	
LSD at $p\leq0.05$ for nitrogen management = 4.7				
LSD at $p\leq0.05$ for sweet corn hybrids = 3.6				
			Zn	
Silver Queen	23.6	30.8	27.0	27.1 a
8100R	22.8	25.6	23.2	23.9 ab
Prime Plus	21.2	24.4	24.2	23.3 b
8102R	22.0	21.0	21.0	21.3 bc
Big Time	17.4	17.4	20.6	18.5 c
$\overline{X}$	21.4 x	23.8 x	23.2 x	
LSD at $p\leq0.05$ for nitrogen management = ns				
LSD at $p\leq0.05$ for sweet corn hybrids = 3.7				

†Values in columns (a,b,c) not followed by the same letter are significantly different ($p\leq0.05$) according to LSD.

‡Values in rows (x,y,z) not followed by the same letter are significantly different ($p\leq0.05$) according to LSD.

Table 2-20. Mineral analysis for soil samples following sweet corn harvest, fall 2003.

N management	Mineral concentration			
	mg kg^{-1}			
	Ca	Mg	K	N
Two splits	776 a	52.9 a	32.7 a	471.8 a
Three splits	716 a	53.6 a	35.0 a	496.2 a
Four splits	684 a	51.2 a	33.4 a	469.0 a
LSD at $p \leq 0.05$	ns†	ns	ns	ns
	P	Na	Cu	
Two splits	82.9 a	8.5 a	0.3 a	
Three splits	80.2 a	9.0 a	0.3 a	
Four splits	72.6 a	7.9 a	0.3 a	
LSD at $p \leq 0.05$	ns	ns	ns	
	Fe	Mn	Zn	
Two splits	32.7 a	4.8 a	4.7 a	
Three splits	29.4 a	4.4 a	3.8 a	
Four splits	29.0 a	3.9 a	3.6 a	
LSD at $p \leq 0.05$	ns	ns	ns	

†ns = not significant.
‡Values in columns (a,b,c) not followed by the same letter are significantly different ($p \leq 0.05$) according to LSD.

Table 2-21. Soil characteristic analysis for soil samples following sweet corn harvest, fall 2003.

N management	pH	BpH	OM	CEC
			%	meq 100 g^{-1}‡
Two splits	6.8 a§	7.9 a	1.0 b	10.4 a
Three splits	6.9 a	7.9 a	1.0 b	10.0 a
Four splits	7.0 a	7.9 a	1.3 a	10.0 a
LSD at $p \leq 0.05$	ns†	ns	ns	ns

†ns = not signigicant.
‡ (cmol kg^{-1})
§Values in columns (a,b,c) not followed by the same letter are significantly different ($p \leq 0.05$) according to LSD

Table 2-22. Sufficiency range of macro- and micro- nutrients for diagnostic leaf of sweet corn during tasseling and early silking.

	Hochmuth et al.† sufficiency range	Mills and Jones† sufficiency range
	Macronutrients $g\ kg^{-1}$	
N	15–25	25–30
P	2–4	2.5–4
K	12–20	15–28
Ca	3–6	6–9
Mg	1.5–4	2–8
Na	NA	NA
	Micronutrients $mg\ kg^{-1}$	
Cu	4–10	5–25
Fe	30–100	50–350
Mn	20–100	20–300
Zn	20–40	20–150

†(Hochmuth et al., 1991; Mills and Jones, 1996).

CHAPTER 3
YIELD AND NUTRIENT ELEMENT RELATIONSHIPS OF FIVE VARIETIES OF COWPEA AND LIMA BEAN

Introduction

Cowpea (*Vigna unguiculata* (L.) Walp.) is one of many legume species that are very important world food crops. This particular legume, which dates back as far as ancient West African cereal farming 6,000 yr ago, remains a widely grown crop (Davis et al., 1991). It is cultivated on about 7 million ha worldwide, ranging from warm temperate regions to tropical areas of Africa, Asia, and America (Ehlers and Hall, 1997). Cowpea is used in cropping systems to improve soil quality and fertility in addition to being a major source of high quality fodder and forage. It is also an important crop for human consumption in the southern U.S. and Africa, providing affordable and good quality protein and B vitamins.

Cowpea has many beneficial attributes. It has been used successfully as a means of nematode control as well as helping to reduce soil erosion (Davis et al., 1991). Being a legume, cowpeas have a unique symbiotic relationship with certain N_2 fixing bacteria, *Bradyrhizobim* sp., allowing them to actually increase the amount of N in soil (Luyindula and Weaver, 1989). In a study conducted in Nigeria, the apparent N contribution of cowpea to late season corn (*Zea mays* L.) was approximately 30 kg N ha^{-1} (Carsky and Schultz, 1999). Cowpea is also well adapted to sandy soil, which makes it a viable candidate for use in cropping systems in Florida. It has also been found to tolerate heat and drought better than almost any other legume (Auguiar et al., 1999).

Lima bean (*Phaseolus lunatus*), another legume species, is native to Central America, its culture dating back as far as 7,000 years ago (Redden and Wright, 1998). The United States was the top-ranking country in lima bean production in 1996 with Florida being one of the main production areas by acreage of harvested beans (Luo, 2000; Nwosolo, 1996; Peet, 2002). Lima beans have been found to thrive in sandy or clay loam soils and have also been found to be drought-resistant, making them well suited for inclusion in cropping systems in Florida.

A considerable amount of variation can be assumed to be present in any test field. Use of a proper blocking technique can significantly reduce experimental error that might occur due to that variation (Gomez and Gomez, 1984). The 3 single-factor experimental designs chosen for this study were a completely randomized (CRD), a randomized complete block (RCB), and a Latin square (LS). Differences in blocking are what define these 3 designs. The main purpose of blocking is to decrease experimental error by eliminating the contribution of known sources of variation among experimental plots (Gomez and Gomez, 1984). Blocking maximizes the difference among blocks while minimizing the differences among treatment plots. Correct blocking can increase precision, though an increase in blocking does cause a decrease in the degrees of freedom in the error term used for statistical analysis of the experimental results.

A CRD has no blocking at all and is only applicable for homogenous experimental plots. When a known source of variation is present among plots, a RCB design should be utilized. This deign is characterized by blocks of equal size, each containing all of the treatments in the study. When 2 known sources of variation are present among plots, they can be controlled using a LS design. The LS is characterized by 2-directional blocking, or row- and column- blocking. Every treatment of the study appears once in each row-block and once in each column-block. These 3 different experimental designs were utilized for teaching purposes as well as to account for a physical slope in the experimental field. There was no slope variation in the area where the CRD experiment was conducted. There was a single-direction slope in the field where the RCB experiment was conducted. There was a 2-directional slope present in the field where the LS experiment was conducted.

A 2-yr experiment was conducted to examine how well various varieties of cowpea and lima bean would perform in Florida. This test was also part of a larger study (see Chapter 6) that was performed to investigate the effects of various cropping histories on no-till sweet corn. This specific portion of the overall study comprised the second of 3 cropping histories examined. The objectives of this study were to evaluate the yield and plant nutrition of the cowpea and lima bean varieties. Minor objectives were to demonstrate the use of 3 single factor experimental designs and to fulfill statistical teaching purposes.

Materials and Methods

Three cowpea variety experiments were established on 31 July of 2002 and 3 lima bean experiments on 29 July of 2003 on a Millhopper fine sand (loamy siliceous hyperthermic Grossarenic Paleodults) (USDA-NRCS, 2003) at Gainesville, Florida. Five varieties of cowpea (‘California Blackeye #5’, ‘White Acre’, ‘Texas Cream 12’, ‘Mississippi Cream’, and ‘Iron Clay’) and 5 varieties of lima bean (‘Fordhook’, ‘Florida Butter Lima’, ‘Henderson Bush’, ‘Cangreen’, and ‘White Dixie Butter Lima’) were planted by hand at a rate of 25 seeds m^{-1} of row. Experimental plots were 6 m^2, each containing four 0.75 m wide rows, 2.0 m long.

Experimental Design

Three experiments were established for both cowpea and lima bean, using 3 single-factor experimental designs including a CRD, a RCB, and a LS. The CRD experiment was established on a level area of the field with no apparent variation. We established the RCB in an area of the field with an evident slope running east to west. The LS was placed in an area of the experimental field where a slope was observed to run in 2 directions, east to west as well as north to south. Varieties were the single factor in all of the cowpea and lima bean experiments. In the lima bean RCB study, ‘Jackson Wonder’ replaced ‘Fordhook’ due to germination problems. All designs tested the same hypothesis and were used to fulfill statistical teaching purposes. The hypothesis stated that cowpea and lima bean would not significantly differ in yield or nutrient content by variety.

After the implementation of the treatments, the plots were rotortilled as well as hand-weeded several times to minimize competition. Lannate LV was applied at 2 L ha^{-1} to control pests. The cowpea and lima bean received water from rainfall and from overhead sprinkler irrigation. The 3 cowpea and the 3 lima bean experiments were harvested on 26 September 2002 and on 29 September 2003, respectively, all by hand. Pods from all rows in the cowpea and lima beans studies and whole plants from the center 2 rows of each plot of the cowpea studies were bagged and removed from the field to obtain fresh and dry weights and for mineral analysis. Soil samples were obtained from the top 20 cm of soil from each plot of the lima bean studies and were combined across treatments. Data from each experiment of each year was analyzed separately.

Nitrogen Analysis

Cowpea pods and plants were separated and fresh and dry weight yields obtained for each. Fresh and dry weights were also obtained for lima bean pods. Plant fresh weight was determined using the stems, leaves, and roots before placing them in a forced air oven at 70°C before obtaining dry weights. Whole plant samples were then chopped in a hammer mill, mixed well, and grab samples were ground to pass through a 2 mm stainless steel screen using a Wiley mill. The pod samples were ground using a Wiley mill after they were dried in the forced air oven and weighed for dry weight yields. All samples were stored in plastic sample bags.

For N analysis, a micro-Kjeldahl procedure was used (Gallaher et al., 1975). A mixture of 0.100 g of each cowpea pod or plant sample, 3.2 g salt-catalyst (9:1 K_2SO_4:$CuSO_4$), 2 to 3 glass boiling beads and 10 mL of H_2SO_4 were vortexed in a 100-mL test tube under a hood. To reduce frothing, 2 mL 30% H_2O_2 were added in 1 mL increments and tubes were then digested in an aluminum block digester at 370°C for 3.5 h (Gallaher et al., 1975). Tubes were capped with small Pyrex funnels that allowed for evolving gases to escape while preserving reflux action. Cool digested solutions were vortexed with approximately 30 mL of de-ionized water, allowed to cool to room temperature, brought to 75 mL volume, and filtered to remove the boiling beads. Solutions were then transferred to square Nalgene storage bottles, sealed, mixed, and stored. Nitrogen trapped as $(NH_4)_2SO_4$ was analyzed on an automatic solution sampler and a proportioning pump. A plant standard with a known N concentration value was subjected to the same procedure as the cowpea pod and plant samples and used as a check (Multiple Cropping Agronomy Lab, University of Florida). Fresh weight, dry weight, and N concentration, as appropriate, were recorded for each study.

Mineral Analysis

For mineral analysis, 1.0 g from each cowpea pod and plant sample was weighed into 50 mL beakers and ashed in a muffle furnace at 480°C for 6 h. The samples were then cooled to room temperature and moistened with de-ionized water. Under a hood, 20 mL of de-ionized water and 2 mL of concentrated HCl were added to each beaker. The beakers were placed on a hot plate, slowly boiled until dry, and then removed. An additional 20 mL of de-ionized water and 2 mL concentrated HCl were then added to the beakers before small Pyrex watch glasses were used to cover the beakers for reflux. The samples were placed on the hot plate and brought to a forceful boil. They were then removed and again allowed to cool to room temperature. Each sample was then brought to volume in 100 mL flasks and mixed. The flasks were set aside overnight to allow the Si to settle. The solutions were then decanted into 20 mL scintillation vials for analysis. Phosphorus concentration was analyzed by colorimetry, K and Na concentrations by flame emission, and Ca, Mg, Cu, Fe, Mn, and Zn concentrations by atomic adsorption spectrometry (AA). Mineral concentrations were multiplied by dry matter yield to obtain mineral content (yield of or crop removal of minerals).

Soil Analysis

During the lima bean studies, soil samples were obtained from the top 20 cm of soil directly following harvest of each experiment. Samples were air-dried in open paper bags, then screened through a 2.0 mm stainless steel sieve to remove any rocks or debris and stored for further analysis. The samples were then analyzed for N, mineral concentrations, pH, buffer pH (BpH), organic matter (OM), and cation exchange capacity (CEC). For soil N, a mixture of 2.0 g of each soil sample, 3.2 g of salt catalyst (9:1 K_2SO_4:$CuSO_4$), and 10 mL of H_2SO_4 were subjected to the same procedures for N analysis as leaf tissue was, except that boiling beads were not used because the particles of soil served the same purpose. A soil sample of known N concentration was also analyzed and used as a check.

For soil mineral analysis, a Mehlich I (Mehlich, 1953), extraction method was used. Five g of each soil sample were weighed and extracted with 20 mL of a combination of 0.025 N H_2SO_4 and 0.05 N HCl. Using an Eberach shaker at 240 oscillations minute^{-1}, mixtures were shaken for 5 min. The mixtures were then filtered using Schleischer and Schuell 620 (11 cm) filter paper and poured into scintillation vials. The remaining solutions were then subjected to analysis of P, K, Ca, Mg, Na, Cu, Fe, Mn, and Zn in the same manner as described for leaf tissue analysis.

Soil pH was found using a 1:2 soil to water volume ratio using a glass electrode pH meter (Peech, 1965). Buffer pH (BpH) was found using Adams/Evans buffered solution (Adams and Evans, 1962). Cation exchange capacity (CEC) was estimated by the summation of relevant cations (Hesse, 1972; Jackson, 1958). Estimated soil CEC was calculated by summing the milliequivalents of the determined bases of Ca, Mg, K, and Na (where applicable) and adding them to exchangeable H^+ expressed in milliequivalents per 100 g (cmol kg^{-1}) (Hesse, 1972).

For the determination of soil organic matter (OM), a modified version of the Walkley Black method was used, in which 1.0 g of soil was weighed into a 500 mL Earlenmeyer flask, and 10 mL of 1 N $K_2Cr_2O_7$ solution was then pipetted into the flask. Twenty mL of concentrated H_2SO_4 was added and mixed by gentle rotation for 1 min using care to avoid throwing soil up onto the sides of the flask. The flask was then left to stand for 30 min, and then diluted to 200 mL with de-ionized water. Five drops of indicator were added, and the solution was titrated with 0.5 N Ferrous Sulfate Solution until the color sharply changed from a dull green to a reddish brown color. A flask without soil was prepared in the same manner and titrated to determine the blank titrant, along with a flask containing a check soil with a known amount of OM. Percent OM was determined using the equation: percent OM = (1-T/S) x 6.8, where S is blank-titration in mL of ferrous ammonium sulfate solution, and T is sample titration in mL ferrous ammonium sulfate solution (Walkley, 1935; Allison, 1965).

Nematode Analysis

Five lima bean plants from each variety in each experimental design were sampled for nematode infestation ratings. Visual gall rating of plant roots was performed for each of the samples. The rating scheme for evaluation of nematode galls was based on a scale from 1-10, 0 signifying no infestation and 10 signifying root death (Netscher and Sikora, 1990).

Statistical Analysis

Data were recorded in Quattro Pro (Anonymous, 1987) spreadsheets and transferred to MSTAT 4.0 (Anonymous, 1985) for analysis of variance using the appropriate model for the experimental design (Table 3-1 to 3-3). Mean separation was performed using fixed LSD at the 0.05 level of probability (Gomez and Gomez, 1984).

Results

When comparing the 5 cowpea varieties in terms of fresh whole plant (no pods) yield, differences ($p \geq 0.05$) were exhibited and 'Iron Clay' produced the highest yields in all 3 experiments (Table 3-4). 'California Blackeye #5'and 'Mississippi Cream' produced the highest ($p \leq 0.05$) fresh pod yields (Table 3-4). 'Iron Clay' produced the highest ($p \leq 0.05$) dry whole plant matter for all 3 experimental designs while 'California

Blackeye #5' did for pods (Table 3-5). The highest ($p \leq 0.05$) pod yielding varieties, in terms of percentage of pods produced, were 'Mississippi Cream' and 'California Blackeye #5' (Table 3-6).

Mineral analysis of macronutrient content in cowpea plant determined that 'Iron Clay' had the highest ($p \leq 0.05$) P content in all 3 experiments and some of the highest N and K contents, along with the hybrids 'California Blackeye #5' and 'Mississippi Cream' (Table 3-7). 'Iron Clay' also had some of the highest ($p \leq 0.05$) contents of Ca and Na and had the highest ($p \leq 0.05$) levels of Mg and P (Table 3-7). Analysis of micronutrient content in cowpea plant determined that the highest ($p \leq 0.05$) contents of Cu and Mn and some of the highest ($p \leq 0.05$) contents of Fe and Zn occurred in 'Iron Clay' (Table 3-7).

Highest ($p \leq 0.05$) content of N, Mg, and P in cowpea pods for all 3 experiments were found in 'California Blackeye #5' (Table 3-8). 'California Blackeye #5' was among the varieties found to have the highest ($p \leq 0.05$) Ca, K, and Na contents (Table 3-8). Micronutrient analysis of the pod determined that 'Iron Clay' contained the highest ($p \leq 0.05$) content of Cu, Mn, and Zn while also containing some of the highest ($p \leq 0.05$) content of Fe (Table 3-8).

When comparing varieties of lima bean for differences in pods produced, no particular variety stood out as producing the highest ($p \leq 0.05$) fresh weight of pods. In the CRD, 'Fordhook' and 'Henderson Bush' were top producers, while in the RCB, 'Florida Butter' and Jackson Wonder' were top producers (Table 3-9). In the LS, 'Fordhook' and 'Florida Butter' were the highest ($p \leq 0.05$) producers of fresh pods (Table 3-9). 'Henderson Bush' had some of the highest ($p \leq 0.05$) percent of pods that were beans for all experiments (Table 3-10). This variety also had some of the highest ($p \leq 0.05$) nematode infestation ratings (Table 3-11).

Mehlich I (Mehlich, 1953) extractable minerals for soil samples taken directly after harvest of lima bean was averaged over 5 replications taken from each experimental design (Table 3-12). Macronutrient levels were all found to be within acceptable ranges (Table 3-12). Micronutrients were also found to be at adequate levels, except for Cu (Table 3-12), which was low possibly due to higher pH in the soil (Kidder and Rhue, 1983).

Discussion and Conclusion

Of the cowpea varieties tested, there was no specific variety that stood out as being the most suitable for production in Florida. Both 'Iron Clay' and 'California Blackeye #5' proved to be strong varieties, but each had very different strengths. 'Iron Clay' produced the highest whole plant matter yield of all of the varieties. The plant biomass produced by this variety also had some of the highest contents of the important minerals N, P, and K. 'Iron Clay' also had the lowest percentage of pods produced, therefore producing more plant biomass than any other variety tested. 'California Blackeye #5' had some of the highest pod yields as well as some of the highest percentage of pod production. The pods from this variety were very healthy, containing the highest levels of N, Mg, P, Cu, Mn, and Zn.

Each of the 2 varieties would be appropriate for use in different situations. For production in Florida as part of a cropping system or for use as organic mulch, 'Iron Clay' would make the strongest choice. This variety of cowpea has the capacity to provide extra N for succeeding crops, when used in a system, following the harvest of its pods. The remaining plant residue would be high in K and P, as well as N, which would become available for utilization by other crops. ‘Iron Clay’ also produces more plant biomass than pods, which makes it preferable for use as a mulch. This particular variety of cowpea has also been found to suppress populations of the extremely detrimental plant-parasitic nematode, *M. incognita*, which can pose a huge problem in crop production in Florida (Wang et al., 2002). For use as a cover crop in cropping systems in Florida, ‘Iron Clay’ would be the most appropriate variety choice.

‘California Blackeye #5’ is a variety of cowpea that would make a good candidate for a very different situation, of consumption. This variety has several advantages over other varieties of cowpea for use in this area and is basically grown for consumption purposes. ‘California Blackeye #5’ pods are high in many nutrients and have the potential to be very beneficial when consumed. This variety of cowpea also has a higher percentage of pod production than other varieties, which is preferable for varieties grown as food crops. ‘California Blackeye #5’ would be the most appropriate variety of cowpea for production for consumption purposes in Florida.

The lima bean pods were harvested from the field before whole plant samples could be obtained, so the information for comparison of lima bean varieties was minimal. No particular variety stood out when pod yield was examined. ‘Henderson Bush’, ‘Cangreen’, and ‘Fordhook’ had the highest bean percentage of harvested pods. The varieties that had the lowest nematode infestation ratings were ‘Florida Butter’, ‘White Dixie Butter’, and again ‘Fordhook’. The variety that seems to be the most suited for production, possibly as a food crop, in Florida is ‘Fordhook’. Lima bean is a crop that is produced primarily for consumption, and this variety would be the most appropriate of those tested for this purpose.

Table 3-1. Cowpea plant yield, pod yield, and percentage of plant that was pods for cowpea variety analysis of variance.

Source of variation	df	Plant fr. wght.	Pod fr. wght.	Plant dry wght.	Pod dry wght.	Pod % of plant, fr.	Pod % of plant, dry
				CRD			
Variety	4	*	*	*	*	*	*
Error	20	—	—	—	—	—	—
Total	24	—	—	—	—	—	—
				RCB			
Replications	4	—	—	—	—	—	—
Variety	4	*	*	*	*	*	*
Error	16	—	—	—	—	—	—
Total	24	—	—	—	—	—	—
				LS			
Row	4	—	—	—	—	—	—
Column	4	—	—	—	—	—	—
Variety	4	*	*	*	*	*	*
Error	12	—	—	—	—	—	—
Total	24	—	—	—	—	—	—

* Significant at the 0.05 level.

Table 3-2. Cowpea plant mineral content and cowpea pod mineral content for cowpea variety analysis of variance.

Source of variation	df	N	Ca	Mg	K	Na	P	Cu	Fe	Mn	Zn	N	Ca	Mg	K	Na	P	Cu	Fe	Mn	Zn
		Plant										Pod									
										CRD											
Variety	4	*	ns†	*	*	ns	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Error	20	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	24	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
										RCB											
Replications	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Variety	4	*	*	*	*	*	*	*	*	*	*	*	*	*	ns	*	*	*	*	*	*
Error	16	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	24	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
										LS											
Row	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Column	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Variety	4	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Error	12	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	24	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

*Significant at the 0.05 level.
†ns = not significant.

Table 3-3. Lima bean pod yield, percent pods that were beans, and nematode ratings for lima bean variety analysis of variance.

Source of variation	df	Pod yield, fr.	Pod yield, dry	Bean % of pod, dry	Nematode rating
			CRD		
Variety	4	*	*	*	*
Error	20	—	—	—	—
Total	24	—	—	—	—
			RCB		
Replications	4	—	—	—	—
Variety	4	*	*	*	*
Error	16	—	—	—	—
Total	24	—	—	—	—
			LS		
Row	4	—	—	—	—
Column	4	—	—	—	—
Variety	4	*	*	*	*
Error	12	—	—	—	—
Total	24	—	—	—	—

* Significant at the 0.05 level.

Table 3-4. Fresh weights of cowpea for three experimental designs and five varieties, fall 2002.

Variety	CRD	RCB	LS
		Fresh weight, g m^{-2}	
		Plant	
Iron Clay	4910 a†	4310 a	2402 a
TX Cream 12	3056 b	2156 b	964 b
MS Cream	2982 b	2340 b	880 b
White Acre	2800 bc	2112 b	906 b
CA Blackeye #5	2262 c	1912 b	1264 b
LSD at $p \leq 0.05$	636	518	633
		Pod	
Iron Clay	256 c	227 c	112 c
TX Cream 12	483 b	340 bc	88 c
MS Cream	755 a	560 a	237 b
White Acre	492 b	380 b	148 c
CA Blackeye #5	687 a	580 a	373 a
LSD at $p \leq 0.05$	128	137	88

†Values in columns not followed by the same letter are significantly different ($p \leq 0.05$) according to LSD.

Table 3-5. Dry weights of cowpea for three experimental designs and five varieties, fall 2002.

Variety	CRD	RCB	LS
		Dry weight, g m^{-2}	
		Plant	
Iron Clay	836 a†	764 a	428 a
TX Cream 12	514 b	354 b	176 c
MS Cream	488 b	442 b	176 c
White Acre	460 b	384 b	162 c
CA Blackeye #5	452 b	442 b	306 b
LSD at $p \leq 0.05$	113	115	108
		Pod	
Iron Clay	41 c	37 c	18 c
TX Cream 12	101 b	71 b	18 c
MS Cream	119 b	88 b	40 b
White Acre	105 b	82 b	32 bc
CA Blackeye #5	197 a	166 a	106 a
LSD at $p \leq 0.05$	25	28	20

†Values in columns not followed by the same letter are significantly different ($p \leq 0.05$) according to LSD.

Table 3-6. Percent of cowpea plant that was pods for three experimental designs and five varieties, fall 2002.

Variety	CRD	RCB	LS
	% plant that was pods		
		Fresh	
Iron Clay	5.25 d†	5.43 c	4.95 c
TX Cream 12	16.24 c	16.84 b	8.42 bc
MS Cream	25.98 ab	24.09 b	26.80 a
White Acre	17.95 bc	19.67 b	16.70 b
CA Blackeye #5	32.20 a	31.62 a	29.12 a
LSD at $p \leq 0.05$	8.0	7.0	8.0
		Dry	
Iron Clay	4.84 c	4.95 c	4.41 c
TX Cream 12	20.26 b	21.83 b	9.46 c
MS Cream	24.76 b	20.48 b	22.35 b
White Acre	23.09 b	22.01 b	19.39 b
CA Blackeye #5	45.07 a	38.35 a	34.37 a
LSD at $p \leq 0.05$	8.0	9.0	9.0

†Values in columns not followed by the same letter are significantly different ($p \leq 0.05$) according to LSD.

Table 3-7. Mineral content in cowpea plant for three experimental designs and five varieties, fall 2002.

Variety	CRD	RCB	LS
	Mineral content, g m^{-2}		
		N	
Iron Clay	19.4 a†	14.9 a	10.1 a
TX Cream 12	14.4 b	10.5 b	5.1 bc
MS Cream	13.0 b	10.4 b	5. bc
White Acre	13.8 b	10.5 b	4.33 c
CA Blackeye #5	12.4 b	10.5 b	7.6 ab
LSD at $p \leq 0.05$	3.7	2.7	2.9
		Ca	
Iron Clay	7.3 a	8.6 a	5.4 a
TX Cream 12	5.0 a	3.8 b	2.3 b
MS Cream	4.7 a	4.9 b	2.2 b
White Acre	4.1 a	4.0 b	2.1 b
CA Blackeye #5	4.0 a	4.1 b	3.4 b
LSD at $p \leq 0.05$	ns	1.2	1.4
		Mg	
Iron Clay	2.8 a	3.2 a	1.9 a
TX Cream 12	1.5 b	1.3 c	0.8 c
MS Cream	1.4 b	1.4 bc	0.7 c
White Acre	1.5 b	1.5 bc	0.7 c
CA Blackeye #5	1.4 b	1.7 b	1.3 b
LSD at $p \leq 0.05$	0.5	0.4	0.5
		K	
Iron Clay	14.9 a	10.1 a	4.3 a
TX Cream 12	9.8 b	6.4 b	2.1 b
MS Cream	9.8 b	7.6 ab	2.0 b
White Acre	10.2 b	6.0 b	2.0 b
CA Blackeye #5	6.3 c	5.2 b	3.1 ab
LSD at $p \leq 0.05$	3.4	2.8	1.8
		Na	
Iron Clay	0.7 a	0.8 a	0.5 a
TX Cream 12	0.4 a	0.3 b	0.2 c
MS Cream	0.4 a	0.3 b	0.2 bc
White Acre	0.3 a	0.2 b	0.2 c
CA Blackeye #5	0.3 a	0.3 b	0.4 ab
LSD at $p \leq 0.05$	ns	0.2	0.2
		P	
Iron Clay	2.8 a	2.7 a	1.7 a
TX Cream 12	1.9 b	1.4 b	0.8 bc
MS Cream	1.6 b	1.5 b	0.7 c
White Acre	1.7 b	1.4 b	0.6 c
CA Blackeye #5	1.6 b	1.4 b	1.2 b
LSD at $p \leq 0.05$	0.5	0.4	0.4

Table 3-7. Continued.

Variety	CRD	RCB	LS
	Mineral content, mg m^{-2}		
		Cu	
Iron Clay	4.86 a	3.84 a	2.06 a
TX Cream 12	2.80 b	2.03 b	0.88 c
MS Cream	2.52 b	2.30 b	0.74 cd
White Acre	2.19 b	2.17 b	0.70 d
CA Blackeye #5	2.58 b	2.26 b	1.48 b
LSD at $p \leq 0.05$	0.85	0.81	0.17
		Fe	
Iron Clay	142.26 a	193.60 a	75.84 a
TX Cream 12	65.02 b	62.76 b	33.94 b
MS Cream	89.52 b	76.46 b	34.28 b
White Acre	74.74 b	63.10 b	28.28 b
CA Blackeye #5	74.46 b	70.77 b	65.58 a
LSD at $p \leq 0.05$	37.3	89.0	22.7
		Mn	
Iron Clay	16.31 a	15.63 a	13.24 a
TX Cream 12	7.95 b	6.64 bc	5.34 bc
MS Cream	8.42 b	6.33 c	5.41 bc
White Acre	6.30 b	8.61 bc	4.13 c
CA Blackeye #5	7.67 b	9.93 b	7.77 b
LSD at $p \leq 0.05$	4.4	3.4	3.3
		Zn	
Iron Clay	30.16 a	32.13 a	16.53 a
TX Cream 12	18.10 b	13.74 c	10.16 bc
MS Cream	15.92 b	14.04 c	8.10 c
White Acre	13.99 b	14.34 c	6.55 c
CA Blackeye #5	16.11 b	20.71 b	14.74 ab
LSD at $p \leq 0.05$	5.3	5.0	5.4

†Values in columns not followed by the same letter are significantly different ($p \leq 0.05$) according to LSD.

Table 3-8. Mineral content in cowpea pod for three experimental designs and five varieties, fall 2002.

Variety	CRD	RCB	LS
	Mineral content, g m^{-2}		
		N	
Iron Clay	1.7 c†	1.3 c	0.7 c
TX Cream 12	3.7 b	2.6 b	0.7 c
MS Cream	4.8 b	3.4 b	1.7 b
White Acre	3.8 b	3.0 b	1.2 bc
CA Blackeye #5	7.0 a	5.6 a	3.7 a
LSD at $p \leq 0.05$	2.0	1.0	0.7
		Ca	
Iron Clay	0.2 c	0.1 c	0.1 cd
TX Cream 12	0.2 c	0.1 c	0.1 d
MS Cream	0.4 b	0.3 ab	0.2 b
White Acre	0.2 c	0.2 b	0.1 c
CA Blackeye #5	0.4 a	0.3 a	0.2 a
LSD at $p \leq 0.05$	0.01	0.1	0.04
		Mg	
Iron Clay	0.1 d	0.1 d	0.1 b
TX Cream 12	0.3 c	0.2 c	0.1 b
MS Cream	0.4 b	0.3 b	0.1 b
White Acre	0.3 c	0.2 bc	0.1 b
CA Blackeye #5	0.5 a	0.4 a	0.3 a
LSD at $p \leq 0.05$	0.09	0.07	0.06
		K	
Iron Clay	0.6 d	0.5 a	0.2 b
TX Cream 12	1.2 c	0.7 a	0.2 b
MS Cream	1.6 b	1.2 a	0.5 b
White Acre	1.3 c	1.0 a	0.4 b
CA Blackeye #5	2.2 a	1.3 a	1.0 a
LSD at $p \leq 0.05$	0.29	ns	0.32
		Na	
Iron Clay	0.03 b	0.02 b	0.01 b
TX Cream 12	0.1 ab	0.03 ab	0.01 b
MS Cream	0.1 a	0.1 ab	0.03 ab
White Acre	0.1 ab	0.04 ab	0.02 b
CA Blackeye #5	0.1 a	0.1 a	0.1 a
LSD at $p \leq 0.05$	0.04	0.04	0.04
		P	
Iron Clay	0.2 c	0.2 c	0.1 c
TX Cream 12	0.4 b	0.3 b	0.1 c
MS Cream	0.6 b	0.4 b	0.2 b
White Acre	0.5 b	0.4 b	0.2 bc
CA Blackeye #5	0.9 a	0.7 a	0.5 a
LSD at $p \leq 0.05$	0.13	0.12	0.10

Table 3-8. Continued.

Variety	CRD	RCB	LS
	Mineral content, mg m^{-2}		
		Cu	
Iron Clay	0.25 d	0.22 c	0.08 c
TX Cream 12	0.46 c	0.31 bc	0.06 c
MS Cream	0.68 b	0.50 b	0.19 b
White Acre	0.57 bc	0.44 b	0.09 c
CA Blackeye #5	1.32 a	0.97 a	0.50 a
LSD at $p \leq 0.05$	0.13	0.19	0.07
		Fe	
Iron Clay	33.10 d	30.34 c	13.80 d
TX Cream 12	67.86 c	46.70 bc	47.48 bc
MS Cream	100.38 b	67.30 b	60.58 ab
White Acre	90.58 b	59.98 b	28.08 cd
Ca Blackeye #5	141.28 a	145.74 a	76.64 a
LSD at $p \leq 0.05$	21.3	22.4	26.1
		Mn	
Iron Clay	1.00 c	0.62 c	0.46 c
TX Cream 12	1.22 c	1.01 bc	0.33 c
MS Cream	2.21 b	1.21 b	0.93 b
White Acre	1.27 c	1.33 b	0.62 bc
CA Blackeye #5	2.70 a	2.46 a	1.54 a
LSD at $p \leq 0.05$	0.40	0.48	0.35
		Zn	
Iron Clay	1.61 d	1.18 c	0.81 bc
TX Cream 12	2.61 c	1.96 bc	0.66 c
MS Cream	4.45 b	2.49 b	1.71 b
White Acre	3.18 c	2.87 b	1.22 bc
CA Blackeye #5	5.99 a	5.77 a	4.45 a
LSD at $p \leq 0.05$	0.87	1.0	0.93

†Values in columns not followed by the same letter are significantly different ($p \leq 0.05$) according to LSD.

Table 3-9. Pod yield for six lima bean varieties over three experimental designs, fall 2003.

Variety	CRD	RCB	LS
	Yield, g m^{-2}		
		Fresh	
Fordhook	891 a†	—	629 a
FL Butter	685 b	687 a	530 ab
Henderson Bush	753 ab	658 b	466 b
Cangreen	722 b	577 b	431 b
White Dixie Butter	678 b	588 b	467 b
Jackson Wonder	—	763 a	—
LSD at $p \leq 0.05$	48	78	122
		Dry	
Fordhook	159 c	—	188 a
FL Butter	131 c	131 b	116 c
Henderson Bush	245 a	156 a	155 b
Cangreen	209 b	145 ab	154 b
White Dixie Butter	136 ab	125 b	119 c
Jackson Wonder	—	160 a	—
LSD at $p \leq 0.05$	32	24	33

†Values in columns not followed by the same letter are significantly different ($p \leq 0.05$) according to LSD.

Table 3-10. Percent of lima bean pods that were beans for six lima bean varieties over three experimental designs, fall 2003.

Variety	CRD	RCB	LS
	% of plant that was pods		
Fordhook	17.8 c†	—	30.4 ab
FL Butter	19.2 c	19.1 b	21.8 c
Henderson Bush	32.9 a	23.8 a	33.2 a
Cangreen	29.0 b	25.3 a	37.4 a
White Dixie Butter	20.1 c	21.2 b	25.5 bc
Jackson Wonder	—	20.9 b	—
LSD at $p \leq 0.05$	3.5	2.1	7.4

†Values in columns not followed by the same letter are significantly different ($p \leq 0.05$) according to LSD.

Table 3-11. Nematode infestation ratings for six lima bean varieties over three experimental designs, fall 2003.

Variety	CRD	RCB	LS
	Rating†		
Fordhook	2.3 b‡	—	4.2 bc
FL Butter	2.8 b	3.2 b	3.4 c
Henderson Bush	7.7 a	6.0 ab	5.7 abc
Cangreen	7.3 a	8.8 a	7.3 a
White Dixie Butter	6.4 a	2.8 b	6.5 ab
Jackson Wonder	—	3.0 b	—
LSD at $p \leq 0.05$	2.3	3.9	2.6

†Nematode infestation rating scale: 0-10, 0 = no infestation, 10 = severe infestation.
‡Values in columns not followed by the same letter are significantly different ($p \leq 0.05$) according to LSD.

Table 3-12. Soil mineral analysis for samples following lima bean harvest for three experimental designs, fall 2003.

Average†	CRD	RCB	LS
	Mineral concentration, mg kg^{-1}		
Ca	624	463	253
Mg	207.2	77.0	55.3
K	81.0	41.0	30.6
N	700	666	519
P	227	190	127
Na	11.1	10.2	7.0
Cu	0.40	0.30	0.27
Fe	50.2	37.7	33.2
Mn	11.30	8.66	5.79
Zn,	10.47	8.51	4.44
	Soil characteristics		
pH	7.3	7.4	7.3
BpH	7.86	7.88	7.88
OM, %	1.53	1.55	1.43
CEC, meq 100 g^{-1}‡	5.13	4.03	2.76

†Values are averages of 5 replications taken from each experimental design.
‡cmol kg^{-1}

CHAPTER 4
MINERAL CONTENT AND YIELD OF SUNN HEMP DUE TO CLIPPING HEIGHTS AND PLANT POPULATIONS

Introduction

Sunn hemp (*Crotalaria juncea* L.) is a tropical branching annual legume that has recently become a crop of interest for sustainable farmers. The reason for their interest stems from the crop's wide array of benefits, including erosion prevention, improvement of soil properties, weed suppression and reduction of nematode populations. This crop could possibly be a simple and inexpensive solution to many of the problems that the average farmer faces.

Sunn hemp is native to India and Pakistan where it has been used to produce cloth, twine, and rope for centuries (Li et al., 2000). Today, it is cultivated in many regions of the world, ranging from Hawaii and California to the tropics of Uganda, Zimbabwe, and Brazil to the southwestern United States (Duke, 1981). Traditionally, it has been utilized as a green manure, livestock feed, and a non-wood fiber crop (USDA, 1999).

The possibility of using sunn hemp in cropping systems and as a cover crop has been the focus of many tests recently. Sunn hemp has proven to be a valuable crop to grow for high-protein forage in late summer when pastures perform poorly (Li et al., 2000). When grown as a summer annual, it was found to produce over 5,600 kg ha^{-1} of dry biomass (USDA, 1999). It can be used to prevent erosion of soil and to suppress weed growth (Li et al., 2000). Sunn hemp has also shown good resistance to root-knot nematodes (*Meloidogyne incognita*) and has actually reduced nematode populations

(Li et al., 2000; Marshall, 2002; Wang et al., 2002a). Since it is a legume, sunn hemp can also fix much of the N needed for succeeding crops. Sunn hemp can contribute a significant amount of N to the soil, over 112 kg N ha^{-1} (USDA, 1999). When it is used as a cover crop, it can conserve soil water and recycle plant nutrients (USDA, 1999). Sunn hemp has also been found to be very beneficial when used as an amendment in crop production (Marshall et al., 2002).

Sunn hemp has proven to be very beneficial in multiple cropping systems in the southeast U.S. The cultivar Tropic Sunn was grown in Alabama as a cover crop/green manure after corn (*Zea* mays L.) harvest. The dry matter biomass achieved was on average 5,829 kg ha^{-1} in a 9-12 week period over the 2-yr study (Mansoer et al., 1997). In an additional study conducted with 'Tropic Sunn', the crop was found to have added 150 to 164 kg N ha^{-1} to the soil after a 60-d growth period (Rotar and Joy, 1983). The legume yielded a total of 3,495 kg of dry biomass (roots and shoots) and fixed 204 kg N ha^{-1} in three months after seeding in a study conducted in Homestead, FL (Li et al., 2002).

In attempts to investigate this beneficial crop even further, a 2-yr experiment was conducted at the University of Florida to determine the effects of different plant heights and plant populations on plant yield and mineral concentration. This test was also part of a larger study (see Chapter 6) conducted to examine the effects of cropping histories on no-till sweet corn. The objectives of the test were to analyze sunn hemp for mineral concentrations to determine mineral contents as well as to find the best clip height and population for maximum yield and N content. Our null hypothesis stated that the varying clip heights and populations tested would not affect yield or mineral content.

Materials and Methods

This study involved a split-split plot experiment, conducted from August to December of 2002 and again in 2003 on a Millhopper fine sand, classified as loamy siliceous semiactive hyperthermic Grossarenic Paleodults (USDA-NRCS, 2003) in Gainesville, FL. Main effects were the year during which the test was performed (2002, 2003). Sub-effects were 3 different plant populations (6, 18, and 30 plants m^{-2}) of sunn hemp. Sub-sub effects for the test were 5 different plant heights (0.4, 0.8, 1.2, 1.6, and 2.0 m) at which the sunn hemp was maintained. The 2003 portion of the experiment was re-randomized and year was treated as the main effect in a split-split plot experimental design. Data from each year were analyzed together.

The split-split plot design is uniquely suited for a 3-factor experiment when 3 different levels of precision are desired for various effects (Gomez and Gomez, 1984). Each level of precision is assigned to the effects associated with each of the 3 factors. The main-plot factor receives the lowest degree of precision and the sub-sub plot factor receives the highest.

Plant Population

Sunn hemp seed was planted with a Flex 71 planter and a tractor on 29 August 2002 and 30 August 2003 at a rate of 200 seeds 6 m^{-1} of row (44 seeds m^{-2}). Each plot contained 4 rows, each 0.76 m wide. Plot size was 6 m^2. Plant populations were established by hand thinning on 17 September 2002 and 15 September 2003.

After the implementation of the plant populations, Lannate LV was applied to control pests at a rate of 1.2 L ha^{-1} during both years of the study. The hemp received water from rainfall and from overhead sprinkler irrigation, ensuring at least 3 cm of water per week. Weeds were controlled with plowing by cultivator sweeps.

Yield

Plant height treatments were maintained by hand trimming. The plants were checked on a weekly basis to ensure specific heights were maintained. When plants exceeded the specific height by 0.6 m, the tops were clipped back to that height. Sub-plot treatments 1 and 2, the 0.4 m (4 clippings required) and 0.8 m (3 clippings required) heights, were initially implemented on 10 October and 13 October of 2002 and 2003, respectively. Treatment 3, the 1.2 m (2 clippings required) height, was initially implemented on 30 October and 8 November of 2002 and 2003, respectively. Treatment 4, the 1.6 m (1 clipping required) height, was initially implemented 8 November of 2002 and 12 November of 2003, respectively. Treatment 5, the 2.0 m height, never had to be implemented because the plants never exceeded this specific height. Whole plants were harvested on 5 December 2002 and 7 December 2003.

The plant material that was harvested with the implementation of each treatment as well as the whole plants were kept for analysis. Fresh weights were obtained and then the hemp was placed into a 60°C forced air oven to dry. Dry matter yields were obtained from the dried plant material before it was chopped in a hammer mill, mixed well, and ground to pass a 2-mm stainless steel screen using a Wiley mill. All plant material was stored in plastic sample bags before analysis.

Nitrogen Analysis

For N analysis of the plant material, a micro-Kjeldahl procedure was used (Gallaher et al., 1975). A mixture of 0.100 g of each sunn hemp plant material sample, 3.2 g salt-catalyst (9:1 K_2SO_4:$CuSO_4$), 2 Pryrex beads and 10-mL of H_2SO_4 were vortexed in a 100-mL Pyrex test-tube under a hood. To reduce frothing, 2 mL of 30% H_20_2 was added in 1 mL increments and tubes were digested in an aluminum block digester at 370°C for 3.5 hr. Tubes were capped with small Pyrex funnels that allowed for evolving gases to escape while preserving reflux action. Cool digested solutions were vortexed with approximately 30 mL of de-ionized water, allowed to cool to room temperature, brought to 75 mL volume, transferred to square Nalgene bottles (glass beads were filtered out), sealed, mixed, and stored.

Nitrogen trapped as $(NH_4)_2SO_4$ was analyzed on an automatic Technicon Sampler IV (solution sampler) and an Alpkem Corporation Proportioning Pump III. A plant standard with known N concentration was subjected to the same procedure as above and used as a check. Fresh weight, dry matter yield, and N concentration were recorded for each of the tests. Nitrogen concentration (g kg^{-1}) was multiplied by dry matter yield to obtain N content (g m^{-2}).

Mineral Analysis

For the determination of nutrient concentrations of other elements in the plant material, 1.0 g from each of the samples was weighed into 50 mL Pyrex beakers and ashed in a muffle furnace at 480°C for 6 hr. The samples were then cooled to room temperature and mixed with de-ionized water. Under a hood, 20 mL of de-ionized water and 2 mL of concentrated HCl were added to each beaker. The beakers were placed on a hot plate, slowly boiled until dry, and then removed.

An additional 20 mL of de-ionized water and 2 mL of concentrated HCl were added to the beakers before small Pyrex watch glasses were used to cover the tops for reflux. The samples were placed on the hot plate and brought to a forceful boil. They were then removed and allowed to cool to room temperature. Each sample was then brought to volume in 100 mL flasks and mixed. They were then left for several hours to allow all of the Si to settle out. Twenty mL of solution was decanted into 20 mL scintillation vials for analysis.

Phosphorus was analyzed by colorimetry, K and Na by flame emission, and Ca, Mg, Cu, Fe, Mn, and Zn by atomic adsorption spectrometry (AA). Mineral concentrations were multiplied by dry matter yield to obtain mineral content. Data was analyzed by ANOVA for a split-split plot experimental design using MSTAT 4.0 (1985). Means were separated by least significant difference (LSD) at the 0.05 level of probability (Gomez and Gomez, 1984).

Soil Analysis

Soil samples were obtained from the top 20 cm of soil directly following harvest of each experiment. Samples were air-dried in open paper bags, then screened through a 2.0-mm stainless steel sieve to remove any rocks or debris and stored for further analysis.

The samples were then analyzed for N, mineral concentrations, pH, buffer pH (BpH), organic matter (OM), and cation exchange capacity (CEC). For soil N, a mixture of 2.0 g of each soil sample, 3.2 g of salt catalyst (9:1 K_2SO_4:$CuSO_4$), and 10-mL of H_2SO_4 were subjected to the same procedures for N analysis as leaf tissue was, except that boiling beads were not used because the particles of soil served the same purpose. A soil sample of known N concentration was also analyzed and used as a check.

For soil extractable mineral analysis a Mehlich I (Mehlich, 1953) extraction method was used. Five g of each soil sample were weighed and extracted with 20 mL of a combination of 0.025 N H_2SO_4 and 0.05 N HCl. Using an Eberach shaker at 240 oscillations minute^{-1}, mixtures were shaken for 5 min. The mixtures were then filtered using Schleischer and Schuell 620 (11 cm) filter paper and poured into scintillation vials.

The remaining solutions were then subjected to analysis of P, K, Ca, Mg, Na, Cu, Fe, Mn, and Zn in the same manner as described for leaf tissue analysis.

Soil pH was found using a 1:2 soil to water volume ratio using a glass electrode pH meter (Peech, 1965). Buffer pH (BpH) was found using Adams/Evans buffered solution (Adams and Evans, 1962). Cation exchange capacity (CEC) was estimated by the summation of relevant cations (Hesse, 1972; Jackson, 1958). Estimated soil CEC was calculated by summing the milliequivalents of the determined bases of Ca, Mg, K, and Na (where applicable) and adding them to exchangeable H^+ expressed in milliequivalents per 100 grams (cmol kg^{-1}) (Hesse, 1972).

For the determination of OM, a modified version of the Walkley Black method was used, in which 1.0 g of soil was weighed into a 500-mL Earlenmeyer flask, and 10 mL of 1 N $K_2Cr_2O_7$ solution was then pipetted into the flask. Twenty mL of concentrated H_2SO_4 was added and mixed by gentle rotation for 1 min using care to avoid throwing soil up onto the sides of the flask. The flask was then left to stand for 30 min, and then diluted to 200 mL with de-ionized water. Five drops of indicator were added, and the solution was titrated with 0.5 N Ferrous Sulfate Solution until the color changed from a dull green to a reddish brown color. The titrating solution was added one drop at a time until the end point when the color sharply shifted to a brilliant reddish brown. A flask without soil was prepared in the same manner and titrated to determine the blank titrant, along with a flask containing a check soil with a known amount of OM. Percent OM was determined using the equation: percent OM = (1-T/S) x 6.8, where S is blank-titration in mL of ferrous ammonium sulfate solution, and T is sample titration in mL ferrous ammonium sulfate solution (Walkley, 1935; Allison, 1965).

Statistical Analysis

Data was analyzed as a split-split plot with the main treatments (year) in a randomized complete block design. An example of the breakdown of the degrees of freedom (df) is shown in Table 4-1. Analysis of variance (ANOVA) for this split-split plot experimental design was conducted by use of MSTAT 4.0 (Anonymous, 1985). Data from each ANOVA was placed in a 4-way table as illustrated in Table 4-2. Explanation of the location of each of the treatment effects and all of the possible interactions in the table are keyed at the bottom of Table 4-2. Means were separated by least significant difference (LSD) at the 0.05 level of probability (Gomez and Gomez, 1976). All treatments and interactions that were significant at $p \leq 0.05$ were highlighted in bold in the data tables (Tables 4-3 to 4-38). Plant mineral data were analyzed as split-split plot designs and means were separated using least significant difference (LSD) at the 0.05 level of probability.

Results

Yield

For total clipped sunn hemp fresh matter produced, a year and clip height interaction as well as a plant population and clip height interaction were displayed (Table 4-3). For final non-clipped sunn hemp fresh matter, year was significant ($p \leq 0.05$) and there was a population and height interaction (Table 4-4). For total plant fresh matter, a year and population, a year and height, and a population and height interaction were all displayed (Table 4-5). Two interactions were exhibited for total clipped dry matter, between year and height and between population and height (Table 4-6). Final non-clipped dry matter exhibited several interactions, between year and population, year and height, and between population and height (Table 4-7). For total sunn hemp dry matter, year, population, and height all displayed significant ($p \leq 0.05$) differences (Table 4-8).

Mineral Analysis: Clipped Material

For total clipped sunn hemp matter, content of N (Table 4-9), P (Table 4-10), Ca (Table 4-12), and Mg (Table 4-13) exhibited year and clip height as well as population and height interactions. Three interactions, between year and population, year and height, and population and height, were exhibited in K content (Table 4-11). For Na content, population was significant ($p \leq 0.05$) and a year and height interaction was displayed (Table 4-14). For Cu (Table 4-15) and Zn (Table 4-18) content, year and height interactions as well as population and height interactions were displayed. Population was found to be significant ($p \leq 0.05$) in addition to an interaction between year and height for Fe content (Table 4-16). For Mn content, a year and population interaction as well as a year and height interaction were present (Table 4-17).

Mineral Analysis: Final Non-clipped Material

In total final non-clipped sunn hemp matter, N (Table 4-19) and P (Table 4-20) content displayed significant ($p \leq 0.05$) differences due to year, population, and height. For K content, both year and height and population and height interactions were present (Table 4-21). Population was found to be significant ($p \leq 0.05$), in addition to a year and height interaction, for both Ca (Table 4-22) and Na (Table 4-24) content. For Mg content, year and population as well as year and height interactions were displayed (Table 4-23). A year and clip height interaction as well as a population and clip height interaction were exhibited in Cu content (Table 4-25). Plant population and clip height were both significant ($p \leq 0.05$) for Fe content (Table 4-26). Year, population, and clip height were all significant ($p \leq 0.05$) for Mn (Table 4-27) and Zn (Table 4-28) content.

Mineral Analysis: Total Plant Material

For N content in total clipped plus final non-clipped material, both a year and clip height interaction as well as a population and clip height interaction were displayed (Table 4-29). Year, population, and clip height were found to be significant ($p \leq 0.05$) for P (Table 4-30), Ca (Table 4-32), and Na (Table 4-34) content. For K content, population was significant ($p \leq 0.05$) and a year and clip height interaction was exhibited (Table 31). Year and plant population were both significant ($p \leq 0.05$) in Mg content (Table 4-33). Plant population was significant ($p \leq 0.05$) for Cu content, which also displayed a year and clip height interaction (Table 4-35). Plant population as well as clip height were significant ($p \leq 0.05$) for Fe content (Table 4-36). Year, population, and height were all significant ($p \leq 0.05$) for Mn (Table 4-37) and Zn (Table 4-38) content.

Discussion and Conclusion

Yield: Clipped Fresh Matter

The tested plant populations and clip heights were found to affect sunn hemp yield; therefore the null hypothesis could not be supported. For total clipped sunn hemp fresh matter, several interactions were displayed. The interaction between year and clip height was due to a greater fresh matter yield at the 0.8 m clip height compared to the 0.4 m clip height in 2003. For both years, there was a trend for fresh yield to decrease as clip height increased with the exception of the 0.8 m clip height as mentioned above. Also, greater fresh matter tended to be produced in 2003 than 2002 for each clip height, with the exception of the 0.4 m and 1.6 m clip heights. Fresh matter produced was the same for both years at the 0.4 m height and actually lower in 2003 than 2002 at the 1.6 m height. The interaction between population and clip height was caused by the yield increase between 6 and 30 plants m^{-2} for the 0.4 m clip height compared to the increase between the 6 and 18 plants m^{-2} populations for the other clip heights. Highest yields were obtained at the 0.4 m and 0.8 m clip heights.

Yield: Non-clipped Fresh Matter

Significant ($p \leq 0.05$) differences due to year were displayed in final non-clipped sunn hemp fresh matter. Yield was significantly ($p \leq 0.05$) higher in 2002 than in 2003. For final non-clipped sunn hemp fresh matter, only one interaction was exhibited, between plant population and clip height. This was due to a trend for fresh matter to increase as population increased from 6 to 18 plants m^{-2}, and then decrease from 18 to 30 plants m^{-2}. This trend was followed with the exception of the 1.2 and 2.0 m clip heights, which increased in fresh matter as population increased. Fresh yield was also found to increase for 6 and 18 plants m^{-2} as clip height increased, until the 1.6 m clip height. For 30 plants m^{-2}, fresh matter stopped increasing at the 1.2 m clip height.

Yield: Total Fresh Matter

Three interactions were present for total sunn hemp fresh matter and they were all due to differing trends in yield production. The first was an interaction between year and plant population. Year did not differ in yields at 30 plants m^{-2}, but higher yields occurred in 2002 than 2003 at 6 and 18 plants m^{-2}. In 2002, 18 and 30 plants m^{-2} produced higher yield compared to 6 plants m^{-2}. In 2003, 30 plants m^{-2} gave higher yield compared to the other populations. In 2002, yield increased as population increased from 6 to 18 plants m^{-2}. But in 2003, yield increased as population increased from 6 to 30 plants m^{-2}. The second interaction was between year and clip height and was due to differing trends displayed by each year. In 2002, fresh yield increased as clip height increased while in 2003, the 0.8 and 1.2 m heights and the 1.6 and 2.0 m heights did not differ in yield, respectively. A trend was displayed within clip heights to produce equal amounts of fresh matter for both 2002 and 2003 with the exception of the 1.6 and 2.0 m clip heights, which produced greater fresh matter in 2002 than in 2003. The third interaction occurred between plant population and clip height. A trend was displayed in fresh matter production, with yield increasing from 6 to 18 plants m^{-2} and remaining equal from 18 to 30 plants m^{-2}. The 1.6 and 2.0 m heights did not follow the trend, with fresh matter decreasing from 18 to 30 plants m^{-2} for the 1.6 m height and increasing from 18 to 30 plants m^{-2} for the 2.0 m height. Populations 6 and 18 plants m^{-2} increased in yield produced from 0.4 to 0.8 m clip heights and decreased from 1.2 to 1.6 m. The remaining population, 30 plants m^{-2}, increased in yield produced from 1.6 to 2.0 m.

Yield: Clipped Dry Matter

For total clipped sunn hemp dry matter, 2 interactions occurred. The first was due to differing trends in yield production and was between year and clip height. In 2002, clip height tended to produce less dry matter than in 2003, with the exception of the 1.6 m clip height, which produced more dry matter in 2002. Also in 2002, dry matter produced decreased as clip heights increased. In 2003, dry matter increased between the 0.4 and 0.8 m clip heights, but then decreased as following heights increased. The second interaction was between population and clip height and was also due to differing trends. Within clip heights, dry matter tended to increase from 6 to 18 plants m^{-2} and then remain equal from 18 to 30 plants m^{-2}. This trend was not followed in the 0.4 m height where dry matter increased as population increased. The 18 and 30 plants m^{-2} populations increased in yield from 0.4 to 0.8 m and then decreased as following heights increased. The 6 plants m^{-2} population did not follow this trend, with dry matter remaining equal from 0.4 to 0.8 m clip heights and then decreasing as clip height increased.

Yield: Non-clipped Dry Matter

Three significant interactions were present in final non-clipped sunn hemp dry matter. The first was between year and plant population and was due to differing trends in yield production. A trend was exhibited by populations to produce higher yield in 2002 than 2003. The trend was followed with the exception of the 6 plants m^{-2} population, which produced equal dry matter in 2002 and 2003. In 2002, yield increased from 6 to 18 plants m^{-2} and remained equal from 18 to 30 plants m^{-2}, while in 2003, yield produced was equal for all populations. The second interaction was between year and clip height. This interaction was due to clip heights in 2002 producing higher yields than in 2003, except for the 0.4 and 0.8 m heights. The 0.4 m height produced less in 2002 than 2003 while the 0.8 m height produced equal yields in 2002 and 2003. In 2002, yield increased as clip height increased for the heights 0.4 to 1.2 m. Heights 1.6 and 2.0 m produced equal dry matter yields. In 2003, heights 0.4 to 1.2 m all produced equal yields while the last 2 heights, 1.6 and 2.0 m, also produced equal yields that were higher than that of the first 3 heights. The final interaction was between plant population and clip height. Several trends were exhibited by the clip heights and possibly led to this interaction. The 0.4 and 2.0 m heights produced constant yields for all populations. The 0.8 m height produced increasing yield as population increased. The 1.2 and 1.6 m heights produced constant yield for the 6 and 18 plants m^{-2} populations, but the 1.2 m height yield decreased for the 30 plants m^{-2} population and the 1.6 m height increased. For the 6 plants m^{-2} population, yield remained constant between the 0.4 and 0.8 m heights, but for both 18 and 30 plants m^{-2}, yield increased between the 2 heights.

Yield: Total Dry Matter

No significant interactions occurred for total sunn hemp dry matter. Year, plant population, and clipping height were all significant. Dry matter produced in 2002 was significantly higher than that produced in 2003. Plants grown at 30 plants m^{-2} produced the highest dry matter. Plants maintained at 0.8 and 1.2 m clipping heights produced the highest dry matter.

Mineral Content: Total Clipped Material

The tested plant populations and clip heights were also found to effect sunn hemp mineral content. Two interactions were present for N content in total clipped sunn hemp. The first was between year and clip height and was due to differing trends in N production. In 2002, clip heights produced lower N content than in 2003, with the exception of the 1.6 m clip height, which produced higher N content in 2002 than in 2003. In 2002, the 0.4 and 0.8 m clip heights produced equal N content, after which it decreased as clip height increased. In 2003, N content produced increased between the 0.4 and 0.8 m clip heights before decreasing as clip heights increased. The second interaction occurred between plant population and clip height and again was due to differing trends. A trend was exhibited among populations where N content produced increased between 6 and 18 plants m^{-2} and then remained constant between populations 18 and 30 plants m^{-2}. This trend was followed with the exception of the 0.8 m clip height, which increased N content produced as population increased. Another trend was exhibited by plant populations to produce increased N content between 0.4 and 0.8 m clip heights before decreasing content as clip height increased. The lowest population, 6 plants m^{-2}, did not follow the trend and produced equal N content at both the 0.4 and 0.8 m clip heights.

Two significant interactions occurred for P content in total clipped sunn hemp and were due to differing trends in P production. The first was between year and clip height. In 2002, P content produced remained constant from the 0.4 to the 1.2 m clip height before finally decreasing at the 1.6 m height. In 2003, P content produced behaved differently, increasing between the 0.4 and 0.8 m clip heights and then decreasing as clip heights increased. Both the 0.4 and 1.6 m clip heights decreased in produced P content between 2002 and 2003 while the two remaining heights, 0.8 and 1.2 m, increased in produced content from 2002 to 2003. The second interaction, between population and clip height, was due to the trend among populations for P content produced to increase as population increased. This trend was not followed by only one height, 1.6 m, which produced constant P content between 18 and 30 plants m^{-2}. Both plant populations 18 and 30 plants m^{-2} increased production of P content between 0.4 and 0.8 m clipping heights before decreasing production as heights increased. The lowest population, 6 plants m^{-2}, did not follow this trend, producing decreasing P content as clip height increased.

For K content in total clipped sunn hemp, 3 interactions were present and were all due to differing trends in K production that were expressed. The first was between year and plant population. In 2002, K content produced increased between the 6 and 18 plants m^{-2} populations but then remained constant between 18 to 30 plants m^{-2}. In 2003, production of K content increased as plant population increased. In 2002, K content produced was consistently less than that produced in 2003 for all plant populations. An interaction between year and clip height was also displayed. A trend was exhibited within clipping heights to produce less K content in 2002 than in 2003. The interaction was due to 1 clip height not following this trend, the 1.6 m height, and producing equal K content in both 2002 and 2003. In 2002, K content produced remained constant between the 0.4 and 0.8 m clipping heights before decreasing as remaining heights increased. In 2003, K content produced behaved differently, increasing between the 0.4 and 0.8 m heights before decreasing as clip height increased. The third interaction displayed was between plant population and clip height and was due to differing trends in K production. Two clip heights, 0.4 and 1.2 m, behaved similarly, increasing produced K content as population increased. The remaining heights, 0.8 and 1.6 m, both increased in K content production between populations 6 and 18 plants m^{-2} and produced equal content for both 18 and 30 plants m^{-2}. Both 6 and 30 plants m^{-2} exhibited similar trends, with K content produced remaining equal between 0.4 and 0.8 m clip heights before decreasing as heights increased. The remaining population, 18 plants m^{-2}, did not follow the trend, producing increased K content between 0.4 and 0.8 m clip heights before decreasing content as heights increased.

Calcium content in total clipped sunn hemp displayed only 2 significant interactions. The first, between year and clip height, was due to differing trends exhibited among populations and among clip heights. Two clip heights, 0.4 and 1.6 m, exhibited similar trends, producing equal Ca content in 2002 and 2003. Clip heights 0.8 and 1.2 m also displayed similar trends, increasing in Ca content produced between 2002 and 2003. In 2002, Ca content decreased in production as clip heights increased. In 2003, Ca content increased in production between 0.4 and 0.8 m clip heights, and then decreased as clip heights increased. The second interaction, between population and clip height, was also caused by differing trends of Ca production. Two of the clip heights, 0.4 and 1.2 m, expressed similar trends, increasing production of Ca as plant population increased. The remaining 2 heights, 0.8 and 1.6 m, increased Ca production between the 6 and 18 plants m^{-2} populations and then produced equal Ca for both populations 18 and 30 plants m^{-2} and produced equal Ca content in all populations, respectively. The first population, 6 plants m^{-2}, decreased in Ca production as clip heights increased. The remaining 2 populations, 18 and 30 plants m^{-2}, both produced equal Ca content for the 0.4 and 0.8 m heights before decreasing in production as clip heights increased.

Two interactions were present in Mg content, both due to conflicting trends in Mg production. The first was between year and clip height. Clip heights 0.8 and 0.2 m followed a similar trend, producing higher Mg content in 2003 than in 2002. The lowest clip height, 0.4 m, produced equal Mg content in both years, while the highest clip height, 1.6 m, produced lower Mg in 2003 than in 2002. In 2002, Mg produced decreased between 0.4 and 0.8 m clip heights, remained constant between 0.8 and 1.2 m, and decreased again from 1.2 to 1.6 m. In 2003, Mg produced increased between 0.4 and 0.8 m clipping heights and then decreased as clip height increased. The second interaction was between plant population and clip height. Two clip heights, 0.4 and 1.2 m, exhibited similar trends, increasing Mg produced as plant population increased. The 0.8 m height increased Mg produced between populations 6 and 18 plants m^{-2} and then produced constant Mg between 18 and 30 plants m^{-2}. The final clip height, 1.6 m, produced equal Mg for all clip heights. The lowest population, 6 plants m^{-2}, produced equal Mg for the 0.4 and 0.8 m clip heights before decreasing production as clip heights increased. The 2 remaining populations, 18 and 30 plants m^{-2}, produced equal Mg content from 0.4 to 1.2 m heights and then lower Mg for the 1.6 m height.

Significant ($p \leq 0.05$) differences occurred in Na content due to plant population. Plants grown at a population of 30 plants m^{-2} produced higher Na than those grown at 18 and 6 plants m^{-2}. For Na content in total clipped sunn hemp, 1 interaction was exhibited, between year and clip height, due to conflicting trends in Na production. Two clip heights, 0.4 and 1.2 m, differed in Na production between 2002 and 2003. The remaining heights, 0.8 and 1.6 m, produced equal Na in both 2002 and 2003. The Na produced by the 0.4 m clip height in 2002 decreased as clip height increased to 0.8 m, where Na then remained constant between it and the 1.2 m height before decreasing at the 1.6 m height. In 2003, Na content increased between 0.4 and 0.8 m clip heights before decreasing as clip heights increased.

Two significant interactions were displayed for Cu content in total clipped sunn hemp. The first, between year and clip height, was due to differing trends of Cu production. All clip heights produce higher Cu in 2003 than in 2002 except the 1.6 m height, which produced lower Cu in 2003 than in 2002. In 2002, Cu content decreased as clip height increased. In 2003, Cu content increased between 0.4 and 0.8 m heights but then decreased as clip heights increased. The second interaction was also due to conflicting trends and exceptions and was between plant population and clip height. The 0.8 and 1.2 m clipping heights followed a similar trend, increasing Cu production between 6 and 18 plants m^{-2} and then remaining constant between 18 and 30 plants m^{-2}. The 0.4 m clip height increased Cu production as population increased, while the 1.6 m clip height produced equal Cu for all populations. The 6 plants m^{-2} population produced constant Cu from heights 0.4 to 1.2 m, but decreased Cu for the 1.6 m height. The last 2 populations, 18 and 30 plants m^{-2}, both increased in Cu production between 0.4 and 0.8 m heights before decreasing production as remaining heights increased.

Significant ($p \leq 0.05$) differences due to plant population occurred in Fe content in total clipped sunn hemp. Plants grown at the 30 plants m^{-2} population produced higher Fe than plants grown at the 18 and 6 plants m^{-2} populations. Only 1 significant interaction was displayed in Fe content in total clipped sunn hemp. The interaction was between year and clip height and was due to different trends in Fe production. Clip heights from 0.4 to 1.2 m increased in Fe production between 2002 and 2003. Only the 1.6 m height differed from this trend, with Fe production decreasing from 2002 to 2003. In 2002, Fe produced remained constant from the 0.4 to 0.8 m heights before decreasing from the 0.8 to 1.2 m height. It also remained constant from 1.2 to 1.6 m. In 2003, Fe produced increased from 0.4 to 0.8 m before decreasing as remaining clip heights increased.

Two interactions for Mn content in total clipped sunn hemp were exhibited. The first was between year and plant population and was due to conflicting trends displayed by each population in Mn production. The lowest population, 6 plants m^{-2}, produced less Mn in 2002 than in 2003. The 18 plants m^{-2} population decreased Mn production from 2002 to 2003. The final population, 30 plants m^{-2}, maintained Mn production for both 2002 and 2003. In 2002, production of Mn increased from 6 to 18 plants m^{-2}, but remained constant from 18 to 30 plants m^{-2}, while in 2003, Mn increased as plant population increased. The second interaction was also due to differing patterns of Mn production and was between year and clip height. Clip heights 0.4 and 1.6 m behaved similarly, both producing high Mn content in 2002 than 2003. Remaining heights

0.8 and 1.2 m also behaved similarly to each other, producing less Mn in 2002 than 2003. In 2002, production of Mn decreased as clip height increased, while in 2003 content increased between 0.4 and 0.8 m before decreasing as remaining heights increased.

For Zn content in total clipped sunn hemp, 2 interactions were displayed. The first, between year and clip height, was due to conflicting trends in Zn production. The first clip height, 0.4 m, produced equal Zn in both 2002 and 2003. Both the 0.8 and 1.2 m heights behaved similarly, producing less Zn in 2002 than 2003. The final height, 1.6 m, produced higher Zn in 2002 than in 2003. In 2002, Zn production decreased as clip height increased while in 2003, production increased between 0.4 and 0.8 m clip heights before decreasing as clip height increased. The second interaction, between population and clip height, was also due to differing trends of Zn production. Clip height 0.4 m produced increasing Zn as population increased. The remaining clip heights all produced increasing Zn between 6 and 18 plants m^{-2} and constant Zn from 18 to 30 plants m^{-2}. Populations 6 and 30 plants m^{-2} exhibited similar trends, both producing constant Zn from 0.4 to 0.8 m clip heights before decreasing production as remaining heights increased. The 18 plants m^{-2} population increased Zn production between 0.4 and 0.8 m clip heights and then decreased production as clip heights increased.

Mineral Content: Total Final Non-clipped Material

For N and P content in total final non-clipped sunn hemp, significant differences were displayed due to year, plant population, and clipping height. Both N and P content produced in 2002 were higher than that produced in 2003. Plants grown at 30 plants m^{-2} produced the highest N and P. Plants maintained at the highest clip height, 2.0 m, produced the highest N and P.

Two significant interactions were displayed for K content in total final non-clipped sunn hemp. The first was between year and clip height and was due to different trends expressed in K production. Clipping heights followed the same trend, producing constant K from 2002 to 2003. The exception was the final clip height, 2.0 m, which produced lower K in 2002 than 2003. In 2002, K production increased between 0.4 and 0.8 m clip heights, remained constant between 0.8 and 0.2 m, then increased as clip height increased. In 2003, production of K increased as clip height increased. The second interaction was between plant population and clip height and was due to the several different trends of K production. The 0.4 m clip height produced constant K content for all plant populations. The 0.8 m height produced constant K from 6 to 18 plants m^{-2} and higher, but constant, K between 18 and 30 plants m^{-2}. Both the 1.2 and 1.6 m heights produced increasing K between 6 and 18 plants m^{-2} populations and constant K for both the 18 and 30 plants m^{-2} populations. Finally, the 2.0 m height produced increasing K as population increased. The 6 and 30 plants m^{-2} populations followed the same pattern of K production, each increasing as clip height increased. The 18 plants m^{-2} population increased K production as clipping heights increased, but K was equal for the 1.6 and 2.0 m heights.

Significant ($p \leq 0.05$) differences due to plant population were displayed in Ca content in total final non-clipped sunn hemp. The highest Ca content was produced by plants grown at the 30 plants m^{-2} population. Only one interaction was displayed by Ca content in total final non-clipped sunn hemp. It occurred between year and clip height and was caused by conflicting patterns in Ca production. Most clipping heights produced more Ca in 2002 than in 2003. The 0.4 m height was the exception, producing equal Ca for both years. Clip heights in 2002 increased Ca production from the 0.4 to the 1.2 m height and produced constant Ca from the 1.2 to the 2.0 m height. In 2003, clip heights produced constant Ca between the 0.4 and 0.8 m height, higher but constant Ca from the 0.8 to the 1.6 m height, and higher still and constant Ca from the 1.6 to the 2.0 m height.

For Mg content in total final non-clipped sunn hemp, 2 significant interactions were displayed. The first was between year and plant population and was due to conflicting trends in the production of Mg. Plant populations in 2002 consistently produced higher Mg than in 2003. In 2002, Mg produced between 6 and 18 plants m^{-2} increased, but remained constant between 18 and 30 plants m^{-2}. In 2003, all 3 plant populations produced equal Mg. The second interaction, also due to differing trends of Mg production, occurred between year and clip height. All clip heights consistently produced less Mg in 2002 than in 2003. In 2002, produced Mg increased as clip height increased from 0.4 to 1.2 m, and remained constant from the 1.2 to 2.0 m heights. In 2003, production of Mg increased between clip heights 0.4 and 0.8 m, remained constant between 0.8 and 1.2 m, and then increased between 1.2 and 1.6 m before increasing at the highest height, 2.0 m.

Significant differences in Na content of total final non-clipped sunn hemp occurred due to plant population. Plants grown at the 30 plants m^{-2} population produced more Na than plants grown at the 18 and the 6 plants m^{-2} populations. Sodium content in total final non-clipped sunn hemp displayed only one interaction. The interaction occurred between year and clip height and was due to conflicting trends in Na production. Three clipping heights, 0.8, 1.2, and 2.0 m, behaved similarly in Na production, decreasing from 2002 to 2003. In 2002, Na produced increased from heights 0.4 to 1.2 m, then decreased at the 1.6 m height before increasing again with the final clip height, 2.0 m. In 2003, production of Na remained equal between the 0.4 and 0.8 m heights, increased between the 0.8 and 1.2 m heights, and finally remained constant across the final three clip heights.

Two significant interactions occurred in Cu content in total final non-clipped sunn hemp. The first, between year and clip height, occurred due to conflicting trends in Cu production. The first 2 clipping heights, 0.4 and 0.8 m, behaved similarly, both producing equal Cu in 2002 and 2003. The 1.2 and 2.0 m heights also behaved similarly to each other, producing higher Cu in 2002 than 2003. In 2002, Cu production increased between the 0.4 and 0.8 m clip heights and then remained constant as clip height increased. In 2003, Cu production increased between the 0.4 and 0.8 m heights, remained constant between the 0.8 and 1.2 m heights and between the 1.2 and 1.6 m heights, and finally increased at the 2.0 m height. The second, between plant population and clip height, was also due to several different trends displayed of Cu production. Both the 0.4 and 0.8 m clip heights produced equal Cu for all plant populations. The 1.2 m height produced equal Cu for both the 6 and 18 plants m^{-2} populations and equal, but increased, Cu for the 18 and 30 plants m^{-2} populations. The 1.6 m height increased Cu content production between 6 and 18 plants m^{-2}, but produced constant Cu between 18 and 30 plants m^{-2}. Finally, the 2.0 m clip height produced equal levels of Cu for both the 6 and 18 plants m^{-2} populations, but higher Cu for 30 plants m^{-2}. Each plant population behaved differently. The 6 plants m^{-2} population increased Cu production between the 0.4 and 0.8 m clip heights, produced constant Cu from the 0.8 to 1.6 m heights, and increased production between the 1.6 and 2.0 m heights. The 18 plants m^{-2} population increased Cu production between the 0.4 and 0.8 m heights, produced equal Cu from the 0.8 to the 0.2 m height, increased production again between the 1.2 and the 1.6 m height, and then produced equal Cu for both the 1.6 and 2.0 m heights. Finally, the 30 plants m^{-2} population increased Cu production between the 0.4 and the 1.2 m clip heights, produced constant Cu from the 1.2 to the 1.6 m height, and increased Cu at the 2.0 m clip height.

Significant ($p \leq 0.05$) differences occurred in Fe content in total final non-clipped sunn hemp due to plant population and clipping height. The highest Fe was produced by plants grown at 30 plants m^{-2}. Plants maintained at the 2.0 m height produced the highest Fe.

Year, plant population, and clip height caused significant differences in both Mn and Zn content in total final non-clipped sunn hemp. Sunn hemp grown in 2002 produced more Mn and Zn than plants grown in 2003. Plants grown at the 30 plants m^{-2} population produced the highest Mn and Zn. Sunn hemp maintained at the 2.0 clip height produced the highest Mn and Zn.

Mineral Content: Total Clipped Plus Final Non-clipped Material

For N content in total clipped and final non-clipped sunn hemp, two significant interactions were displayed. The first, due to conflicting trends in N production, was between year and clip height. Clip heights 0.4 and 1.2 m displayed one trend, producing constant N for both 2002 and 2003. The 0.8 m height displayed another trend, producing lower N in 2002 than in 2003. The 1.6 and 2.0 m heights displayed still another trend, producing greater N in 2002 than in 2003. In 2002, N production peaked at the 0.8 and 1.2 m clip heights, with the 0.4, 1.6, and 2.0 m heights all producing equal, but lower, N. In 2003, N production increased between the 0.4 and the 0.8 m heights, remained constant between the 0.8 and 1.2 m heights, increased from the 1.2 to the 1.6 m height, and remained equal between the 1.6 and 2.0 m heights. The second interaction, between plant population and clip height, was due to different N production trends. The first 4 clipping heights displayed the same trend, increasing N production from 6 to 18 plants m^{-2} and producing equal N from 18 to 30 plants m^{-2}. The remaining height, 2.0 m, did not follow the trend and produced constant N from 6 to 18 plants m^{-2} and from 18 to 30 plants m^{-2}. All 3 populations exhibited a similar trend, N production peaking at the 0.8 and 1.2 m heights. The 6 and 30 plants m^{-2} populations both produced constant N between the 1.6 and 2.0 m heights while the 18 plants m^{-2} population produced decreasing N for the last clip height, 2.0 m.

Significant ($p \leq 0.05$) differences were displayed in P content in total clipped plus final non-clipped sunn hemp. Sunn hemp grown in 2002 produced significantly more P than that grown in 2003. Plants grown at 30 plants m^{-2} produced the highest level of P. Plants maintained at the 0.8 and the 1.2 m clip heights produced the highest levels of P.

Significant ($p \leq 0.05$) differences due to plant population occurred in K content for in total clipped plus final non-clipped sunn hemp. Plants grown at the 30 plants m^{-2} population produced the highest K. One significant interaction also occurred in K content, between year and clip height, due to conflicting trends in K production. One trend was exhibited for all clip heights, to produce less K in 2002 than in 2003, with the exception of the 1.6 m height, which produced equal K content for both 2002 and 2003. In 2002, all clip heights produced equal K. In 2003, clip heights 0.4 to 1.2 m produced equal K and clip heights 1.6 and 2.0 m produced decreased, but constant, K.

Significant differences due to year, plant population, and clip height occurred in Ca content in total clipped plus final non-clipped sunn hemp. Significantly higher Ca was produced by plants grown in 2002 than in 2003. Plants grown at 30 plants m^{-2} produced the highest Ca. Sunn hemp maintained at the 0.8 and 1.2 m heights produced the highest Ca.

Magnesium content in total clipped plus final non-clipped sunn hemp displayed significant ($p \leq 0.05$) differences, due to year and plant population. Sunn hemp grown in 2002 produced significantly more Mg than that grown in 2003. Plants grown at 30 plants m^{-2} produced the highest level of Mg.

Significant ($p \leq 0.05$) differences due to year, plant population, and clip height were displayed in Na content in total clipped plus final non-clipped sunn hemp. Higher Na was produced by plants grown in 2002. Plants grown at the 30 plants m^{-2} population produced the highest Na. Plants maintained at the 0.8 and 1.2 m clipping heights produced the highest Na.

For Cu content in total clipped plus final non-clipped sunn hemp, significant ($p \leq 0.05$) differences were displayed due to plant population. Plants grown at the 30 plants m^{-2} population produced the highest Cu. A significant interaction also occurred in Cu content, between year and clip height. The interaction was due to conflicting trends in Cu production. Two trends were exhibited by clip heights between years. The first was equal Cu production between 2002 and 2003, which was displayed by the 0.4 and the 1.6 m clip heights. The second was lower Cu production in 2002 than in 2003, displayed by the 0.8, 1.2, and 2.0 m heights. In 2002, the 0.4 to 1.6 m clip heights produced equal K. In 2003, the 0.4, 1.6, and 2.0 m heights produced equal K while the 0.8 and 1.2 m heights produced increased, but constant, K.

Significant ($p \leq 0.05$) differences were displayed in Fe content in total clipped plus final non-clipped sunn hemp, due to plant population and clip height. Plants grown at the 30 plants m^{-2} population produced the highest Fe. The highest Fe was produced by plants maintained at the 1.2 and 1.6 m clip heights.

Year, plant population, and clip height caused significant differences in both Mn and Zn content in total clipped plus final non-clipped sunn hemp. Plants grown in 2002 produced more Mn and Zn than plants grown in 2003. Plants grown at the 30 plants m^{-2} population produced the highest Mn and Zn. Sunn hemp maintained at the 0.8 and the 1.2 m clip heights produced the highest Mn and Zn.

Summary

Clipping sunn hemp repeatedly in 30 d intervals at 0.6 m above designated heights caused prolific and branched re-growth of the plants. Repetitive clipping of the young plant material did not cause any detrimental effects to the plants and produced material that was extremely high in minerals. Sunn hemp grown at 18 and 30 plants m^{-2} and maintained at 0.4 and 0.8 m produced plant material that contained an N:P:K ratio of 10:1:5 kg ha^{-1}. This ratio is equivalent to one of $N:P_2O_5:K_2O$ at 4.3:1:2.6 kg ha^{-1}, as reported for general consumer fertilizers. Maximum yield and mineral content was produced by sunn hemp that was grown at 18 or 30 plants m^{-2} and maintained at heights of 0.4 or 0.8 m. These low clipping heights would be suitable for maintaining by mechanical means, which would be more economical than manual maintenance.

A potential practical application for an organic farmer would be to grow part of a sunn hemp crop for use as a green manure in order to increase OM, added minerals, especially N, and nematode suppression for use with another crop. The portion of the sunn hemp not harvested could be maintained for clipping and production of mulch. The mulch could be utilized for weed control, soil moisture conservation, and the slow release of additional N and other minerals.

Table 4-1. Analysis of variance for a split-split plot experimental design with main treatments in a randomized complete block design.

Source of variation	Description	df
Total (1)	Total for overall experiment (5*2*3*4) = 120-1=	119
Total (2)	Total for year (5*2) = 10-1=	9
Reps (R)	5-1=	4
Main (A)	2-1=	1
Error a	Error main treatment (a)	4
Total (3)	Total plant populations (5*2*3) = 30-1-9=	20
Sub (B)	3-1=	2
A*B	A*B (2-1)*(3-1) =	2
Error b	Error sub treatment (b)	16
Total (4)	Total clip height: Total (1) – Total (2) – Total (3) =	90
Sub-sub (c)	Clip height (4-1) =	3
A*C	A*C (2-1)*(4-1) =	3
B*C	B*C (3-1)*(4-1) =	6
A*B*C	A*B*C (2-1)*(3-1)*(4-1) =	6
Error c	Error sub-sub treatment (c)	72

Table 4-2. Statistics key for two years, three plant populations and four clipping heights of sunn hemp.

Clip height	2002 Plants m^{-2} 30	18	6	$\overline{X}$	2003 Plants m^{-2} 30	18	6	$\overline{X}$	2 yr $\overline{X}$ Plants m^{-2} 30	18	6	$\overline{X}$
—m—	kg ha^{-2}											
0.40	y*p*h	y*p*h	y*p*h	Y*H	y*p*h	Y*p*h	y*p*h	Y*H	P*H	P*H	P*H	**H**
0.80	y*p*h	y*p*h	y*p*h	Y*H	y*p*h	Y*p*h	y*p*h	Y*H	P*H	P*H	P*H	**H**
1.20	y*p*h	y*p*h	y*p*h	Y*H	y*p*h	Y*p*h	y*p*h	Y*H	P*H	P*H	P*H	**H**
1.60	y*p*h	y*p*h	y*p*h	Y*H	y*p*h	Y*p*h	y*p*h	Y*H	P*H	P*H	P*H	**H**
$\overline{X}$	Y*P	Y*P	Y*P		Y*P	Y*P	Y*P		**P**	**P**	**P**	
$\overline{X}$ $\overline{X}$				**Y**				**Y**				

Y (y) = Main treatment (year, 1 to 2).
P (p) = Sub treatment (plant population, 6 plants m-2 to 30 plants m-2).
H (h) = Sub-sub treatment (maintained clipping height, 0.40 to 1.60 m).
Y*P = Main treatment * sub treatment interaction (year * plant population).
Y*H = Main treatment * sub-sub treatment interaction (year * clipping height).
P*H = Sub treatment * sub-sub treatment interaction (plant population * clipping height).
y*p*h = Main treatment * sub treatment * sub-sub treatment interaction (year * plant population * clipping height).

Table 4-3. Fresh matter for total clipped sunn hemp for two years, four clipping heights and three plant populations.

Clip height	2002				2003				2 yr $\overline{X}$			
	Plants m^{-2}				Plants m^{-2}				Plants m^{-2}			
	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$
—m—	kg ha^{-2}											
0.40	13337	11660	7554	**10850**	13324	10527	8963	**10938**	**13330**	**11093**	**8259**	10894
0.80	10934	10690	6920	**9515**	15113	14697	9713	**13175**	**13023**	**12694**	**8317**	11344
1.20	8543	8983	5230	**7586**	11313	10480	6897	**9563**	**9928**	**9732**	**6063**	8574
1.60	4167	3850	2217	**3411**	2756	2207	1260	**2075**	**3462**	**3028**	**1738**	2743
$\overline{X}$	9245	8796	5480		10627	9478	6708		9936	9137	6094	
$\overline{X}$ $\overline{X}$				7840				8938				

Relevant means are highlighted in bold.

Significant year * clip height interaction. For comparison among clipping height means within a year, LSD = 724 at $p \leq 0.05$. For comparison between year means within a clipping height LSD = 2449 at $p \leq 0.05$.

Significant plant population * clip height interaction. For comparison among plant population means within a clipping height, LSD = 884 at $p \leq 0.05$. For comparison among clipping height means within a plant population, LSD = 892 at $p \leq 0.05$.

Table 4-4. Fresh matter for final non-clipped sunn hemp for two years, four clipping heights and three plant populations.

Clip height	2002				2003				2 yr $\overline{X}$			
	Plants m^{-2}				Plants m^{-2}				Plants m^{-2}			
	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$
—m—	kg ha^{-2}											
0.40	5027	6560	3313	4967	3713	2687	2313	2905	**4370**	**4623**	**2813**	3936
0.80	8933	9863	6374	8390	6540	5940	4627	5702	**7737**	**7902**	**5500**	7046
1.20	14323	13757	9620	12567	9900	9453	6233	8529	**12112**	**11605**	**7927**	10547
1.60	14860	16040	12160	14353	12100	12246	8770	11039	**13480**	**14143**	**10465**	12696
2.00	20050	18380	12100	16843	16187	12153	10927	13089	**18118**	**15267**	**11513**	14966
$\overline{X}$	12639	12920	8713		9688	8496	6574		11163	10708	7644	
$\overline{X}\ \overline{X}$				**11424**				**8253**				

Relevant means are highlighted in bold.
Significant year treatment effect. For comparison between year means LSD = 1566 at $p \leq 0.05$.
Significant plant population * clip height interaction. For comparison among plant population means within a clipping height, LSD = 1809 at $p \leq 0.05$. For comparison among clipping height means within a plant population, LSD = 1770 at $p \leq 0.05$.

Table 4-5. Fresh matter for total sunn hemp plant for two years, four clipping heights and three plant populations.

	2002				2003				2 yr $\overline{X}$			
Clip	Plants m^{-2}				Plants m^{-2}				Plants m^{-2}			
height	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$
—m—	kg ha^{-2}											
0.40	18363	18220	10867	**15817**	17037	13213	11276	**13842**	**17700**	**15717**	**11072**	14829
0.80	19867	20553	13293	**17904**	21653	20637	14340	**18877**	**20760**	**20595**	**13817**	18391
1.20	22867	22740	14850	**20152**	21213	19933	13130	**18092**	**22040**	**21337**	**13990**	19122
1.60	19027	19890	14377	**17764**	14857	14453	10030	**13113**	**16942**	**17171**	**12203**	15439
2.00	20050	18380	12100	**16843**	16187	12153	10927	**13089**	**18118**	**15267**	**11513**	14966
$\overline{X}$	**20025**	**19957**	**13097**		**18189**	**16078**	**11941**		19112	18017	12518	
$\overline{X}$ $\overline{X}$				17696				15403				

Relevant means are highlighted in bold.

Significant year * plant population interaction. For comparison between year means within a plant population, LSD = 1819 at $p \leq 0.05$. For comparison among population means within a year LSD = 1455 at $p \leq 0.05$.

Significant year * clip height interaction. For comparison between year means within a clipping height, LSD = 2127 at $p \leq 0.05$. For comparison among clipping height means within a year, LSD = 1647 at $p \leq 0.05$.

Significant plant population * clip height interaction. For comparison among plant population means within a clipping height, LSD = 2065 at $p \leq 0.05$. For comparison among clipping height means within a plant population, LSD = 2016 at $p \leq 0.05$.

Table 4-6. Dry matter for total clipped sunn hemp for two years, four clipping heights and three plant populations.

	2002				2003				2 yr $\overline{X}$			
Clip	Plants m^{-2}				Plants m^{-2}				Plants m^{-2}			
height	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$
—m—	kg ha^{-2}											
0.40	2123	1800	1227	**1717**	2287	1923	1710	**1973**	**2205**	**1862**	**1468**	1845
0.80	1827	1833	1200	**1620**	3017	2787	2070	**2625**	**2422**	**2310**	**1635**	2122
1.20	1577	1670	983	**1410**	2650	2413	1753	**2272**	**2113**	**2042**	**1368**	1841
1.60	917	833	483	**744**	753	613	367	**578**	**835**	**723**	**425**	661
$\overline{X}$	1611	1534	937		2177	1934	1475		1894	1734	1224	
$\overline{X}$ $\overline{X}$				1372				1862				

Relevant means are highlighted in bold.

Significant year * clip height interaction. For comparison between year means within a clipping height, LSD = 147 at $p \leq 0.05$. For comparison among clipping height means within a year, LSD = 159 at $p \leq 0.05$.

Significant plant population * clip height interaction. For comparison among plant population means within a clipping height, LSD = 186 at $p \leq 0.05$. For comparison among clipping height means within a plant population, LSD = 194 at $p \leq 0.05$.

Table 4-7. Dry matter for final non-clipped sunn hemp for two years, four clipping heights and three plant populations.

Clip height	2002				2003				2 yr $\bar{X}$			
	Plants m^{-2}				Plants m^{-2}				Plants m^{-2}			
	30	18	6	$\bar{X}$	30	18	6	$\bar{X}$	30	18	6	$\bar{X}$
m	kg ha^{-2}											
0.40	1347	1470	914	**1243**	1003	2130	3070	**2068**	**1175**	**1800**	**1992**	1656
0.80	3383	3090	2357	**2943**	3557	3217	733	**2502**	**3470**	**3154**	**1545**	2723
1.20	3877	4100	2897	**3624**	1783	3083	4253	**3040**	**2830**	**3592**	**3575**	3332
1.60	5103	4800	3640	**4514**	4433	660	1456	**2183**	**4768**	**2730**	**2548**	3349
2.00	5873	5123	4284	**5093**	2023	2730	3417	**2723**	**3948**	**3927**	**3850**	3908
$\bar{X}$	**3917**	**3717**	**2818**		**2560**	**2364**	**2586**		3238	3040	2702	
$\bar{X}$ $\bar{X}$				3484				2503				

Relevant means are highlighted in bold.

Significant Year * Plant population interaction. For comparison between year means within a plant population, LSD = 428 at $p \leq 0.05$. For comparison among population means within a year, LSD = 396 at $p \leq 0.05$.

Significant year * clip height interaction. For comparison between year means within a clipping height, LSD = 621 at $p \leq 0.05$. For comparison among clipping height means within a year, LSD = 602 at $p \leq 0.05$.

Significant plant population * clip height interaction. For comparison among plant population means within a clipping height, LSD = 707 at $p \leq 0.05$. For comparison among clipping height means within a plant population LSD = 737 at $p \leq 0.05$.

Table 4-8. Dry matter for total sunn hemp plant for two years, four clipping heights and three plant populations.

	2002				2003				2 yr $\overline{X}$			
Clip	Plants m^{-2}				Plants m^{-2}				Plants m^{-2}			
height	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$
—m—	kg ha^{-2}											
0.40	3470	3270	2140	2960	3290	4053	4780	4041	3380	3662	3460	**3501**
0.80	5210	4923	3557	4563	6573	6003	2803	5127	5891	5463	3180	**4845**
1.20	5453	5770	3880	5035	4433	5496	6007	5312	4943	5633	4943	**5173**
1.60	6020	5633	4123	5259	5187	1273	1823	2761	5603	3453	2973	**4010**
2.00	5873	5123	4284	5093	2023	2730	3417	2723	3948	3927	3850	**3908**
$\overline{X}$	5205	4944	3597		4301	3911	3766		**4753**	**4428**	**3681**	
$\overline{X}$ $\overline{X}$				**4582**				**3993**				

Relevant means are highlighted in bold.
Significant year treatment effect. For comparison between year means, LSD = 413 at $p \leq 0.05$.
Significant plant population treatment effect. For comparison between year means, LSD = 321 at $p \leq 0.05$.
Significant clipping height treatment effect. For comparison between year means, LSD = 452 at $p \leq 0.05$.

Table 4-9. Nitrogen content in total clipped sunn hemp for two years, four clipping heights and three plant populations.

Clip height	2002 Plants m^{-2}				2003 Plants m^{-2}				2 yr $\bar{X}$ Plants m^{-2}			
	30	18	6	$\bar{X}$	30	18	6	$\bar{X}$	30	18	6	$\bar{X}$
—m—	kg ha^{-2}											
0.40	85	75	51	**71**	101	85	75	**87**	**93**	**80**	**63**	79
0.80	78	77	52	**69**	124	115	83	**107**	**101**	**96**	**67**	88
1.20	67	72	41	**60**	96	91	63	**83**	**81**	**82**	**52**	72
1.60	37	33	19	**30**	23	21	12	**19**	**30**	**27**	**16**	24
$\bar{X}$	67	64	41		86	78	58		76	71	50	
$\bar{X}$ $\bar{X}$				57				74				

Relevant means are highlighted in bold.
Significant year * clip height interaction. For comparison between year means within a clipping height, LSD = 6 at $p \leq 0.05$. For comparison among clipping height means within a year, LSD = 6 at $p \leq 0.05$.
Significant plant population * clip height interaction. For comparison among plant population means within a clipping height LSD = 7 at $p \leq 0.05$. For comparison among clipping height means within a plant population LSD = 7 at $p \leq 0.05$.

Table 4-10. Phosphorus content in total clipped sunn hemp for two years, four clipping heights and three plant populations.

	2002				2003				2 yr $\overline{X}$			
Clip	Plants m^{-2}				Plants m^{-2}				Plants m^{-2}			
height	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$
—m—	kg ha^{-2}											
0.40	9.9	9.2	6.3	**8.5**	9.5	7.9	6.9	**8.1**	**9.7**	**8.6**	**6.6**	8.3
0.80	8.8	8.8	6.0	**7.9**	11.8	10.9	8.3	**10.3**	**10.3**	**9.8**	**7.1**	9.1
1.20	7.3	7.5	5.1	**6.6**	9.8	9.3	6.6	**8.6**	**8.5**	**8.4**	**5.8**	7.6
1.60	3.3	3.9	2.0	**3.1**	2.6	2.2	1.3	**2.0**	**3.0**	**3.0**	**1.7**	2.6
$\overline{X}$	7.3	7.3	4.9		8.4	7.6	5.8		7.9	7.5	5.3	
$\overline{X}$ $\overline{X}$				6.5				7.3				

Relevant means are highlighted in bold.

Significant year * clip height interaction. For comparison between year means within a clipping height, LSD = 0.6 at $p \leq 0.05$. For comparison among clipping height means within a year, LSD = 0.6 at $p \leq 0.05$.

Significant plant population * clip height interaction. For comparison among plant population means within a clipping height, LSD = 0.08 at $p \leq 0.05$. For comparison among clipping height means within a plant population, LSD = 0.07 at $p \leq 0.05$.

Table 4-11. Potassium content in total clipped sunn hemp for two years, four clipping heights and three plant populations.

Clip height	2002				2003				2 yr $\overline{X}$			
	Plants m^{-2}				Plants m^{-2}				Plants m^{-2}			
	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$
—m—	kg ha^{-2}											
0.40	35.6	31.1	21.9	**29.6**	59.2	48.9	39.8	**49.3**	47.4	40.0	30.1	**39.4**
0.80	29.4	30.3	19.7	**26.5**	66.3	62.8	44.8	**58.0**	47.9	46.6	32.3	**42.2**
1.20	22.9	24.5	14.9	**20.8**	47.4	43.2	31.9	**40.8**	35.1	33.9	23.4	**30.8**
1.60	13.3	12.3	7.1	**10.9**	11.2	9.7	5.9	**9.0**	12.2	11.0	6.5	**9.9**
$\overline{X}$	**25.3**	**24.6**	**15.9**		**46.0**	**41.2**	**30.6**		35.7	32.9	23.3	
$\overline{X}$ $\overline{X}$				21.9				39.3				

Relevant means are highlighted in bold.
Significant year * plant population interaction. For comparison between year means within a plant population LSD = 3.0 at $p \leq 0.05$. For comparison among population means within a year LSD = 3.1 at $p \leq 0.05$.
Significant year * clip height interaction. For comparison between year means within a clipping height, LSD = 3.5 at $p \leq 0.05$. For comparison among clipping height means within a year, LSD = 3.4 at $p \leq 0.05$.
Significant plant population * clip height interaction. For comparison among plant population means within a clipping height, LSD = 4.2 at $p \leq 0.05$. For comparison among clipping height means within a plant population, LSD = 4.3 at $p \leq 0.05$.

Table 4-12. Calcium content in total clipped sunn hemp for two years, four clipping heights and three plant populations.

	2002				2003				2 yr $\overline{X}$			
Clip	Plants m^{-2}				Plants m^{-2}				Plants m^{-2}			
height	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$
—m—	kg ha^{-2}											
0.40	34.3	30.6	18.8	**27.9**	32.5	27.6	24.6	**28.2**	**33.4**	**29.1**	**21.7**	28.1
0.80	24.2	21.8	15.3	**20.4**	36.1	33.3	24.7	**31.4**	**30.1**	**27.6**	**20.0**	25.9
1.20	17.7	16.6	10.1	**14.8**	32.4	30.1	17.9	**26.8**	**25.0**	**23.4**	**14.0**	20.8
1.60	9.0	8.6	8.6	**8.7**	9.5	6.5	3.4	**6.6**	**9.2**	**7.6**	**6.1**	7.6
$\overline{X}$	21.3	19.4	13.2		27.6	24.4	17.7		24.5	21.9	15.5	
$\overline{X}$ $\overline{X}$				18.0				23.2				

Relevant means are highlighted in bold.

Significant year * clip height interaction. For comparison between year means within a clipping height, LSD = 2.5 at $p \leq 0.05$. For comparison among clipping height means within a year, LSD = 2.3 at $p \leq 0.05$.

Significant plant population * clip height interaction. For comparison among plant population means within a clipping height, LSD = 3.1 at $p \leq 0.05$. For comparison among clipping height means within a plant population, LSD = 3.1 at $p \leq 0.05$.

Table 4-13. Magnesium content in total clipped sunn hemp for two years, four clipping heights and three plant populations.

	2002				2003				2 yr $\overline{X}$			
Clip	Plants m^{-2}				Plants m^{-2}				Plants m^{-2}			
height	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$
—m—	kg ha^{-2}											
0.40	9.2	7.6	4.6	**7.1**	8.3	6.9	5.6	**6.9**	**8.8**	**7.2**	**5.1**	7.0
0.80	6.7	6.6	3.9	**5.7**	10.0	8.9	6.1	**8.3**	**8.3**	**7.7**	**5.0**	7.0
1.20	8.0	5.3	3.0	**5.4**	8.4	7.5	4.6	**6.8**	**8.2**	**6.4**	**3.8**	6.1
1.60	2.7	2.5	1.3	**2.1**	1.7	1.5	0.8	**1.3**	**2.2**	**2.0**	**1.1**	1.7
$\overline{X}$	6.7	5.5	3.2		7.1	6.2	4.3		6.9	5.8	3.8	
$\overline{X}$ $\overline{X}$				5.1				5.9				

Relevant means are highlighted in bold.

Significant year * clip height interaction. For comparison between year means within a clipping height, LSD = 1.1 at $p \leq 0.05$. For comparison among clipping height means within a year, LSD = 1.0 at $p \leq 0.05$.

Significant plant population * clip height interaction. For comparison among plant population means within a clipping height, LSD = 1.3 at $p \leq 0.05$. For comparison among clipping height means within a plant population, LSD = 1.4 at $p \leq 0.05$.

Table 4-14. Sodium content in total clipped sunn hemp for two years, four clipping heights and three plant populations.

	2002				2003				2 yr $\overline{X}$			
Clip	Plants m^{-2}				Plants m^{-2}				Plants m^{-2}			
height	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$
—m—	kg ha^{-2}											
0.40	1.6	1.2	0.7	**1.2**	0.9	0.9	0.9	**0.9**	1.2	1.0	0.8	1.0
0.80	1.1	1.0	0.5	**0.9**	1.6	1.4	1.0	**1.3**	1.3	1.2	0.8	1.1
1.20	1.0	1.0	0.5	**0.8**	1.4	1.3	1.0	**1.2**	1.2	1.1	0.8	1.0
1.60	0.4	0.4	0.2	**0.4**	0.3	0.2	0.2	**0.2**	0.4	0.3	0.2	0.3
$\overline{X}$	1.0	0.9	0.5		1.1	0.9	0.7		**1.0**	**0.9**	**0.6**	
$\overline{X}$ $\overline{X}$				0.8				0.9				

Relevant means are highlighted in bold.
Significant Plant population treatment effect. For comparison between year means, LSD = 0.1 at $p \leq 0.05$.
Significant year * clip height interaction. For comparison between year means within a clipping height, LSD = 0.2 at $p \leq 0.05$. For comparison among clipping height means within a year, LSD = 0.2 at $p \leq 0.05$.

Table 4-15. Copper content in total clipped sunn hemp for two years, four clipping heights and three plant populations.

	2002				2003				2 yr $\bar{X}$			
Clip	Plants m^{-2}				Plants m^{-2}				Plants m^{-2}			
height	30	18	6	$\bar{X}$	30	18	6	$\bar{X}$	30	18	6	$\bar{X}$
—m—	g ha^{-2}											
0.40	7.1	6.9	4.5	**6.2**	8.8	6.7	6.5	**7.3**	**7.9**	**6.8**	**5.5**	6.8
0.80	6.0	6.5	3.9	**5.5**	10.8	10.5	7.2	**9.5**	**8.4**	**8.5**	**5.6**	7.5
1.20	4.9	5.2	3.1	**4.4**	7.9	8.2	6.5	**7.5**	**6.4**	**6.7**	**4.8**	6.0
1.60	2.8	2.7	1.5	**2.4**	1.8	1.8	1.1	**1.6**	**2.3**	**2.3**	**1.3**	2.0
$\bar{X}$	5.2	5.4	3.3		7.3	6.8	5.3		6.3	6.1	4.3	
$\bar{X}$ $\bar{X}$				4.6				6.5				

Relevant means are highlighted in bold.

Significant year * clip height interaction. For comparison between year means within a clipping height, LSD = 0.7 at $p \leq 0.05$. For comparison among clipping height means within a year, LSD = 0.8 at $p \leq 0.05$.

Significant plant population * clip height interaction. For comparison among plant population means within a clipping height, LSD = 1.0 at $p \leq 0.05$. For comparison among clipping height means within a plant population, LSD = 1.0 at $p \leq 0.05$.

Table 4-16. Iron content in total clipped sunn hemp for two years, four clipping heights and three plant populations.

Clip height	2002				2003				2 yr $\overline{X}$			
	Plants m^{-2}				Plants m^{-2}				Plants m^{-2}			
	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$
—m—	g ha^{-2}											
0.40	294	246	173	**238**	380	285	256	**307**	337	265	215	272
0.80	248	237	162	**216**	407	351	276	**345**	328	294	219	280
1.20	243	206	157	**202**	308	311	210	**276**	276	258	183	239
1.60	141	156	91	**129**	71	64	33	**56**	106	110	62	93
$\overline{X}$	232	212	146		292	253	194		**262**	**232**	**170**	
$\overline{X}$ $\overline{X}$				196				246				

Relevant means are highlighted in bold.
Significant plant population treatment effect. For comparison between year means, LSD = 16 at $p \leq 0.05$.
Significant year * clip height interaction. For comparison between year means within a clipping height, LSD = 34 at $p \leq 0.05$. For comparison among clipping height means within a year, LSD = 34 at $p \leq 0.05$.

Table 4-17. Manganese content in total clipped sunn hemp for two years, four clipping heights and three plant populations.

	2002				2003				2 yr $\bar{X}$			
Clip	Plants m^{-2}				Plants m^{-2}				Plants m^{-2}			
height	30	18	6	$\bar{X}$	30	18	6	$\bar{X}$	30	18	6	$\bar{X}$
—m—	g ha^{-2}											
0.40	48.4	47.0	23.8	**39.7**	43.4	36.6	31.8	**37.3**	45.9	41.8	27.8	38.5
0.80	37.2	36.4	21.8	**31.8**	53.6	42.4	32.2	**42.7**	45.4	39.4	27.0	37.3
1.20	37.2	36.4	17.8	**30.5**	38.6	37.8	27.4	**34.6**	37.9	37.1	22.6	32.5
1.60	19.2	19.4	8.6	**15.7**	6.0	8.4	4.4	**6.3**	12.6	13.9	6.5	11.0
$\bar{X}$	**35.5**	**34.8**	**18.0**		**35.4**	**31.3**	**24.0**		35.5	33.1	21.0	
$\bar{X}$ $\bar{X}$				29.4				30.2				

Relevant means are highlighted in bold.

Significant year * plant population interaction. For comparison between year means within a plant population, LSD = 4.0 at $p \leq 0.05$. For comparison among population means within a year, LSD = 3.7 at $p \leq 0.05$.

Significant year * clip height interaction. For comparison between year means within a clipping height, LSD = 5.0 at $p \leq 0.05$. For comparison between clipping height means within a clipping year, LSD = 4.9 at $p \leq 0.05$.

Table 4-18. Zinc content in total clipped sunn hemp for two years, four clipping heights and three plant populations.

Clip height	2002 Plants m^{-2} 30	18	6	$\overline{X}$	2003 Plants m^{-2} 30	18	6	$\overline{X}$	2 yr $\overline{X}$ Plants m^{-2} 30	18	6	$\overline{X}$
—m—	g ha^{-2}											
0.40	7.1	6.6	4.6	**6.1**	7.4	6.1	5.2	**6.2**	**7.2**	**6.3**	**4.9**	6.2
0.80	6.7	6.6	4.3	**5.9**	8.9	8.6	6.2	**7.9**	**7.8**	**7.6**	**5.3**	6.9
1.20	6.0	6.4	4.0	**5.4**	7.0	7.2	4.9	**6.4**	**6.5**	**6.8**	**4.4**	5.9
1.60	3.6	3.7	1.8	**3.1**	1.9	1.6	0.9	**1.5**	**2.7**	**2.7**	**1.4**	2.3
$\overline{X}$	5.9	5.8	3.7		6.3	5.9	4.3		6.1	5.9	4.0	
$\overline{X}$ $\overline{X}$				5.1				5.5				

Relevant means are highlighted in bold.

Significant Year * Clip height interaction. For comparison between year means within a clipping height LSD = 0.06 at $p \leq 0.05$. For comparison among clipping height means within a year LSD = 0.05 at $p \leq 0.05$.

Significant plant population * clip height interaction. For comparison among plant population means within a clipping height LSD = 0.6 at $p \leq 0.05$. For comparison among clipping height means within a plant population LSD = 0.6 at $p \leq 0.05$.

Table 4-19. Nitrogen content in total final non-clipped sunn hemp for two years, four clipping heights and three plant populations.

Clip height	2002				2003				2 yr $\overline{X}$			
	Plants m^{-2}				Plants m^{-2}				Plants m^{-2}			
	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$
—m—	kg ha^{-2}											
0.40	20	21	13	18	14	11	9	12	17	16	11	**15**
0.80	48	42	35	42	22	18	18	19	35	30	26	**31**
1.20	56	61	43	53	35	31	25	30	45	46	34	**42**
1.60	62	66	56	61	46	50	34	43	54	58	45	**52**
2.00	91	71	70	78	71	28	57	62	81	65	64	**70**
$\overline{X}$	56	52	43		38	34	29		**47**	**43**	**36**	
$\overline{X}\ \overline{X}$				**50**				**33**				

Relevant means are highlighted in bold.
Significant year treatment effect. For comparison between year means, LSD = 17 at $p \leq 0.05$.
Significant plant population treatment effect. For comparison between year means, LSD = 5 at $p \leq 0.05$.
Significant clipping height treatment effect. For comparison between year means, LSD = 8 at $p \leq 0.05$.

Table 4-20. Phosphorus content in total final non-clipped sunn hemp for two years, four clipping heights and three plant populations.

	2002				2003				2 yr $\overline{X}$			
Clip	Plants m^{-2}				Plants m^{-2}				Plants m^{-2}			
height	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$
—m—	kg ha^{-2}											
0.40	4.3	4.7	3.0	4.0	3.1	2.3	2.0	2.5	3.7	3.5	2.5	**3.3**
0.80	11.1	10.1	8.6	9.9	5.9	4.8	4.6	5.1	8.5	7.4	6.6	**7.5**
1.20	12.9	12.9	10.1	12.0	8.2	8.5	5.7	7.5	10.6	10.7	7.9	**9.7**
1.60	11.1	13.5	11.3	12.0	10.1	9.8	7.8	9.2	10.6	11.7	9.6	**10.6**
2.00	16.5	14.7	13.6	14.9	13.4	11.2	10.0	11.5	15.0	12.9	11.8	**13.2**
$\overline{X}$	11.2	11.2	9.3		8.2	7.3	6.0		**9.7**	**9.2**	**7.7**	
$\overline{X}$ $\overline{X}$				**10.6**				**7.2**				

Relevant means are highlighted in bold.
Significant year treatment effect. For comparison between year means, LSD = 1.4 at $p \leq 0.05$.
Significant plant population treatment effect. For comparison between year means, LSD = 1.2 at $p \leq 0.05$.
Significant clipping height treatment effect. For comparison between year means, LSD = 1.4 at $p \leq 0.05$.

Table 4-21. Potassium content in total final non-clipped sunn hemp for two years, four clipping heights and three plant populations.

Clip height	2002				2003				2 yr $\overline{X}$			
	Plants m^{-2}				Plants m^{-2}				Plants m^{-2}			
	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$
—m—	kg ha^{-2}											
0.40	14.6	15.5	10.0	**13.4**	18.1	13.1	11.2	**14.1**	**16.4**	**14.3**	**10.6**	13.8
0.80	28.9	25.5	20.4	**24.9**	27.3	26.5	21.4	**25.1**	**28.1**	**26.0**	**20.9**	25.0
1.20	32.3	34.4	21.9	**29.5**	35.5	40.0	28.3	**34.6**	**33.9**	**37.2**	**25.1**	32.1
1.60	37.8	43.5	30.4	**37.3**	44.4	50.2	37.0	**43.9**	**41.1**	**46.9**	**33.7**	40.6
2.00	56.3	47.9	36.0	**46.7**	71.1	58.0	46.7	**58.6**	**63.7**	**52.9**	**41.3**	52.7
$\overline{X}$	34.0	33.4	23.7		39.2	37.6	28.9		36.6	35.5	26.3	
$\overline{X}$ $\overline{X}$				30.4				35.3				

Relevant means are highlighted in bold.

Significant Year * Clip height interaction. For comparison between year means within a clipping height, LSD = 7.5 at $p \leq 0.05$. For comparison among clipping height means within a year, LSD = 6.0 at $p \leq 0.05$.

Significant plant population * clip height interaction. For comparison among plant population means within a clipping height, LSD = 7.5 at $p \leq 0.05$. For comparison among clipping height means within a plant population, LSD = 7.0 at $p \leq 0.05$.

Table 4-22. Calcium content in total final non-clipped sunn hemp for two years, four clipping heights and three plant populations.

	2002				2003				2 yr $\overline{X}$			
Clip	Plants m^{-2}				Plants m^{-2}				Plants m^{-2}			
height	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$
—m—	kg ha^{-2}											
0.40	19.0	16.8	12.9	**16.2**	11.4	9.4	6.8	**9.2**	15.2	13.1	9.8	12.7
0.80	51.1	36.0	33.6	**40.3**	17.4	10.5	14.2	**14.0**	34.3	23.3	23.9	27.2
1.20	57.4	60.1	39.9	**52.5**	22.7	20.2	15.5	**19.5**	40.1	40.2	27.7	36.0
1.60	64.8	42.6	44.3	**50.6**	28.9	26.8	20.1	**25.3**	46.8	34.7	32.2	37.9
2.00	43.3	45.7	49.5	**46.2**	38.0	27.1	28.4	**31.2**	40.7	36.4	38.9	38.7
$\overline{X}$	47.1	40.3	36.1		23.7	18.8	17.0		**35.4**	**29.5**	**26.5**	
$\overline{X}$ $\overline{X}$				41.1				19.8				

Relevant means are highlighted in bold.
Significant plant population treatment effect. For comparison between year means, LSD = 6.4 at $p \leq 0.05$.
Significant year * clip height interaction. For comparison between year means within a clipping height, LSD = 12.5 at $p \leq 0.05$. For comparison among clipping height means within a year, LSD = 10.1 at $p \leq 0.05$.

Table 4-23. Magnesium content in total final non-clipped sunn hemp for two years, four clipping heights and three plant populations.

	2002				2003				2 yr $\overline{X}$			
Clip	—Plants m^{-2}—				—Plants m^{-2}—				—Plants m^{-2}—			
height	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$
—m—	—kg ha^{-2}—											
0.40	5.4	5.5	3.5	**4.8**	2.7	2.1	1.9	**2.3**	4.0	3.8	2.7	3.5
0.80	13.0	12.2	9.4	**11.5**	4.7	3.9	4.0	**4.2**	8.9	8.0	6.7	7.9
1.20	15.5	14.6	9.7	**13.3**	7.0	6.9	4.7	**6.2**	11.3	10.8	7.2	9.8
1.60	16.1	14.7	11.2	**14.0**	8.8	8.3	6.5	**7.9**	12.4	11.5	8.8	10.9
2.00	16.5	14.9	12.9	**14.8**	11.0	8.8	7.9	**9.2**	13.8	11.8	10.4	12.0
$\overline{X}$	**13.3**	**12.4**	**9.4**		**6.8**	**6.0**	**5.0**		10.1	9.2	7.2	
$\overline{X}$ $\overline{X}$				11.7				6.0				

Relevant means are highlighted in bold.

Significant year * plant population interaction. For comparison between year means within a plant population, LSD = 1.3 at $p \leq 0.05$. For comparison among population means within a year, LSD = 1.3 at $p \leq 0.05$.

Significant year * clip height interaction. For comparison among clipping height means within a year, LSD = 2.1 at $p \leq 0.05$. For comparison between year means within a clipping height, LSD = 2.1 at $p \leq 0.05$.

Table 4-24. Sodium content in total final non-clipped sunn hemp for two years, four clipping heights and three plant populations.

	2002				2003				2 yr $\bar{X}$			
Clip	Plants m^{-2}				Plants m^{-2}				Plants m^{-2}			
height	30	18	6	$\bar{X}$	30	18	6	$\bar{X}$	30	18	6	$\bar{X}$
—m—	kg ha^{-2}											
0.40	0.6	0.6	0.4	**0.6**	0.5	0.3	0.3	**0.4**	0.6	0.5	0.4	0.5
0.80	2.1	1.7	1.3	**1.7**	0.7	0.5	0.8	**0.7**	1.4	1.1	1.0	1.2
1.20	3.0	2.1	1.7	**2.3**	1.1	1.2	0.9	**1.1**	2.1	1.7	1.3	1.7
1.60	2.1	1.6	1.3	**1.7**	1.5	1.1	1.3	**1.3**	1.8	1.4	1.3	1.5
2.00	3.0	2.4	2.2	**2.5**	1.6	1.7	1.2	**1.5**	2.3	2.0	1.7	2.0
$\bar{X}$	2.2	1.7	1.4		1.1	1.0	0.9		**1.6**	**1.3**	**1.1**	
$\bar{X}$ $\bar{X}$				1.7				1.0				

Relevant means are highlighted in bold.

Significant plant population treatment effect. For comparison between year means, LSD = 0.5 at $p \leq 0.05$.

Significant year * clip height interaction. For comparison between year means within a clipping height, LSD = 0.6 at $p \leq 0.05$. For comparison among clipping height means within a year, LSD = 0.4 at $p \leq 0.05$.

Table 4-25. Copper content in total final non-clipped sunn hemp for two years, four clipping heights and three plant populations.

	2002				2003				2 yr $\bar{X}$			
Clip	Plants m^{-2}				Plants m^{-2}				Plants m^{-2}			
height	30	18	6	$\bar{X}$	30	18	6	$\bar{X}$	30	18	6	$\bar{X}$
—m—	g ha^{-2}											
0.40	2.5	2.4	1.9	**2.3**	2.6	2.4	2.6	**2.6**	**2.5**	**2.4**	**2.3**	2.4
0.80	4.5	4.4	4.5	**4.4**	4.6	6.1	5.2	**5.3**	**4.6**	**5.3**	**4.9**	4.9
1.20	6.0	5.8	4.7	**5.5**	9.2	7.4	6.1	**7.6**	**7.6**	**6.6**	**5.4**	6.5
1.60	6.3	7.7	5.1	**6.4**	9.5	10.0	6.6	**8.7**	**7.9**	**8.9**	**5.8**	7.5
2.00	7.1	7.3	4.9	**6.4**	15.6	9.6	9.7	**11.6**	**11.3**	**8.4**	**7.3**	9.0
$\bar{X}$	5.2	5.5	4.2		8.3	7.1	6.0		6.8	6.3	5.1	
$\bar{X}$ $\bar{X}$				5.0				7.2				

Relevant means are highlighted in bold.

Significant year * clip height interaction. For comparison between year means within a clipping height, LSD = 1.9 at $p \leq 0.05$. For comparison among clipping height means within a year, LSD = 1.6 at $p \leq 0.05$.

Significant plant population * clip height interaction. For comparison among plant population means within a clipping height, LSD = 2.0 at $p \leq 0.05$. For comparison among clipping height means within a plant population, LSD = 2.0 at $p \leq 0.05$.

Table 4-26. Iron content in total final non-clipped sunn hemp for two years, four clipping heights and three plant populations.

	2002				2003				2 yr $\overline{X}$			
Clip	Plants m^{-2}				Plants m^{-2}				Plants m^{-2}			
height	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$
—m—	g ha^{-2}											
0.40	481	793	376	550	550	289	239	359	516	541	307	**455**
0.80	1624	1551	1114	1430	834	658	460	651	1230	1105	787	**1041**
1.20	1151	1783	989	1308	1086	1143	877	1036	1119	1463	933	**1172**
1.60	2167	587	1555	1437	1183	1523	971	1225	1675	1055	1263	**1331**
2.00	568	1560	1345	1158	2079	1643	851	1524	1323	1601	1099	**1341**
$\overline{X}$	1198	1255	1076		1147	1051	680		**1172**	**1153**	**878**	
$\overline{X}$ $\overline{X}$				1176				959				

Relevant means are highlighted in bold.
Significant plant population treatment effect. For comparison between year means, LSD = 261 at $p \leq 0.05$.
Significant clipping height treatment effect. For comparison between year means, LSD = 458 at $p \leq 0.05$.

Table 4-27. Manganese content in total final non-clipped sunn hemp for two years, four clipping heights and three plant populations.

Clip height	2002				2003				2 yr $\overline{X}$			
	Plants m^{-2}				Plants m^{-2}				Plants m^{-2}			
	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$
—m—	g ha^{-2}											
0.40	18	32	14	21	17	11	12	13	18	22	13	**17**
0.80	51	47	36	45	26	26	21	24	39	37	29	**35**
1.20	67	65	37	56	40	42	33	38	53	54	35	**47**
1.60	62	50	52	55	46	47	29	41	54	49	41	**48**
2.00	52	68	59	60	70	46	44	53	61	57	52	**57**
$\overline{X}$	50	53	40		40	35	28		**45**	**44**	**34**	
$\overline{X}$ $\overline{X}$				**47**				**34**				

Relevant means are highlighted in bold.
Significant year treatment effect. For comparison between year means, LSD = 6 at $p \leq 0.05$.
Significant plant population treatment effect. For comparison between year means, LSD = 9 at $p \leq 0.05$.
Significant clipping height treatment effect. For comparison between year means, LSD = 11 at $p \leq 0.05$.

Table 4-28. Zinc content in total final non-clipped sunn hemp for two years, four clipping heights and three plant populations.

Clip height	2002				2003				2 yr $\overline{X}$			
	Plants m^{-2}				Plants m^{-2}				Plants m^{-2}			
	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$
—m—	g ha^{-2}											
0.40	30	38	20	29	23	16	18	19	26	27	19	**24**
0.80	78	73	62	71	35	29	35	33	57	51	48	**52**
1.20	84	95	65	81	48	54	44	49	66	75	54	**65**
1.60	97	91	78	89	69	71	56	65	83	81	67	**77**
2.00	104	103	91	99	102	86	64	84	103	94	78	**92**
$\overline{X}$	78	80	63		56	51	43		**67**	**66**	**53**	
$\overline{X}$ $\overline{X}$				**74**				**50**				

Relevant means are highlighted in bold.
Significant year treatment effect. For comparison between year means, LSD = 10 at $p \leq 0.05$.
Significant plant population treatment effect. For comparison between year means, LSD = 9 at $p \leq 0.05$.
Significant clipping height treatment effect. For comparison between year means, LSD = 12 at $p \leq 0.05$.

Table 4-29. Nitrogen content in total clipped plus final non-clipped sunn hemp for two years, four clipping heights and three plant populations.

Clip height	2002				2003				2 yr $\bar{X}$			
	Plants m^{-2}				Plants m^{-2}				Plants m^{-2}			
	30	18	6	$\bar{X}$	30	18	6	$\bar{X}$	30	18	6	$\bar{X}$
—m—	kg ha^{-2}											
0.40	106	96	64	**89**	115	97	84	**99**	**110**	**96**	**74**	94
0.80	126	120	86	**111**	146	133	101	**127**	**136**	**126**	**94**	119
1.20	123	133	84	**113**	130	122	88	**114**	**127**	**128**	**86**	113
1.60	99	99	75	**91**	69	70	46	**62**	**84**	**84**	**61**	76
2.00	91	71	70	**78**	71	58	57	**62**	**81**	**65**	**64**	70
$\bar{X}$	109	104	76		107	96	75		108	100	76	
$\bar{X}$ $\bar{X}$				96				92				

Relevant means are highlighted in bold.
Significant year * clip height interaction. For comparison between year means within a clipping height, LSD = 14 at $p \leq 0.05$. For comparison among clipping height means within a year, LSD = 13 at $p \leq 0.05$.
Significant plant population * clip height interaction. For comparison among plant population means within a clipping height, LSD = 16 at $p \leq 0.05$. For comparison among clipping height means within a plant population, LSD = 17 at $p \leq 0.05$.

Table 4-30. Phosphorus content in total clipped plus final non-clipped sunn hemp for two years, four clipping heights and three plant populations.

Clip height	2002 Plants m^{-2} 30	18	6	$\overline{X}$	2003 Plants m^{-2} 30	18	6	$\overline{X}$	2 yr $\overline{X}$ Plants m^{-2} 30	18	6	$\overline{X}$
—m—	kg ha^{-2}											
0.40	14.2	13.9	9.4	12.5	12.6	10.2	8.9	10.6	13.4	12.0	9.1	**11.5**
0.80	20.0	18.8	14.6	17.8	17.6	15.7	12.8	15.4	18.8	17.3	13.7	**16.6**
1.20	20.2	20.4	15.2	18.6	18.0	17.8	12.3	16.0	19.1	19.1	13.8	**17.3**
1.60	17.4	17.4	13.4	16.1	12.7	12.0	9.1	11.3	15.1	14.7	11.2	**13.7**
2.00	16.5	14.7	13.6	14.9	13.4	11.1	10.0	11.5	15.0	12.9	11.8	**13.2**
$\overline{X}$	17.7	17.0	13.2		14.9	13.4	10.6		**16.3**	**15.2**	**11.9**	
$\overline{X}$ $\overline{X}$				**20.0**				**13.0**				

Relevant means are highlighted in bold.
Significant year treatment effect. For comparison between year means, LSD = 1.7 at $p \leq 0.05$.
Significant plant population treatment effect. For comparison between year means, LSD = 1.0 at $p \leq 0.05$.
Significant clipping height treatment effect. For comparison between year means, LSD = 1.5 at $p \leq 0.05$.

Table 4-31. Potassium content in total clipped plus final non-clipped sunn hemp for two years, four clipping heights and three plant populations.

Clip height	2002 Plants m^{-2} 30	18	6	$\overline{X}$	2003 Plants m^{-2} 30	18	6	$\overline{X}$	2 yr $\overline{X}$ Plants m^{-2} 30	18	6	$\overline{X}$
—m—	kg ha^{-2}											
0.40	50	47	32	**43**	77	82	51	**70**	64	64	41	57
0.80	58	56	40	**51**	94	89	66	**83**	76	73	53	67
1.20	55	59	37	**50**	83	83	60	**75**	69	71	49	63
1.60	51	56	38	**48**	56	60	43	**53**	53	58	40	50
2.00	56	48	36	**47**	71	58	47	**59**	64	53	41	53
$\overline{X}$	54	53	37		76	75	53		**65**	**64**	**45**	
$\overline{X}$ $\overline{X}$				48				68				

Relevant means are highlighted in bold.

Significant plant population treatment effect. For comparison between year means, LSD = 7 at $p \leq 0.05$.

Significant year * clip height interaction. For comparison between year means within a clipping height, LSD = 10 at $p \leq 0.05$. For comparison among clipping height means within a year, LSD = 13 at $p \leq 0.05$.

Table 4-32. Calcium content in total clipped plus final non-clipped sunn hemp for two years, four clipping heights and three plant populations.

Clip height	2002 Plants m^{-2} 30	18	6		2003 Plants m^{-2} 30	18	6		2 yr $\overline{X}$ Plants m^{-2} 30	18	6	
—m—	kg ha^{-2}											
0.40	53	47	32	44	44	37	31	38	49	42	32	**41**
0.80	75	58	49	61	54	44	39	45	65	51	44	**53**
1.20	75	77	50	67	55	50	33	46	65	64	42	**57**
1.60	74	51	53	59	38	33	24	32	56	42	38	**46**
2.00	43	46	50	46	38	27	28	31	41	36	39	**39**
$\overline{X}$	64	56	47		46	38	31		**55**	**47**	**39**	
$\overline{X}\ \overline{X}$				**56**				**38**				

Relevant means are highlighted in bold.
Significant year treatment effect. For comparison between year means, LSD = 11 at $p \leq 0.05$.
Significant plant population treatment effect. For comparison between year means, LSD = 7 at $p \leq 0.05$.
Significant clipping height treatment effect. For comparison between year means, LSD = 7 at $p \leq 0.05$.

Table 4-33. Magnesium content in total clipped plus final non-clipped sunn hemp for two years, four clipping heights and three plant populations.

Clip	2002				2003				2 yr $\overline{X}$			
	Plants m^{-2}				Plants m^{-2}				Plants m^{-2}			
height	30	18	6		30	18	6		30	18	6	
—m—	kg ha^{-2}											
0.40	14.6	13.1	8.1	11.9	11.0	9.0	7.5	9.2	12.8	11.0	7.8	10.6
0.80	19.7	18.7	13.3	17.2	14.7	12.7	10.1	12.5	17.2	15.7	11.7	14.9
1.20	23.6	19.9	12.7	18.7	15.4	14.4	9.3	13.0	19.5	17.1	11.0	15.9
1.60	18.7	17.1	12.5	16.1	10.5	9.7	7.4	9.2	14.6	13.4	9.9	12.7
2.00	44.7	14.9	33.5	31.0	11.0	8.8	7.9	9.2	27.9	11.8	20.7	20.1
$\overline{X}$	24.3	16.7	16.0		12.5	10.9	8.4		**18.4**	**13.8**	**12.2**	
$\overline{X}$ $\overline{X}$				**19.0**				**10.6**				

Relevant means are highlighted in bold.
Significant year treatment effect. For comparison between year means, LSD = 8.0 at $p \leq 0.05$.
Significant plant population treatment effect. For comparison between year means, LSD = 4.9 at $p \leq 0.05$.

Table 4-34. Sodium content in total clipped plus final non-clipped sunn hemp for two years, four clipping heights and three plant populations.

Clip height	2002 Plants m^{-2} 30	18	6	$\overline{X}$	2003 Plants m^{-2} 30	18	6	$\overline{X}$	2 yr $\overline{X}$ Plants m^{-2} 30	18	6	$\overline{X}$
—m—	kg ha^{-2}											
0.40	2.2	1.8	1.1	1.7	1.4	1.2	1.2	1.2	1.8	1.5	1.2	**1.5**
0.80	3.3	2.8	1.8	2.6	2.3	1.9	1.8	2.0	2.8	2.3	1.8	**2.3**
1.20	4.0	3.1	2.2	3.1	2.6	2.5	1.9	2.3	3.3	2.8	2.0	**2.7**
1.60	2.6	2.0	1.6	2.1	1.8	1.4	1.4	1.5	2.2	1.7	1.5	**1.8**
2.00	3.0	2.4	2.2	2.5	1.6	1.7	1.2	1.5	2.3	2.0	1.7	**2.0**
$\overline{X}$	3.0	2.4	1.8		1.9	1.7	1.5		**2.5**	**2.1**	**1.6**	
$\overline{X}$ $\overline{X}$				**2.4**				**1.7**				

Relevant means are highlighted in bold.
Significant year treatment effect. For comparison between year means, LSD = 0.6 at $p \leq 0.05$.
Significant plant population treatment effect. For comparison between year means, LSD = 0.6 at $p \leq 0.05$.
Significant clipping height treatment effect. For comparison between year means, LSD = 0.3 at $p \leq 0.05$.

Table 4-35. Copper content in total clipped plus final non-clipped sunn hemp for two years, four clipping heights and three plant populations.

	2002				2003				2 yr $\overline{X}$			
Clip	—Plants m^{-2}—				—Plants m^{-2}—				—Plants m^{-2}—			
height	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$
—m—	—g ha^{-2}—											
0.40	9.6	9.3	6.4	**8.4**	11.3	9.1	9.0	**9.8**	10.4	9.2	7.7	9.1
0.80	10.4	10.9	8.4	**9.9**	15.5	16.6	12.4	**14.8**	13.0	13.8	10.4	12.4
1.20	10.9	11.0	7.7	**9.9**	17.1	15.6	12.6	**15.1**	14.0	13.3	10.2	12.5
1.60	9.1	10.4	6.6	**8.7**	11.4	11.8	7.6	**10.3**	10.2	11.1	7.1	9.5
2.00	7.1	7.3	4.9	**6.4**	15.6	9.6	9.7	**11.6**	11.3	8.4	7.3	9.0
$\overline{X}$	9.4	9.8	6.8		14.2	12.5	10.3		**11.8**	**11.1**	**8.5**	
$\overline{X}$ $\overline{X}$				8.6				12.3				

Relevant means are highlighted in bold.

Significant plant population treatment effect. For comparison among plant population means, LSD = 1.1 at $p \leq 0.05$.

Significant Year * Clip height interaction. For comparison between year means within a clipping height, LSD = 2.2 at $p \leq 0.05$. For comparison among clipping height means within a year, LSD = 1.9 at $p \leq 0.05$.

Table 4-36. Iron content in total clipped plus final non-clipped sunn hemp for two years, four clipping heights and three plant populations.

	2002				2003				2 yr $\overline{X}$			
Clip	Plants m^{-2}				Plants m^{-2}				Plants m^{-2}			
height	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$
—m—	g ha^{-2}											
0.40	775	1038	549	787	931	573	495	666	853	806	522	**727**
0.80	1873	1789	1276	1646	1242	1009	736	996	1557	1399	1006	**1321**
1.20	1395	1989	1146	1510	1395	1454	1087	1312	1395	1721	1116	**1411**
1.60	2308	743	1646	1566	1254	1587	1005	1282	1781	1165	1325	**1424**
2.00	567	1560	1345	1158	2079	1643	852	1524	1323	1602	1099	**1341**
$\overline{X}$	1384	1424	1192		1380	1253	835		**1382**	**1339**	**1015**	
$\overline{X}$ $\overline{X}$				1333				1156				

Relevant means are highlighted in bold.
Significant plant population treatment effect. For comparison between year means, LSD = 267 at $p \leq 0.05$.
Significant clipping height treatment effect. For comparison between year means, LSD = 459 at $p \leq 0.05$.

Table 4-37. Manganese content in total clipped plus final non-clipped sunn hemp for two years, four clipping heights and three plant populations.

	2002				2003				2 yr $\overline{X}$			
Clip	Plants m^{-2}				Plants m^{-2}				Plants m^{-2}			
height	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$
—m—	g ha^{-2}											
0.40	67	79	37	61	60	48	43	50	63	64	40	**56**
0.80	88	84	58	77	80	69	53	67	84	76	55	**72**
1.20	104	102	55	87	79	81	60	73	91	91	57	**80**
1.60	81	70	60	70	52	55	34	47	66	63	47	**59**
2.00	52	68	59	60	70	46	44	53	61	57	52	**57**
$\overline{X}$	78	81	54		68	60	47		**73**	**70**	**50**	
$\overline{X}$ $\overline{X}$				**71**				**58**				

Relevant means are highlighted in bold.
Significant year treatment effect. For comparison between year means, LSD = 7 at $p \leq 0.05$.
Significant plant population treatment effect. For comparison between year means, LSD = 10 at $p \leq 0.05$.
Significant clipping height treatment effect. For comparison between year means, LSD = 11 at $p \leq 0.05$.

Table 4-38. Zinc content in total clipped plus final non-clipped sunn hemp for two years, four clipping heights and three plant populations.

Clip height	2002				2003				2 yr $\overline{X}$			
	Plants m^{-2}				Plants m^{-2}				Plants m^{-2}			
	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$	30	18	6	$\overline{X}$
—m—	g ha^{-2}											
0.40	10.0	10.4	6.6	9.0	9.7	7.7	7.0	8.1	9.9	9.0	6.8	**8.6**
0.80	14.6	13.9	10.5	13.0	12.4	11.5	9.7	11.2	13.5	12.7	10.1	**12.1**
1.20	14.4	15.9	10.5	13.6	11.8	12.6	9.3	11.2	13.1	14.3	9.9	**12.4**
1.60	13.2	12.9	9.7	11.9	8.8	8.8	6.5	8.0	11.0	10.8	8.1	**10.0**
2.00	10.4	10.3	9.1	9.9	10.2	8.6	6.5	8.4	10.3	9.5	7.8	**9.2**
$\overline{X}$	12.5	12.7	9.3		10.6	9.8	7.8		**11.6**	**11.3**	**8.5**	
$\overline{X}$ $\overline{X}$				**11.5**				**9.4**				

Relevant means are highlighted in bold.
Significant year treatment effect. For comparison between year means, LSD = 1.1 at $p \leq 0.05$.
Significant plant population treatment effect. For comparison between year means, LSD = 0.9 at $p \leq 0.05$.
Significant clipping height treatment effect. For comparison between year means, LSD = 1.3 at $p \leq 0.05$

CHAPTER 5
NO-TILL AUSTRIAN WINTER PEA AS A COVER CROP AFFECTED BY CROPPING HISTORY

Introduction

Austrian winter pea (*Pisum arvense* L.), often called “field pea”, is a popular crop native to Europe, northern Africa, and western Asia. This low-growing viny legume is often used for hay, green manure, cover cropping, and grazing management. Austrian winter pea also may reduce the severity of soil borne diseases (Mahler and Auld, 1989). The legume has been found to be a high N_2-fixer that can contribute to short-term soil conditioning (USDA-CSREES, 1998).

When used as a cover crop, Austrian winter pea can enrich the soil with organic matter, cycle nutrients, and protect soil from water and wind erosion. It can also suppress weed growth and reduce seed production by competing directly for light and nutrients (Peachy et al., 1999). The succulent stems break down easily and are a quick source of available N (USDA-CSREES, 1998). Legumes reduce the overall C:N ratio of spring residues, decreasing the time it takes non-legume residues to decompose (Sattell et al., 1999). Legumes have been found too generally decay at a much faster rate than non-legumes (Hargrove et al., 1991).

Austrian winter pea often yields bountiful biomass, having been found to produce more than 5,600 kg of dry matter ha^{-1}. In a comparison of water use with Indian head lentils (*Ascochyta lentis* L.) and black medic (*Medicago lupulina* L.), Austrian winter pea was the most moisture-efficient crop in producing biomass (USDA-CSREES, 1998).

Austrian winter pea has been found to be one of the top N producers among legumes, yielding up to 336 kg N ha^{-1} (Florida Agricultural Statistics Service, 2005). Winter pea harvested as hay and then applied as mulch mineralized N at more than double the rate of alfalfa (*Medicago sativa* L.) hay (USDA-CSREES, 1998). Winter pea used as green manure provided the highest spring wheat (*Triticum aestivum* L.) yield the following year in a Montana trial comparing 10 types of medics, 8 clovers, and 3 grains (USDA-CSREES, 1998).

No-till farming has consistently proven to be effective in conserving soil moisture, reducing soil erosion, and improving water quality, in addition to benefiting wildlife, increasing labor use efficiency, limiting machinery investments, and sequestering atmospheric carbon dioxide (Beck et al., 1998; Gallaher, 1977; Gallaher and Hawf, 1997). No-till is the most effective conservation practice for reducing soil erosion and improving water quality. The crop residue cover and infiltration rates associated with continuous no-till reduce agricultural runoff of contaminants more than other tillage systems (Doup, 2001; Gallaher and Laurent, 1983). No-till also increases the organic matter in the soil as well as improving many other soil properties (Gallaher and Ferrer, 1987). Decay rates of cover crops have been found to be more rapid under conventional tillage systems than no-tillage systems (Hargrove et al., 1991; Marshall, 2002).

Utilizing these ideas, a 2-yr study was conducted evaluating the effect of cropping history on Austrian winter pea yield. This study was also a component of a larger study (see Chapter 6) conducted to examine the effects of cropping histories on no-till sweet corn (*Zea mays* L.). Our main objective for this particular portion of the study was to compare 3 cropping histories for their effect on yield of Austrian winter pea that was to be utilized as a cover crop for a successive sweet corn crop. An additional objective was to compare mineral nutrient content of the crop across the 3 cropping histories. Our null hypothesis stated that the various cropping histories would not affect yield or mineral composition of the Austrian winter pea.

Materials and Methods

For this study, 2 completely randomized experiments were conducted, each from December to March of 2002-03 and 2003-04 at the University of FL, Gainesville, Florida. Treatments consisted of 3 different previous crops [1, sweet corn; 2, cowpea (*Vigna unguiculata* L.); 3, sunn hemp (*Crotalaria juncea* L.)], each containing 5 replications. Austrian winter pea was planted into 25 cm wide rows throughout the entire field with a no-till Tye drill for both experiments. The experiments were established on a loamy siliceous semiactive hyperthermic Grossarenic Paleodults (USDA-NRCS, 2003) and, after inoculation with appropriate rhizobia, the peas were no-till drilled into the residue of the 3 fall-planted crops: sweet corn, cowpea, and sunn hemp. These previous crops were planted in the same plots both years and sampled for Austrian winter pea data from the same replicates the second year as the first. Therefore, this necessitated that previous crops (or histories) be statistically analyzed as main effects in a completely randomized design and year treated as sub treatments.

In February of both 2003 and 2004, 360 kg ha^{-1} of muriate of potash (KCl) and 200 kg ha^{-1} of sul-po-mag (K_2SO_4:$MgSO_4$) were broadcast over the field. No N fertilizers were applied. Overhead sprinkler irrigation was applied when rainfall did not supply enough water for the peas. Only the above ground portion of the crop was examined for yield, mineral concentration, and mineral content.

Yield

On 24 March 2003 and 29 March 2004, 0.5-m^2 samples were harvested from each plot by cutting plants at the soil surface. The plants were placed in 53 cm x 89 cm Midco Mesh Harvest bags (Midco Enterprises, Inc., Kirkwood, MO) and dried in a forced air oven at 70°C until completely dry and then weighed for dry matter yield determination and used for mineral analysis. These samples were chopped in a hammer mill, mixed well, and then representative grab samples were ground in a Wiley mill to pass through a 2-mm stainless steel screen. These samples were stored in plastic sample bags and re-dried at 70°C for 4 h to ensure equal dry matter among all samples for mineral analysis.

Weather data was collected for the 2 yr of this study at Gainesville, FL from the Florida Automated Weather Network (2005). Monthly averages for rainfall, temperature, and solar radiation was recorded and graphed using Microsoft Excel spreadsheet.

Nitrogen Analysis

A mixture of 0.100 g of each winter pea plant sample, 3.2 g of salt-catalyst (9:1 K_2SO_4:$CuSO_4$), 3 Pyrex beads, and 10 mL of H_2SO_4 were vortexed in a 100-mL Pyrex test-tube under a hood. To reduce frothing, 2 mL 30% H_2O_2 was added in 1 mL increments and tubes were digested in an aluminum block digester at 370°C for 3.5 h (Gallaher et al., 1975). Tubes were capped with small Pyrex funnels that allowed for evolving gases to escape while preserving refluxing action. Cool digested solutions were vortexed with approximately 30 mL of de-ionized water, allowed to cool to room temperature, brought to 75 mL volume, transferred to square Nalgene storage bottles, sealed, mixed, and stored.

Nitrogen trapped in the form of $(NH)_2SO_4$ was analyzed on an automatic Technicon Sampler IV (solution sampler) and an Alpkem Corporation Proportioning Pump III (Technicon Instruments Corporation, Tarrytown, NY). A plant standard with known N concentration was subjected to the same procedure and used as a check.

Mineral Analysis

For other mineral analyses, 1.0 g from each sample of Austrian winter pea was weighed into 50 mL Pyrex beakers and ashed in a muffle furnace at 480°C for 6 h. The samples were then cooled to room temperature and moistened with de-ionized water. Under a hood, 20 mL concentrated HCl were added to the beakers which were then placed on a hot plate and slowly boiled to dryness, then removed.

Another 20 mL de-ionized water and 2 mL concentrated HCl were added and small Pyrex watch glasses were used to cover the beakers for reflux. They were brought to a vigorous boil and removed from the hot plate to cool to room temperature. The samples were then brought to volume in 100 mL flasks, mixed, and allowed to set for 24 h to let Si settle out. Twenty mL of solution was decanted into 20 mL scintillation vials for analysis. Phosphorus was analyzed by colorimetery; K and Na by flame emission, and Ca, Mg, Cu, Fe, Mn, and Zn by atomic adsorption spectrometry (AA).

Mineral content (yield of minerals) was determined once mineral concentrations were found for Austrian winter pea. This was determined by multiplying mineral concentrations in the Austrian winter pea on a unit basis by dry matter yield of Austrian winter pea. For example, if Austrian winter pea was 40 g N kg^{-1} concentration for a dry matter yield of 250 g m^{-2}, then the content would be 10 g N m^{-2} [((40 g N kg^{-1}/1000) * 250 g DM m^{-2}) = 10 g N m^{-2}]. In this example the 10 g N m^{-2} is equivalent to 100 kg N ha^{-1} that would be produced in the above ground dry matter of Austrian winter pea.

Soil Analysis

Soil samples were obtained from the top 15 cm soil depth from each cropping history during both years of the study on the same dates that yield samples were collected. Samples were air-dried and sieved through a 2-mm stainless steel screen to remove any rocks or debris and then were stored for further analysis.

The samples were then analyzed for N, mineral concentrations, pH, buffer pH (BpH), organic matter (OM), and cation exchange capacity (CEC). Soil N analysis was identical to plant sample analysis except that 2.00 g of soil was weighed instead of 1.00 g of plant material without glass beads. The samples were subjected to the same procedures for N analysis as for plant tissue. A soil sample of known N concentration was also analyzed and served as a check.

A Mehlich I (Mehlich, 1953) extraction method was used for the remaining soil mineral analyses. Five g of each soil sample were weighed and extracted with 20 mL of a combination of 0.025 $\underline{N}$ H_2SO_4 and 0.05 $\underline{N}$ HCl. Using an Eberach shaker at a rate of 240 oscillations min $^{-1}$, mixtures were shaken for 5 min. The mixtures were then filtered using Schleischer and Schuell 620 (11 cm) filter paper and poured into scintillation vials. The remaining solutions were then subjected to analysis of P, K, Ca, Mg, Na, Cu, Fe, Mn, and Zn in the same manner described for plant tissue analyses.

Soil pH was measured with a 1:2 soil to water volume ratio using a glass electrode pH meter (Peech, 1965). Buffer pH (BpH) was measured using Adams/Evans buffered solution (Adams and Evans, 1962). Cation exchange capacity (CEC) was estimated by the summation of relevant cations (Hesse, 1972; Jackson, 1958). Estimated soil CEC was calculated by summing the milliequivalents of the determined bases of Ca, Mg, K and Na (where applicable) and adding them to exchangeable H^+ expressed in milliequivalents per 100 grams [centimole per kilogram (c mol kg^{-1})] (Hesse, 1972).

For the determination of OM, a modified version of the Walkley Black (Walkley, 1935) method was used, in which 1.0 g of soil was weighed into a 500-mL Erlenmeyer flask, and 10 mL of 1 N $K_2Cr_2O_7$ solution was then pipetted into the flask. Twenty mL of concentrated H_2SO_4 was added and mixed by gentle rotation for 1 min, using care to avoid throwing soil up onto the sides of the flask. The flask was then left to stand for 30 min, and then diluted to 200 mL with de-ionized water. Five drops of indicator were added, and the solution was titrated with 0.5 N ferrous sulfate solution until the color sharply changed from a dull green to a reddish brown. A flask without soil was prepared in the same manner and titrated to determine the blank titrant, along with a flask containing a check soil with a known amount of OM. Percent OM was determined using the equation: percent OM = (1-T/S) x 6.8, where S is blank-titration in mL of ferrous ammonium sulfate solution and T is sample titration in mL of ferrous ammonium sulfate solution (Walkley, 1935; Allison, 1965).

Statistical Analysis

Data was recorded in Quattro Pro (Anonymous, 1987) spreadsheets and transferred to MSTAT 4.0 (Anonymous, 1985) for analysis of variance with the appropriate model for the experimental design (Gomez and Gomez, 1984). Mean separation was by fixed LSD at the 0.05 level of probability (Gomez and Gomez, 1984). Several correlations were determined between dry matter yield and mineral concentrations of Austrian winter pea and dry matter and soil properties. Also correlations were determined between dry matter yield and plant mineral content and between plant mineral content and soil properties. Statistical analyses for these correlations were determined by use of SAS (2000).

Results

Yield and Plant Mineral Concentration

Statistically significant ($p \leq 0.05$) differences were found between years for dry yield of Austrian winter pea, but not among the cropping histories (Tables 5-1 and 5-2). Among the macronutrients, N and Na were the only minerals with concentrations not affected by year (Tables 5-3 and 5-4). The remaining macronutrients, P, K, Ca, and Mg all recorded significant differences ($p \leq 0.05$) in concentrations between years (Tables 5-3 and 5-4). Nitrogen, P, and K were the only macronutrients with concentrations affected ($p \leq 0.05$) by cropping history (Tables 5-3 and 5-4). The pea that was grown following sweet corn displayed a definite N advantage over pea following sunn hemp. The pea grown after cowpea showed higher concentrations of P than when following sweet corn or sunn hemp. The remaining macronutrients, Ca, Mg, and Na were not different in concentrations among cropping histories (Tables 5-3 and 5-4). Of the micronutrients, Cu and Fe, and Mn were significantly different ($p \leq 0.05$) between years but were not different ($p > 0.05$) among cropping histories (Tables 5-3 and 5-4). A significant ($p \leq 0.05$) interaction occurred between cropping history and years for Zn concentration (Tables 5-3 and 5-4). Zinc concentration was not different between years following sweet corn but was higher ($p \leq 0.05$) following cowpea and sunn hemp in 2004 (Tables 5-3 and 5-4).

Plant Mineral Content

The content of all minerals, except Na, in Austrian winter pea were all higher ($p \leq 0.05$) in 2004 than 2003 (Table 5-5 and 5-6). Mineral content of all minerals was not affected ($p > 0.05$) by previous crop treatment (Table 5-5 and 5-6).

Soil Properties

Of the macronutrients in soil, N, P, and K, were not affected by year (Tables 5-7 and 5-8). Concentrations of N and P in soil all showed significant ($p \leq 0.05$) differences due to cropping history (Tables 5-7 and 5-8) with soil from the cowpea rotation having higher levels. Interactions between previous crop and year occurred ($p \leq 0.05$) for Ca and Mg (Tables 5-7 and 5-8). Calcium was highest following cowpea in 2004 but no differences were found among previous crops in 2003. Magnesium was highest following cowpea both years but Mg from cowpea history was not different from the sunn hemp history in 2004.

Potassium, Na, and Cu were the only minerals that were not affected by cropping history (Tables 5-7 and 5-8). Concentrations of Na, Cu, and Mn in soil were all affected by year with 2004 having the highest levels (Table 5-7 and 5-8). Zinc was the only soil micronutrient not affected by year (Table 5-7 and 5-8). A significant ($p \leq 0.05$) interaction occurred between cropping history and year for Fe, with no differences due to cropping history in 2003 but highest levels were found following sunn hemp in 2004 (Tables 5-7 and 5-8). Concentrations of Mn, and Zn were affected by cropping history (Table 5-7 and 5-8) with highest values following cowpea history. For pH, BpH, and OM all displayed no significant ($p > 0.05$) differences due to year except for pH, which was higher in 2003. All three of these soil properties were lowest following the corn history (Table 5-7 and 5-8). An interaction occurred between year and cropping history ($p \leq 0.05$) for CEC, being highest in 2004 following cowpea history (Table 5-7 and 5-8).

Discussion and Conclusion

Yield and Plant Mineral Concentration

Florida winter-grown Austrian winter pea would make a good candidate for use as a cover crop, based on this study. The hypothesis, that previous fall crop would impact yield of Austrian winter pea can not be supported based on these results. However, large differences were found between years with 47% greater yield in 2004 compared to 2003.

The most likely explanation for Austrian winter pea yield being greater in 2004 compared to 2003 (Table 5-2) is differences in climate variables between the 2 winter growing seasons (Figure 5-1, 5-2 and 5-3). For example the average January temperature in 2004 was about 3°C higher than in 2003 (Figure 5-1). Even though rainfall was lower during the months of November 2003 and December of 2004 compared to the same months of 2002 and 2003 (Figure 5-2) water requirements were supplemented by irrigation. Therefore, rainfall distribution should not have impacted growth for either of the 2 yr. The lower rainfall during most of the Austrian winter pea growing period in the 2004 season is likely the reason for higher solar radiation recorded during 2004 compared to 2003 (Figure 5-3). The combination of higher temperatures and solar radiation likely contributed to greater rates of photosynthesis in 2004 compared to 2003. Although other factors could have contributed to year differences in yield, these environmental factors are likely the most important.

The hypothesis that cropping history would not affect mineral concentration of the legume cannot be supported for N, P and Zn (Table 5-4). The peas grown following sweet corn resulted in N levels up to 44.0 g N kg^{-1}, or 4.4 % N. When compared with other sources of organic N, these results suggest that Austrian winter pea would be a good choice for N production. Lupine (*Lupinus angustifolius* L.) has been found to produce 22 g N kg^{-1}, sunn hemp (whole plant) 23 g N kg^{-1}, crimson clover (*Trifolium incarnatum* L.) 30 g N kg^{-1}, vetch (*Vicia villosa* L. Roth.) 33 g N kg^{-1}, and sunn hemp (clipped) 42 g N kg^{-1} (Gallaher, unpublished data). Regardless of cropping history, Austrian winter pea could be left on the ground as a source of N and comprise a substantial portion of N and other minerals for any subsequent crop as well as provide numerous benefits as a mulch (Gallaher, 1977; 1983). An additional benefit to leaving Austrian winter pea on the ground as a cover crop mulch would be the prevention of leaching of such important minerals as N, P, and Mg from the plant matter due to slow mineralization (Hargrove et al., 1991).

Nitrogen concentration in Austrian winter pea was highest following sweet corn. This might be due to the fact that the N recommendation for the crops grown previous to the pea was highest for sweet corn. It is likely that significant N was tied up in sweet corn residue and released more slowly compared to the cowpea residue. Decay of legumes is a rapid process with a quick release of N in the residue (Marshall, 2002) as opposed to sweet corn residue which would have a higher C:N ratio and thus a slower crop residue decay rate and availability of N in the residue for the succeeding crop. For Austrian winter pea following sunn hemp, all the sunn hemp above ground crop was completely removed from the plots each year. Therefore, limited N would be available from the sunn hemp for recycling to the Austrian winter pea crop. As for P concentration in the Austrian winter pea being greater following cowpea history, soil test P was over 180% greater in this history compared to corn and sunn hemp histories. However, no significant correlation was found between soil test P and concentration in plant tissue when correlated over all histories (Table 5-9). Correlations were not made on individual histories, but the principles of plant nutrition would suggest that the high soil test P in the cowpea history is the reason for highest concentration of P in the plant tissue.

Plant Mineral Content

It is expected that mineral content (Table 5-6) should mirror yield (Table 5-2). In other words, the more dry matter produced, the more mineral content produced. This was indeed the case in this study as shown by the high correlation values between dry matter and all of the minerals (Table 5-10). The r values for all minerals ranged from a low of 0.61 for Na and a high of 0.96 for K. All correlations were highly significant ($p \leq 0.001$) between yield of dry matter and content of minerals. Most micronutrients in soil were significantly correlated ($p \leq 0.10$) with micronutrient contents in the plant. This was especially true for Cu, Fe, and Mn. The plant biomass was not washed to remove any possible contamination that could have occurred from soil contamination due to wind or water splashing. In other words, if this happened then the more plant biomass the more the possibility of contamination and thus a positive correlation.

Soil Properties

The pH of the soil was in a good range for nutrient availability, and the OM and CEC (Table 5-8) reflected the high nutrient levels for the sandy soils in this study (Brady and Buckman, 1969). The interaction found between year and cropping history in the CEC was a result of a similar interaction in Ca levels. The soil CEC is primarily governed by 3 different factors, Ca ion activity being the primary factor (Tisdale and Nelson, 1975). Since no Ca was applied to any of the test area during the 2 yr study, the large differences may be attributed to natural variances between actual sites. It was concluded that the soil from history 2 (previous cowpea crop) was the most fertile, followed by history 3 (previous sunn hemp crop), and then history 1 (previous sweet corn crop). Generally, the plant nutrient concentrations (Table 5-4) and contents (Table 5-6) followed this trend. This can be partially explained by the type residue and its relative C:N ratio of the previous crops. Residue from all previous crops was left on the soil surface during the growth period of the no-till Austrian winter pea. Sweet corn residue in history 1 would have had a higher C:N ratio than the cowpea residue in history 2. Even though sunn hemp, a legume, was grown prior to Austrian winter pea in history 3 all the top growth of this crop was removed from the plots prior to planting the Austrian winter pea. Therefore, minerals would recycle quickly following cowpea, much slower following sweet corn and very little minerals were available from residue to recycle in history 3. In fact, significant minerals would have been removed from the plots in history 3 (Marshall, 2002).

Austrian winter pea proved to be a good candidate for use as a cover crop in all systems in this study. It worked well as a legume for no-till management of a succeeding sweet corn crop (data not shown). Data show an N concentration of 37 to 42.5 g kg^{-1} (Table 5-4) that would likely make Austrian winter pea a good source of protein for farm animals. Data also show that it had N content, much of which would have been from N fixation, in the range of 7.27 to 10.46 kg m^{-2}, depending upon year and crop history (Table 5-6), as well as significant quantities of other minerals. Used as a cover crop for a following no-till crop, such as sweet corn, it would be a good source of slow release minerals as well as good for soil conservation.

Table 5-1. Above ground plant dry matter of Austrian winter pea analysis of variance.

Source of variation	df	Dry matter yield
Previous crop (PC)	2	ns†
Error A	12	—
Year (Y)	1	**
PC x Y	2	ns
Error B	12	—
Total	29	—

**Significant at the 0.01 level.
†ns = not significant.

Table 5-2. Yield of Austrian winter pea at early bloom stage.

Previous crop	2003	2004	Average
	Dry matter, g m^{-2}		
Sweet corn	181	276	229 a†
Cowpea/Lima bean	176	296	236 a
Sunn hemp	192	236	214 a
Average	183	269**	

**Significant at the 0.01 level.
†Values in columns not followed by the same letter are significantly different ($p \leq 0.05$) according to LSD.

Table 5-3. Mineral concentration in Austrian winter pea above ground plant dry matter at early bloom stage of growth analysis of variance.

Source of variation	df	Ca	Mg	K	N	P	Na	Cu	Fe	Mn	Zn
Previous crop (PC)	2	ns†	ns	ns	*	**	ns	ns	ns	+	+
Error A	12	—	—	—	—	—	—	—	—	—	—
Year (Y)	1	***	***	***	ns	**	ns	**	***	***	**
PC x Y	2	ns	+	ns	ns	ns	ns	ns	ns	ns	**
Error B	12	—	—	—	—	—	—	—	—	—	—
Total	29	—	—	—	—	—	—	—	—	—	—

+ Significant at the 0.01 level.
* Significant at the 0.05 level.
** Significant at the 0.0 level.
*** Significant at the 0.001 level.
†ns = not significant.

Table 5-4. Mineral concentration for Austrian winter pea at early bloom stage.

Previous crop	2003	2004	$\overline{X}$
	Mineral concentration, g kg^{-1}		
		N	
Sweet corn	44.0	40.9	42.5 a‡
Cowpea/Lima bean	39.1	37.2	38.2 ab
Sunn hemp	36.2	37.7	37.0 b
$\overline{X}$	39.8	38.6 ns†	
		P	
Sweet corn	4.17	3.81	3.99 b
Cowpea/Lima bean	4.71	4.20	4.46 a
Sunn hemp	3.97	3.64	3.80 b
$\overline{X}$	4.28	3.88 **	
		K	
Sweet corn	24.3	30.3	27.3 a
Cowpea/Lima bean	27.4	34.4	30.9 a
Sunn hemp	25.7	31.9	28.8 a
$\overline{X}$	25.8	32.2 ***	
		Ca	
Sweet corn	5.59	8.02	6.81 a
Cowpea/Lima bean	6.35	7.92	7.14 a
Sunn hemp	6.49	8.55	7.52 a
$\overline{X}$	6.14	8.16 ***	
		Mg	
Sweet corn	1.83	2.47	2.15 a
Cowpea/Lima bean	1.65	2.28	1.96 a
Sunn hemp	1.71	2.41	2.06 a
$\overline{X}$	1.73	2.39 ***	
		Na	
Sweet corn	0.77	0.83	0.80 a
Cowpea/Lima bean	0.73	0.55	0.64 a
Sunn hemp	0.81	0.71	0.76 a
$\overline{X}$	0.77	0.70 ns	
	Mineral concentration, mg kg^{-1}		
		Cu	
Sweet corn	5.0	5.4	5.2 a
Cowpea/Lima bean	4.2	5.4	4.8 a
Sunn hemp	2.6	5.0	3.8 a
$\overline{X}$	3.9	5.3 **	
		Fe	
Sweet corn	130	332	231 a
Cowpea/Lima bean	108	416	262 a
Sunn hemp	158	318	238 a
$\overline{X}$	132	355 ***	

Table 5-4. Continued.

Previous crop	2003	2004	$\overline{X}$
	Mineral concentration, mg kg^{-1}		
		Mn	
Sweet corn	27.6	32.4	30.0 a
Cowpea/Lima bean	19.8	29.0	24.4 a
Sunn hemp	23.6	30.8	27.2 a
$\overline{X}$	23.7	30.7 ***	
		Zn	
Sweet corn	48.4 a	44.0 a ns	46.2
Cowpea/Lima bean	38.8 ab	52.8 a *	45.8
Sunn hemp	33.0 a	41.8 a *	37.4
$\overline{X}$	40.1	46.2	

* Significant at the 0.01 level.
** Significant at the 0.05 level.
*** Significant at the 0.001 level.
†ns = not significant.
‡Values in columns not followed by the same letter are significantly different ($p \leq 0.05$) according to LSD.

Table 5-5. Mineral content in Austrian winter pea above ground plant dry matter at early bloom stage of growth analysis of variance.

Source of variation	df	Ca	Mg	K	N	P	Na	Cu	Fe	Mn	Zn
Previous crop (PC)	2	ns†	ns	ns	*	+	ns	ns	ns	ns	ns
Error A	12	—	—	—	—	—	—	—	—	—	—
Year (Y)	1	***	**	***	ns	*	+	**	***	***	**
PC x Y	2	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Error B	12	—	—	—	—	—	—	—	—	—	—
Total	29	—	—	—	—	—	—	—	—	—	—

+ Significant at the 0.01 level.
* Significant at the 0.05 level.
** Significant at the 0.0 level.
*** Significant at the 0.001 level.
†ns = not significant.

Table 5-6. Mineral content for Austrian winter pea at early bloom stage.

Previous crop	2003	2004	$\overline{X}$
	Mineral content, g m^{-2}		
		N	
Sweet corn	7.92	11.15	9.54 a†
Cowpea/Lima bean	6.89	11.31	9.10 a
Sunn hemp	6.99	8.90	7.95 a
$\overline{X}$	7.27	10.46 **	
		P	
Sweet corn	0.75	1.06	0.90 a
Cowpea/Lima bean	0.83	1.26	1.05 a
Sunn hemp	0.76	0.86	0.81 a
$\overline{X}$	0.78	1.06 *	
		K	
Sweet corn	4.45	8.54	6.50 a
Cowpea/Lima bean	4.84	10.2	7.54 a
Sunn hemp	4.91	7.58	6.25 a
$\overline{X}$	4.73	8.79 ***	
		Ca	
Sweet corn	1.01	2.18	1.59 a
Cowpea/Lima bean	1.12	2.31	1.71 a
Sunn hemp	1.24	1.99	1.62 a
$\overline{X}$	1.12	2.16 ***	
		Mg	
Sweet corn	0.33	0.68	0.51 a
Cowpea/Lima bean	0.29	0.66	0.48 a
Sunn hemp	0.33	0.56	0.45 a
$\overline{X}$	0.32	0.64 **	
		Na	
Sweet corn	0.14	0.22	0.18 a
Cowpea/Lima bean	0.13	0.16	0.15 a
Sunn hemp	0.16	0.17	0.17 a
$\overline{X}$	0.14	0.18 +	
	Mineral content, mg m^{-2}		
		Cu	
Sweet corn	0.92	1.52	1.22 a
Cowpea/Lima bean	0.78	1.82	1.30 a
Sunn hemp	0.50	1.18	0.84 a
$\overline{X}$	0.73	1.51 **	
		Fe	
Sweet corn	23.62	93.84	58.73 a
Cowpea/Lima bean	19.10	130.52	74.81 a
Sunn hemp	31.04	74.84	52.94 a
$\overline{X}$	24.59	99.73 ***	

Table 5-6. Continued.

Previous crop	2003	2004	$\overline{X}$
	Mineral content, mg m^{-2}		
		Mn	
Sweet corn	4.98	9.04	7.01 a
Cowpea/Lima bean	3.46	8.78	6.12 a
Sunn hemp	4.58	7.14	5.86 a
$\overline{X}$	4.34	8.32 ***	
		Zn	
Sweet corn	8.70	11.86	10.28 a
Cowpea/Lima bean	6.86	16.58	11.72 a
Sunn hemp	6.34	9.82	8.08 a
$\overline{X}$	7.30	12.75 **	

* Significant at the 0.01 level.
** Significant at the 0.05 level.
*** Significant at the 0.001 level.
†Values in columns not followed by the same letter are significantly different ($p \leq 0.05$) according to LSD.

Table 5-7. Soil mineral concentrations in Austrian winter pea above ground plant dry matter at early bloom stage of growth analysis of variance.

Source of variation	df	Ca	Mg	K	N	P	Na	Cu	Fe	Mn	Zn	pH	BpH	OM	CEC
Previous crop (PC)	2	ns†	ns	ns	*	+	ns	ns	ns	ns	ns	***	*	***	***
Error A	12	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Year (Y)	1	***	**	***	ns	*	+	**	***	***	**	***	+	ns	**
PC x Y	2	**	*	ns	ns	ns	+	ns	***	ns	ns	ns	ns	ns	**
Error B	12	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	29	—	—	—	—	—	—	—	—	—	—	—	—	—	—

+ Significant at the 0.01 level.
* Significant at the 0.05 level.
** Significant at the 0.0 level.
*** Significant at the 0.001 level.
†ns = not significant.

Table 5-8. Soil mineral concentration and properties following harvest of Austrian winter pea.

Previous crop	2003	2004	$\overline{X}$
	Mineral concentration, mg kg^{-1}		
		N	
Sweet corn	506	513	509 b‡
Cowpea/Lima bean	645	656	651 a
Sunn hemp	530	528	529 b
$\overline{X}$	560	566 ns†	
		P	
Sweet corn	64	69	67 b
Cowpea/Lima bean	240	157	199 a
Sunn hemp	68	78	73 b
$\overline{X}$	124	102 ns	
		K	
Sweet corn	61.8	61.8	61.8 a
Cowpea/Lima bean	63.4	65.4	64.4 a
Sunn hemp	47.0	60.0	53.5 a
$\overline{X}$	57.4	62.4 ns	
		Ca	
Sweet corn	597 a	665 b ns	631
Cowpea/Lima bean	1158 a	3047 a *	2103
Sunn hemp	842 a	1050 b ns	946
$\overline{X}$	866	1588	
		Mg	
Sweet corn	47.4 b	58.0 b *	52.7
Cowpea/Lima bean	71.0 a	75.8 a ns	73.4
Sunn hemp	46.2 b	63.6 ab *	54.9
$\overline{X}$	54.9	65.8	
		Na	
Sweet corn	7.4	14.4	10.9 a
Cowpea/Lima bean	11.2	14.6	12.9 a
Sunn hemp	9.00	13.2	11.1 a
$\overline{X}$	9.20	14.1 ***	
		Cu	
Sweet corn	0.17	0.31	0.24 a
Cowpea/Lima bean	0.14	0.38	0.26 a
Sunn hemp	0.08	0.33	0.21 a
$\overline{X}$	0.13	0.34 ***	
		Fe	
Sweet corn	7.28 a	11.7 b *	9.5
Cowpea/Lima bean	9.12 a	13.4 ab *	11.3
Sunn hemp	8.72 a	15.5 a *	12.1
$\overline{X}$	8.37	13.5	

Table 5-8. Continued.

Previous crop	2003	2004	$\overline{X}$
		Mineral concentration, mg kg^{-1}	
		Mn	
Sweet corn	2.42	3.75	3.09 b
Cowpea/Lima bean	5.68	6.69	6.18 a
Sunn hemp	2.95	4.09	3.52 b
$\overline{X}$	3.69	4.84 ***	
		Zn	
Sweet corn	3.70	3.97	3.83 b
Cowpea/Lima bean	7.79	7.03	7.41 a
Sunn hemp	2.46	2.28	2.37 b
$\overline{X}$	4.65	4.43 ns	
		pH	
Sweet corn	6.46	6.32	6.39 b
Cowpea/Lima bean	7.24	7.10	7.17 a
Sunn hemp	7.32	7.12	7.22 a
$\overline{X}$	7.01	6.85 ***	
		BpH	
Sweet corn	7.85	7.84	7.84 b
Cowpea/Lima bean	7.88	7.89	7.89 a
Sunn hemp	7.90	7.88	7.89 a
$\overline{X}$	7.88	7.87 +	
		OM, %	
Sweet corn	1.37	1.46	1.42 b
Cowpea/Lima bean	1.76	1.70	1.73 a
Sunn hemp	1.65	1.65	1.65 a
$\overline{X}$	1.59	1.61 ns	
		CEC, cmol kg^{-1}	
Sweet corn	4.77 a	5.32 b ns	5.05
Cowpea/Lima bean	7.52 a	17.00 a *	12.26
Sunn hemp	5.55 a	6.94 b ns	6.25
$\overline{X}$	5.95	9.75	

+ Significant at the 0.01 level.
* Significant at the 0.05 level.
** Significant at the 0.0 level.
*** Significant at the 0.001 level.
†ns = not significant.
‡Values in columns not followed by the same letter are significantly different ($p \leq 0.05$) according to LSD.

Table 5-9. Correlation coefficients (r) between 2003 Austrian winter pea dry matter yield (DM), plant mineral concentration and soil properties.

Plant DM and soil prop.	Plant DM yield and plant mineral concentration										
	DM	Ca	Mg	K	N	P	Na	Cu	Fe	Mn	Zn
DM		0.23 ns†	0.39 *	0.60 ***	-0.04 ns	-0.11 ns	-0.19 ns	0.59 ***	0.66 ***	0.41 *	0.39 *
Soil Ca	0.32 +	0.39 *	0.09 ns	0.21 ns	0.20 ns	0.54 **	0.31 +	-0.31 +	0.71 ***	0.51 **	0.26 ns
Soil Mg	0.25 ns	0.32 +	0.27 ns	0.35 +	0.17 ns	-0.10 ns	-0.21 ns	-0.29 +	0.23 ns	0.56 ***	0.33 +
Soil K	-0.14 ns	0.25 ns	0.25 ns	0.23 ns	0.41 *	-0.05 ns	0.25 ns	-0.16 ns	0.43 *	0.38 *	0.05 ns
Soil N	0.05 ns	-0.14 ns	0.11 ns	0.16 ns	0.26 ns	-0.11 ns	0.06 ns	-.00 ns	0.22 ns	0.11 ns	0.17 ns
Soil P	-0.02 ns	0.05 ns	0.02 ns	-0.06 ns	0.23 ns	0.00 ns	0.44 **	-.016 ns	0.32 +	0.21 ns	-0.16 ns
Soil Na	0.46 **	-0.03 ns	-0.11 ns	-0.27 ns	0.22 ns	0.08 ns	0.66 ***	-0.09 ns	0.30 +	0.02 ns	-0.36 *
Soil Cu	0.37 *	0.46 **	0.56 ***	0.54 **	0.72 ***	-0.18 ns	0.00 ns	-0.12 ns	0.44 *	0.60 ***	0.33 +
Soil Fe	0.51 **	0.38 *	0.68 ***	0.78 ***	0.50 **	0.02 ns	-0.29 +	-0.27 ns	0.34 +	0.58 ***	0.52 **
Soil Mn	0.27 +	0.51 **	0.53 **	0.61 ***	0.73 ***	-0.08 ns	-0.13 ns	-0.17 ns	0.34 +	0.58 ***	0.22 ns
Soil Zn	0.11 ns	0.28 +	0.27 ns	0.18 ns	0.37 *	-0.08 ns	0.25 ns	-0.24 ns	0.39 *	0.41 *	-0.01 ns
Soil pH	-0.02 ns	0.11 ns	-0.04 ns	0.12 ns	0.10 ns	0.16 ns	0.52 **	-0.22 ns	0.44 *	0.16 ns	-0.15 ns
Soil BpH	0.01 ns	-0.02 ns	-0.00 ns	-0.21 ns	-0.11 ns	-0.17 ns	0.16 ns	-0.09 ns	-0.27 ns	-0.00 ns	-0.47 **
Soil OM	-0.04 ns	0.10 ns	-0.07 ns	-0.16 ns	-0.16 ns	-0.00 ns	0.02 ns	-0.12 ns	-0.20 ns	0.04 ns	-0.36 *
Soil CEC	0.33 +	-0.04 ns	0.10 ns	-0.06 ns	0.18 ns	-0.11 ns	0.38 *	0.03 ns	-0.06 ns	0.04 ns	-0.36 *

+ Significant at the 0.01 level.
* Significant at the 0.05 level.
** Significant at the 0.0 level.
*** Significant at the 0.001 level.
†ns = not significant.

Table 5-10. Correlation coefficients (r) between 2004 Austrian winter pea dry matter yield (DM), plant mineral content and soil properties.

Plant DM and soil prop.	Plant DM yield and plant mineral content										
	DM	Ca	Mg	K	N	P	Na	Cu	Fe	Mn	Zn
DM		0.90 ***	0.91 ***	0.96 ***	0.94 ***	0.94 ***	0.61 ***	0.88 ***	0.86 ***	0.90 ***	0.87 ***
Soil Ca	0.32 +	0.38 ns†	0.40 *	0.29 +	0.27 +	0.24 ns	-0.00 ns	0.26 ns	0.48 **	0.38 *	0.27 ns
Soil Mg	0.25 ns	0.32 +	0.31 +	0.31 +	0.22 ns	0.30 +	0.06 ns	0.31 +	0.34 +	0.23 ns	0.26 ns
Soil K	-0.14 ns	-0.05 ns	-0.01 ns	-0.04 ns	-0.18 ns	-0.14 ns	-0.15 ns	-0.03 ns	-0.01 ns	-0.02 ns	-0.14 ns
Soil N	0.05 ns	0.06 ns	0.05 ns	0.10 ns	0.06 ns	0.18 ns	-0.11 ns	0.17 ns	0.18 ns	0.01 ns	0.06 ns
Soil P	-0.02 ns	-0.06 ns	-0.11 ns	0.04 ns	0.01 ns	0.16 ns	-0.11 ns	0.13 ns	0.03 ns	-0.14 ns	0.04 ns
Soil Na	0.46 **	0.62 ***	0.59 ***	0.57 ***	0.38 *	0.43 *	0.26 ns	0.43 *	0.54 **	0.48 **	0.37 *
Soil Cu	0.37 *	0.61 ***	0.61 ***	0.44 **	0.35 +	0.26 ns	0.06 ns	0.32 +	0.48 **	0.48 **	0.35 +
Soil Fe	0.51 **	0.64 ***	0.64 ***	0.62 ***	0.45 **	0.44 **	0.29 +	0.39 *	0.52 **	0.44 *	0.43 *
Soil Mn	0.27 +	0.35 +	0.31 +	0.32 +	0.24 ns	0.33 +	0.00 ns	0.33 +	0.39 *	0.23 ns	0.28 +
Soil Zn	0.11 ns	0.08 ns	0.05 ns	0.12 ns	0.16 ns	0.25 ns	-0.12 ns	0.29 +	0.20 ns	0.05 ns	0.22 ns
Soil pH	-0.02 ns	-0.02 ns	-0.09 ns	-0.04 ns	-0.06 ns	0.04 ns	-0.09 ns	-0.11 ns	0.02 ns	-0.21 ns	-0.03 ns
Soil BpH	0.01 ns	0.04 ns	0.00 ns	0.03 ns	0.11 ns	0.12 ns	-0.05 ns	0.00 ns	0.10 ns	-0.09 ns	0.10 ns
Soil OM	-0.04 ns	0.01 ns	-0.03 ns	0.02 ns	-0.06 ns	0.08 ns	-0.01 ns	-0.06 ns	-0.00 ns	-0.17 ns	-0.09 ns
Soil CEC	0.33 +	0.39 *	0.42 *	0.30 +	0.28 +	0.25 ns	0.00 ns	0.27 +	0.49 **	0.40 *	0.28 +

+ Significant at the 0.01 level.
* Significant at the 0.05 level.
** Significant at the 0.0 level.
*** Significant at the 0.001 level.
†ns = not significant.

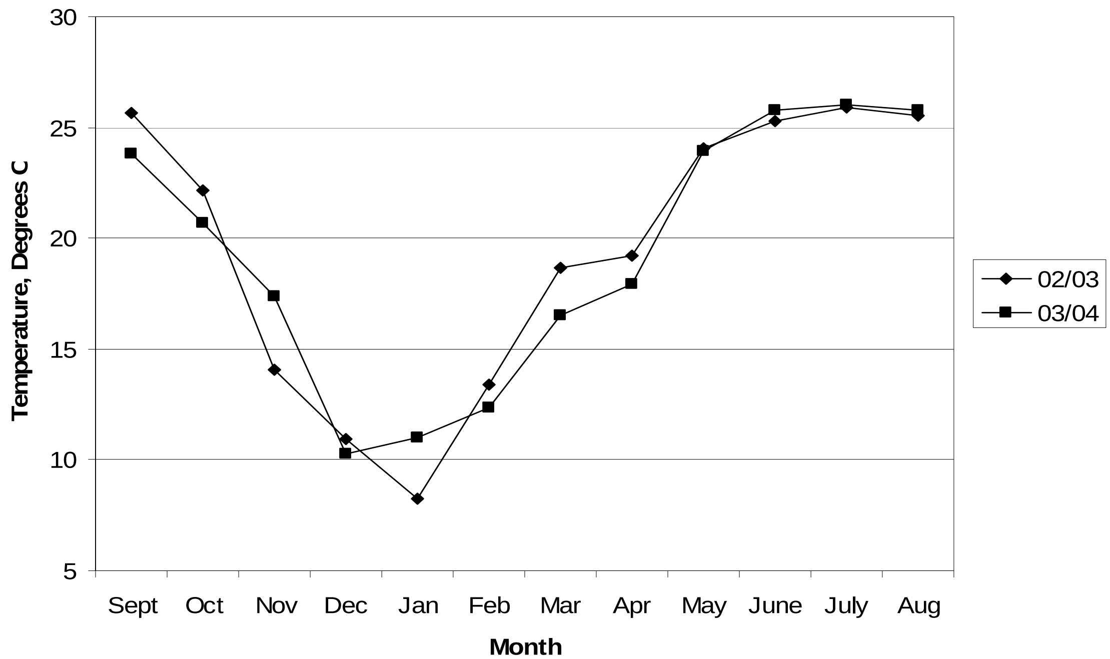

Figure 5-1. Temperature, monthly average, for Alachua County, Florida (Florida Automated Weather Service, 2005).

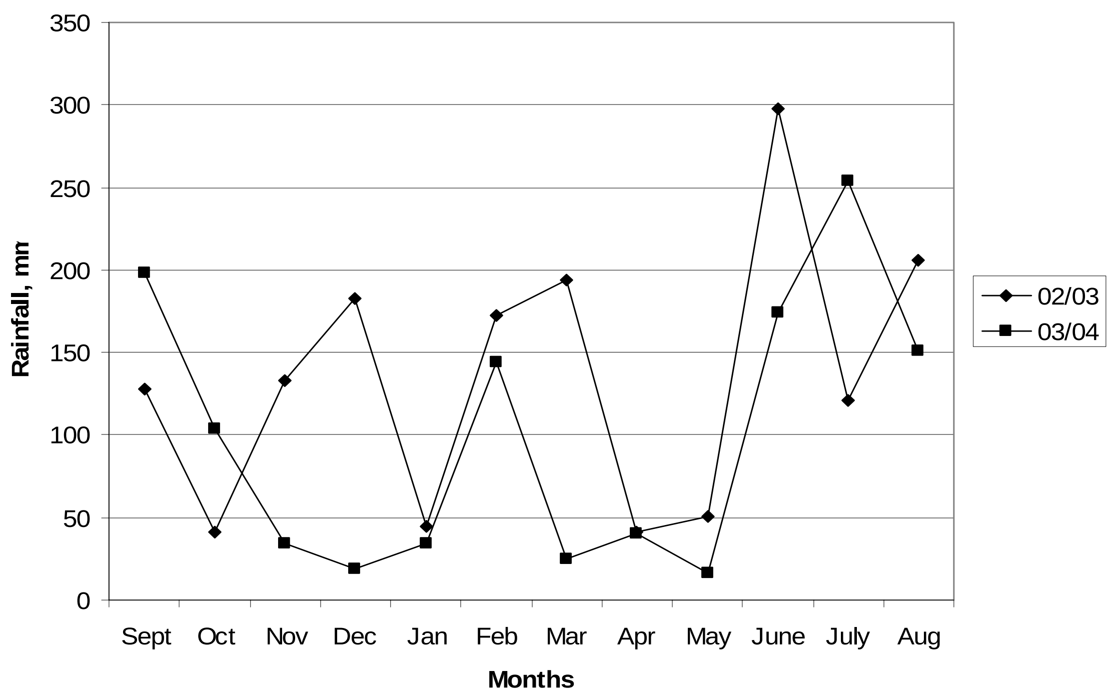

Figure 5-2. Rainfall, monthly average, for Alachua County, Florida (Florida Automated Weather Service, 2005).

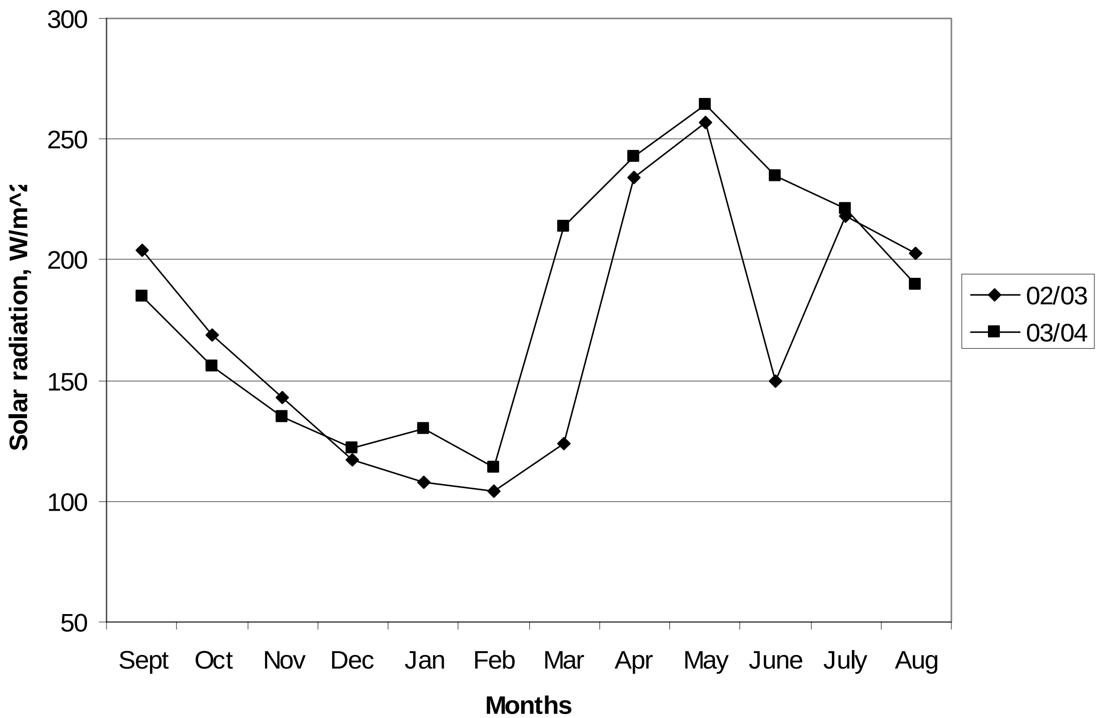

Figure 5-3. Solar radiation, monthly average, for Alachua County, Florida, (Florida Automated Weather Service, 2005).

CHAPTER 6
SWEET CORN *(Zea mays* L.) YIELD AFFECTED BY CROPPING HISTORY AND NITROGEN FERTILIZATION

Introduction

In many parts of the world, the practices of multiple cropping have been in use for thousands of years. Farmers have long since been aware of the many benefits that accompany this type of agriculture and have adapted their practices in order to take advantage of them.

Some of the most important benefits that accompany multiple cropping are the protection and improvement of soil health. Soil conservation can result from this practice, ranging from protection of soil that would otherwise be left bare from erosion to the prevention of surface water runoff to the preservation of soil moisture (Anderson, 1990). Multiple cropping can also contribute to the increase of available nutrient levels in soils, especially when leguminous crops are planted and their N fixation capabilities are utilized. The extensive rooting systems of several successive crops can also loosen and naturally aerate the soil.

Additional advantages of utilizing multiple cropping are the natural diversity provided and its effects on pest populations. By growing various crops in succession, diversity is increased in the natural systems surrounding crop production, which can help to reduce crop-specific pests and possibly attract beneficials (Sullivan, 2003). Certain crops that can be integrated into cropping systems can also provide alleleopathic advantages in controlling nematode and other pest populations (Sullivan, 2003).

Finally, multiple cropping can contribute to the reduction of the cost of crop production. This agronomic practice can reduce the need for fertilizers by bringing in nutrients to the soil, can reduce the need for herbicides by cutting down weed populations, and reduce the need for pesticides by naturally decreasing pest infestations. The decreased need for inputs can greatly cut down on production costs (Reginelli, 1990).

Although multiple cropping can reduce the need for fertilizers with residual nutrients left from one crop to the next, additional nutrients may still be needed for adequate crop growth. Many farmers are becoming more concerned with sustainable farming methods that enhance soil fertility and the natural resource base, while reducing synthetic production inputs and minimizing adverse impacts on the public's health and safety, wildlife, water quality, and the environment. The use of organic fertilizers satisfies these concerns and is rapidly becoming utilized by more farmers across the nation.

Because of the increasing focus on sustainable practices and the rising popularity of organically grown produce, a 2-yr study was conducted investigating the effects of organic and inorganic N sources in 3 different cropping systems on no-till sweet corn. The objectives of this study were to evaluate the yield and plant nutrition of sweet corn due to varying cropping histories, N sources (organic and inorganic), and N rates.

Materials and Methods

For this study, a split-split plot experiment was conducted from August 2002 to June 2004. Main effects were 3 cropping histories that each began in the fall with sweet corn (*Zea mays* L.) (history 1), cowpea (*Vigna unguiculata* (L.) Walp.) (history 2), and sunn hemp (*Crotalaria juncea* L.) (history 3), respectively. In the second year of the experiment, lima bean (*Phaseolus lunatus* L.) replaced cowpea in history 2 because seed was unavailable. Austrian winter pea (*Pisum sativum* L. subsp. *arvense*) was a winter cover crop for all histories and was followed by sweet corn in the spring. Sub-effects were 3 N sources, 2 organic [lupine (*Lupinus angustifolius* L.) and vetch (*Vicia villosa* (L.) Roth)] and one inorganic [ammonium nitrate (AN)]. The sub-effects allowed us to compare the organic N sources to AN for use on sweet corn. Sub-sub effects were 5 N rates (0, 50, 100, 150, and 200 kg ha^{-1} in 2002) (0, 60, 120, 180, and 240 kg ha^{-1} in 2003). The sub-sub effects used allowed us to determine the optimum N rate for sweet corn.

Cropping Histories

In order to examine the different cropping histories, we evaluated the affects of varying multiple cropping systems on a final crop of sweet corn. We examined 3 different histories and assumed that the varying histories would not affect final sweet corn yield or nutrient concentration in diagnostic leaf samples.

History 1 began with a fall crop of sweet corn planted in August of 2002. Each plot contained 4 0.76 m wide rows and measured 2 m by 3 m. Seeds were planted by hand at a rate of 12 seeds m^{-1} of row into Millhopper fine sand (loamy siliceous semiactive hyperthermic Grossarenic Paleodults) [USDA-NRCS, 2003]. Five varieties (‘Merritt’, ‘Silver Queen’, ‘Golden Queen’, ‘Florida Stay Sweet’, and ‘Peaches and Cream’) were used to fulfill teaching purposes. After the sweet corn was harvested in November of 2002, Austrian winter pea was drilled into the sweet corn stalk residue in December 2002. The peas were planted into 0.25 m wide rows throughout the entire field. Following the harvest of Austrian winter pea in March 2003, sweet corn was planted, the final crop of history 1. ‘Silver Queen’ variety was used and was no-till planted into Austrian winter pea residue at a rate of 10 seeds m^{-2} and thinned back to about 6 plants m^{-2}. Plots measured 2 m by 3 m. Sweet corn was harvested in June 2003.

History 2 began with a fall crop of cowpea planted in July of 2002. Each experimental plot contained 4 0.75 m wide rows and measured 2 m by 3 m. Seeds were planted by hand at a rate of 50 seeds 2 m^{-1} of row into Millhopper fine sand (loamy siliceous semiactive hyperthermic Grossarenic Paleodults) [USDA-NRCS, 2003]. Five varieties of cowpea ('California Blackeye #5', 'White Acre', 'Texas Cream 12', 'Mississippi Cream', and 'Iron Clay') were used to fulfill teaching purposes. Directly following the harvest of cowpea in December of 2002, Austrian winter pea was no-till planted across the field in 0.25 m wide rows. After the winter pea was harvested in March 2003, the final crop of history 2, sweet corn, was planted. 'Silver Queen' variety sweet corn was planted into Austrian winter pea residue at a rate of 10 seeds m^{-2} and thinned to about 6 plants m^{-2}. Experimental plots measured 2 m by 3 m. Sweet corn was harvested in June 2003.

History 3 started with a fall crop of sunn hemp planted in August of 2002. Each experimental plot measured 2 m by 3 m and contained 4 0.76 m wide rows. Seed was planted with a Flex 71 planter and a tractor at 200 seeds 6 m^{-1} of row into Millhopper fine sand (loamy siliceous semiactive hyperthermic Grossarenic Paleodults) [USDA-NRCS, 2003]. Sunn hemp was harvested in December 2002 and was immediately followed by a winter crop of Austrian winter pea. The legume was no-till planted into sunn hemp stubble across the field into 0.25 m wide rows. After harvest of the Austrian winter pea in March 2003, sweet corn, the final crop of history 3, was no-till planted into the winter pea residue. 'Silver Queen' sweet corn was planted at a rate of

10 seeds m^{-2} and thinned back to about 7 plants m^{-2}. Plots measured 2 m by 3 m. Sweet corn was harvested in June of 2003.

Nitrogen Sources

While examining the different N sources, we assumed that the source of N would have no effect on sweet corn yield or plant nutrition. Three different N sources were tested in each of the 3 histories during both years of the study.

Each year, plots were side dressed with half rates of AN (34% N) and full rates of lupine and vetch at the planting date. The remaining half of AN was side dressed 30 days after planting. The lupine and vetch were harvested in early February each year and placed in doubled industrial black garbage bags. After the bags were filled to half-capacity with either lupine or vetch, all of the air was pushed out of them and they were sealed to be airtight. The bags were left for about 6 wk before the ensiled plant material was removed and applied to the sweet corn as mulch. The silage of each legume was analyzed for N concentration before application so that N rates could be established. Lupine was found to contain 3.6% N while vetch had 3.5% N. After fertilizer application, each plot was covered with a layer of rye-straw mulch. Mulch was applied by hand at a rate of 4500 kg ha^{-1}.

Nitrogen Rates

We assumed that the current extension recommendations for N fertilization for sweet corn were excessive (Hochmuth et al., 1996). Five different rates of applied N were tested on the final sweet corn crop of each of the 3 histories during both years of the study. The initial rates were tested during the first year of the study and then adjusted for the second year in order to increase the precision of N fertilization. Each crop of sweet corn was analyzed separately for yield and nutrient concentrations.

Throughout both years of the study, sweet corn was irrigated to ensure at least 3 cm of water per week, and weeded manually and mechanically. Sweet corn from each plot was harvested by hand and removed from the field. Soil samples from a depth of 20 cm directly following harvest were also obtained. Leaf samples were taken from each plot at the early tassel stage for N and mineral analysis.

Nitrogen Analysis

Five diagnostic leaves, or the fifth leaf from the top of each plant, were sampled at early tassel stage from each plot during both years of the experiment for analysis (Mills and Jones, 1996). Samples were analyzed for leaf area with a LI-3100 Area Meter (LI-COR, Inc., Lincoln, Nebraska), weighed for fresh matter yield, dried in a forced air oven, and weighed again for dry matter yield. Leaf samples were then chopped in a hammer mill, mixed well, and ground to pass a 2-mm stainless steel screen using a Wiley mill. The samples were then stored in plastic sample bags before analysis.

Nitrogen analysis of the diagnostic leaf samples was performed using a modified micro-Kjedahl procedure. A mixture of 0.100 g of each leaf sample, 3.2 g salt-catalyst (9:1 K_2SO_4:$CuSO_4$), 2 to 3 boiling beads and 10 mL of H_2SO_4 were vortexed in a 100 mL test tube. To reduce frothing, 2 mL 30% H_2O_2 were added in 1 mL increments and then tubes were digested in an aluminum block digester at a temperature of 370°C for 3.5 h (Gallaher et al., 1975). Cool digested solutions were brought to 75 mL volume, transferred to square Nalgene storage bottles (boiling beads were filtered out), sealed, mixed, and stored.

Nitrogen trapped as $(NH_4)_2SO_4$ was analyzed on an automatic solution sampler and a proportioning pump. A plant standard with a history of recorded N concentration values was subjected to the same procedure and used as a check. Fresh matter or dry matter and nutrient concentrations were recorded for each crop of sweet corn.

Mineral Analysis

For mineral analysis, 1.0 g from each diagnostic leaf sample was weighed into 50 mL beakers and ashed in a muffle furnace at 480°C for 6 h. The samples were then cooled to room temperature and moistened with de-ionized water. Twenty mL of de-ionized water and 2 mL of concentrated HCl were added to each beaker, which were then placed on a hot plate and slowly boiled to dryness before being removed.

An additional 20 mL of de-ionized water and 2 mL concentrated HCl were then added and small watch glasses were used to cover the beakers for reflux. They were brought to a vigorous boil and then removed from the hot plate and allowed to cool to room temperature. The samples were then brought to volume in 100 mL flasks and mixed. They were then set aside overnight to allow the Si to settle. The solutions were decanted into 20 mL scintillation vials for analysis. Phosphorus was analyzed by colorimetry, K and Na by flame emission, and Ca, Mg, Cu, Fe, Mn, and Zn by atomic adsorption spectrometry (AA).

Yield

For both years of the experiment, the ears from all plots were hand collected and bagged. The ears were weighed to obtain fresh weights and then graded. The ears were separated into size classes of >15.2 cm, 12.7–15.2 cm, 10.2–12.7 cm, and <10.2 cm categories (USDA, 1954).

Soil Analysis

During each year of the study, soil samples were obtained from the top 20 cm of soil directly following harvest. Samples were air-dried in open paper bags, then screened to pass through a stainless steel sieve with 2 mm holes to remove any rocks or debris and stored for further analysis.

The samples were then analyzed for N, mineral concentrations, pH, buffer pH (BpH), organic matter (OM), and cation exchange capacity (CEC). For soil N, a mixture of 2.0 g of each soil sample, 3.2 g salt catalyst (9:1 K_2SO_4:$CuSO_4$), and 10 mL of H_2SO_4 were subjected to the same procedures for N analysis as leaf tissue was, except that boiling beads were not used because the particles of soil served the same purpose. A soil sample of known N concentration was also analyzed and used as a check.

For soil mineral analysis, a Mehlich I (Mehlich, 1953) extraction method was used. Five g soil samples were weighed and extracted with 20 mL of a combination of 0.025 N H_2SO_4 and 0.05 N HCl. Using an Eberach shaker at 240 oscillations minute^{-1}, mixtures were then shaken for 5 min. The mixtures were then filtered using Schleischer and Schuell 620 (11 cm) filter paper and poured into scintillation vials. The remaining solutions were then subjected to analysis of P, K, Ca, Mg, Na, Cu, Fe, Mn, and Zn in the same manner as described for leaf tissue analysis.

Soil pH was found using a 1:2 soil to water volume ratio using a glass electrode pH meter (Peech, 1965). Buffer pH was found using Adams/Evans buffered solution (Adams and Evans, 1962). Cation exchange capacity was estimated by the summation of relevant cations (Hesse, 1972; Jackson, 1958). Estimated soil CEC was calculated by summing the milliequivalents of the determined bases of Ca, Mg, K, and Na (where applicable) plus exchangeable H^+ expressed in milliequivalents per 100 g (Hesse, 1972).

For organic matter determination, a modified version of the Walkley Black method was used, in which 1.0 g of soil was weighed into a 500-mL Earlenmeyer flask, and

10 mL of 1 N $K_2Cr_2O_7$ solution was pipetted into the flask. Twenty mL of concentrated H_2SO_4 was added and mixed by gentle rotation for 1 min using care to avoid throwing soil up onto the sides of the flask. The flask was then left to stand for 30 min, and then diluted to 200 mL with de-ionized water. Five drops of indicator were added, and the solution was then titrated with 0.5 N Ferrous Sulfate Solution until the color sharply changed from a dull green to a reddish brown color. A flask without soil was prepared in the same manner and titrated to determine the blank titrant, along with a flask containing a check soil with a pre-determined amount of organic matter. Percent OM was determined using the equation: percent OM = (1-T/S) x 6.8, where S is blank-titration in mL of ferrous ammonium sulfate solution, and T is sample titration in mL ferrous ammonium sulfate solution (Walkley, 1935; Allison, 1965).

Statistical Analysis

Sweet corn data from each year was analyzed separately for two reasons. First, the number of crops produced the second year was greater than the first year. Therefore, the 3 histories in the second year were not exactly the same as the first. Second, the N rates were adjusted to be higher the second year compared to the rates in the first year. Data for each year was analyzed as a split-split plot with the main effects (cropping history) in a completely randomized design. An example of the breakdown of the degrees of freedom (df) is shown in Table 6-1. Analysis of variance (ANOVA) for this split-split plot experimental design was conducted by use of MSTAT 4.0 (Anonymous, 1985). Data from each ANOVA was placed in a 4-way table as illustrated in Table 6-2. Means were separated by least significant difference (LSD) at the 0.05 level of probability (Gomez and Gomez, 1976). All treatments and interactions that were significant at $p \leq 0.05$ were highlighted in bold in the data tables (Tables 6-3 to 6-34). Plant mineral data from each year were analyzed as split-split plot designs and means were separated using least significant difference (LSD) at the 0.05 level of probability. Soil data was analyzed as a split-plot with cropping history as the main effect in a completely randomized design and N sources as split plots. This was done because soil samples were collected and combined over all N rates. For soil data treatments and/or interactions that were significant at the 0.05 level of probability or higher, data was highlighted in bold in the data tables (Tables 6-18 and 6-34).

Results

Yield: Ear for 2003

For number of fancy (>15.2 cm) sweet corn ears produced, cropping histories were not significantly ($p>0.05$) different and an interaction between N source and N rate was displayed (Table 6-3). For number of ears 12.7 to 15.2 cm in length, no significant ($p>0.05$) differences were exhibited due to cropping history or to N source, while differences ($p\leq0.05$) were displayed due to N rate (Table 6-4). For number of ears 10.2 to 12.7 cm in length, no significant ($p>0.05$) differences due to cropping history, N source, or N rate were exhibited (Table 6-5). Cropping history, N source, and N rate were all found to be significant ($p\leq0.05$) for number of non-marketable (<10.6 cm) ears produced (Table 6-6). For number of total ears produced, N source was found to be significant ($p\leq0.05$) as was an interaction between cropping history and N rate (Table 6-7).

For ear weight of fancy (>15.2 cm) ears produced, no significant ($p>0.05$) differences due to cropping history were displayed while N source and N rate were significant ($p\leq0.05$) (Table 6-8). Neither cropping history nor N source displayed significant ($p>0.05$) differences for weight of ears 12.7 to 15.2 cm in length, while N rate did (Table 6-9). For ear weight of ears 10.2-12.7 cm in length, no significant (p>0.05) differences were displayed due to cropping history, N source, or N rate (Table 6-10). For ear weight of non-marketable (<10.6 cm) ears, N source was significant ($p \leq 0.05$) as was an interaction between cropping history and N rate (Table 6-11). Ear weight of total ears produced displayed no significant (p>0.05) differences due to cropping history, while N source and N rate were significant ($p \leq 0.05$) (Table 6-12).

Yield: Diagnostic Leaf for 2003

For diagnostic leaf area, significant ($p \leq 0.05$) difference occurred due to cropping history and to N rate, but not N source (Table 6-13). For diagnostic leaf dry weight, cropping history and N rate exhibited significant ($p \leq 0.05$) differences while N source did not (Table 6-14).

Mineral Analysis: Diagnostic Leaf for 2003

For N concentration in diagnostic leaf, cropping history did not display any significant ($p \leq 0.05$) differences while N source and N rate did (Table 6-15). Phosphorus concentration in diagnostic leaf displayed a significant ($p \leq 0.05$) interaction between cropping history and N rate and significant ($p \leq 0.05$) differences due to N source (Table 6-16). For K concentration in diagnostic leaf, cropping history was significant ($p \leq 0.05$) as was an interaction between N source and N rate (Table 6-17).

Mineral Analysis: Soil for 2003

For N and P concentration in soil, cropping history displayed significant ($p \leq 0.05$) difference, while N source did not (Table 6-18). Potassium concentration in soil exhibited significant ($p \leq 0.05$) differences due to both cropping history and N source (Table 6-18). Concentrations of Ca and Mg also displayed significant ($p \leq 0.05$) differences due to cropping history but not N source (Table 6-18). An interaction between cropping history and N source occurred in soil pH (Table 6-18). Significant differences due to cropping history, but not N source, occurred in soil OM and CEC (Table 6-18).

Yield: Ear for 2004

For number of fancy (>15.2 cm) ears produced, no significant (p>0.05) differences were exhibited due to cropping history, while both N source and N rate displayed differences ($p\leq$0.05) (Table 6-19). For number of ears 12.7 to 15.2 cm in length, cropping history was significant ($p\leq$0.05) while N source and N rate were not (Table 6-20). Neither cropping history, nor N source, nor N rate exhibited significant (p>0.05) differences for ears 10.2 to 12.7 cm in length (Table 6-21). For number of non-marketable (<10.6 cm) ears, cropping history and N source did not display differences (p>0.05) while N rate did (Table 6-22). For number of total ears produced, significant ($p\leq$0.05) differences were displayed due to N source and an interaction between cropping history and N rate (Table 6-23).

For ear weight of fancy (>15.2 cm) ears produced, cropping history was not significant (p>0.05), while N source and N rate were (Table 6-24). Cropping history, N source, and N rate did not display significant (p>0.05) differences for ear weight of ears 12.7 to 15.2 cm in length (Table 6-25). For ear weight of ears 10.6 to 12.7 cm length, neither cropping history, N source, nor N rate displayed any differences (p>0.05) (Table 6-26). For ear weight of non-marketable ears (<10.6 cm), cropping history was not significant (p>0.05), while N source and N rate did display differences ($p\leq$0.05) (Table 6-27). For ear weight of total ears produced, significant ($p\leq$0.05) differences were displayed due to N source as well as an interaction between cropping history and N rate (Table 6-28).

Yield: Diagnostic Leaf for 2004

Cropping history and N rate displayed significant ($p \leq 0.05$) differenced for diagnostic leaf area, but N source did not (Table 6-29). For diagnostic leaf dry weight, again only cropping history and N source exhibited differences ($p \leq 0.05$), while N source did not (Table 6-30).

Mineral Analysis: Diagnostic Leaf for 2004

For N concentration of diagnostic leaf, 3 significant ($p \leq 0.05$) interactions were displayed: cropping history and N source, cropping history and N rate, and N source and N rate (Table 6-31). Significant ($p \leq 0.05$) differences due to cropping history and an interaction between N source and N rate were exhibited for p concentration of diagnostic leaf (Table 6-32). For K concentration of diagnostic leaf, cropping history was significant ($p \leq 0.05$) as was an interaction between N source and N rate (Table 6-33).

Mineral Analysis: Soil for 2004

For both N and P concentrations in the soil, an interaction occurred between cropping history and N source (Table 6-34). For K concentration, neither cropping history nor N source displayed significant ($p > 0.05$) differences (Table 6-34). Both cropping history and N source exhibited significant ($p \leq 0.05$) differences for Ca concentration, while only cropping history displayed differences ($p \leq 0.05$) for Mg concentration (Table 6-34). For soil pH, both cropping history and N source displayed significant ($p \leq 0.05$) differences (Table 6-34). An interaction between cropping history and N source occurred in both soil OM and CEC (Table 6-34).

Discussion and Conclusion

Yield: Ear for 2003

For number of fancy (>15.2 cm) ears produced, 1 significant ($p \leq 0.05$) interaction between N source and N rate occurred, due to conflicting trends in ear production. Sweet corn receiving lupine as an N source increased in ear production as N rate increased. Corn receiving vetch produced equal ears at both N rates 0 and 60 kg N ha^{-1}, and equal but increased ears for rates 100, 150, and 200 kg N ha^{-1}. Corn receiving AN increased ear production as N rate increased, except at the 100 and 150 kg N ha^{-1} rates, which produced equal ears. Corn fertilized at 0 and 150 kg N ha^{-1} produced equal ears with all three N sources. Corn fertilized at the 50, 100, and 200 kg N ha^{-1} rates produced a greater increase in number of ears with AN than with either lupine or vetch.

For ears 12.7 to 15.2 cm in length produced, no interactions were displayed and only N rates displayed significant ($p \leq 0.05$) differences. Corn fertilized at rates 200, 150, and 100 kg N ha^{-1} produced highest numbers of ears. Corn fertilized at 0 kg N ha^{-1} produced the lowest number of ears. Cropping history, N source, and N rate did not display any differences ($p > 0.05$) for number of ears 10.6 to 12.7 cm in length produced and no interactions occurred. Differences due to cropping history, N source, and N rate were displayed for number of non-marketable (<10.6 cm) ears produced, while again no interactions were displayed. Corn in cropping history 2 produced the highest number of ears. Corn that received N rates of 0 and 50 kg N ha^{-1} produced the highest number of ears.

One interaction was displayed for number of total ears produced, in addition to N source displaying significant ($p \leq 0.05$) differences. The interaction occurred between cropping history and N rate and was due to conflicting trends in ear yield. Corn grown in cropping history 1 produced equal numbers of ears when it received N rates from 0 to 100 kg N ha^{-1}. Ears then increased at 150 kg N ha^{-1} and then remained equal at 200 kg N ha^{-1}. Corn grown in cropping history 2 produced equal numbers of ears at N rates 50 to 200 kg N ha^{-1}, and lowest ears receiving N at 0 kg N ha^{-1}. Ears produced by corn in cropping history 3 were lowest in number receiving N at 0 kg N ha^{-1} and highest receiving N at 200 kg N ha^{-1}. Corn fertilized at 0, 100, and 200 kg N ha^{-1} exhibited similar trends, producing equal numbers of ears in all 3 cropping histories. Corn receiving 50 kg N ha^{-1} produced the highest number of ears in cropping history 2. Corn fertilized at 150 kg N ha^{-1} produced the highest number of ears in both histories 1 and 2.

No interactions occurred for ear weight of fancy (>15.2 cm) ears produced, but N source and N rate were significant ($p \leq 0.05$). Corn fertilized with AN produced the highest ear weight. Lupine and vetch were used on corn that produced equal, but lower, weights compared to AN. Corn that received the 200 kg N ha^{-1} rate produced the highest ear weight. Ear weight then decreased as N rate decreased, with only corn that received 100 and 150 kg N ha^{-1} producing equal ear weights. No interactions were displayed for ear weight of ears 12.7 to 15.2 cm in length, while N rate was significant ($p \leq 0.05$). Corn that received the three highest N rates, 200, 150, and 100 kg N ha^{-1}, produced the highest ear weights. Corn that was fertilized at rates 50 and 100 kg N ha^{-1} produced equal, but lower ear weights. Corn fertilized at 0 kg N ha^{-1} produced the lowest ear weights. No differences ($p > 0.05$) or interactions were displayed for ear weight of ears 10.2 to 12.7 cm in length.

For ear weight of non-marketable (<10.6 cm) ears, N source was significant ($p \leq 0.05$), with corn fertilized by lupine and vetch producing the highest ear weights. One interaction also occurred, between cropping history and N rate, which was due to differing trends in weight of ears produced. Corn that was grown in cropping history 1 and fertilized at 0, 50, and 150 kg N ha^{-1} produced highest ear weights. Corn that received 100 and 200 kg N ha^{-1} produced equal but lower ear weights. Corn grown in cropping history 2 produced highest ear weights when fertilized at 50 kg N ha^{-1}. Corn that received N at 0, 100, and 100 kg N ha^{-1} produced equal but lower ear weights, while corn that received 200 kg N ha^{-1} produced the lowest weights. Corn grown in cropping history 3 that received 0 and 50 kg N ha^{-1} produced highest ears weights, corn that received 50 and 200 kg N ha^{-1} produced equal, but reduced ear weights, and corn that received 120, 180, and 200 kg N ha^{-1} produced equal and lowest ear weights. Corn fertilized at 0 and 200 kg N ha^{-1} produced equal weight for all 3 cropping histories. Corn that received 100 and 150 kg N ha^{-1} exhibited similar trends, with corn in history 2 producing highest ear weights and corn in histories 1 and 3 producing equal, but lower weights. Corn fertilized at 50 kg N ha^{-1} produced highest ear weights in cropping history 2, followed by history 3 and then 1, respectively.

No interactions occurred for total ear weight, but N source and N rate were significant ($p \leq 0.05$). Corn receiving N source AN produced the highest total ear weight, while the 2 organic sources, lupine and vetch, produced equal but lower weights. Total ear weight increased as N rate increased, but with only the highest 2 N rates, 150 and 200 kg N ha^{-1}, producing equal weights.

Yield: Diagnostic Leaf for 2003

Diagnostic leaf area did not display any interactions, but cropping history and N rate displayed significant ($p \leq 0.05$) differences. Diagnostic leaves from cropping history 2 had the largest area, while leaves from histories 1 and 3 had equal but smaller area.

Leaf area increased as N rate increased from 0 to 100 kg N ha^{-1}, and then remained constant for the 3 highest N rates, 100, 150, and 200 kg N ha^{-1}. No interactions occurred for diagnostic leaf dry weight, while cropping history and N rate were significant. Leaves from cropping history 2 were highest in weight, while leaves from histories 1 and 3 were equal but lower in weight. Dry weight of leaves increased as N rates increased, from 0 to 100 kg N ha^{-1} and then remained equal from rates 100 to 150 kg N ha^{-1}. Leaves that received N at 150 and 200 kg N ha^{-1} had highest leaf weights.

Mineral Analysis: Diagnostic Leaf for 2003

No interaction occurred for N concentration in diagnostic leaf, and only N source and N rate displayed differences ($p \leq 0.05$). Corn that received AN produced highest N in diagnostic leaves, while corn that received lupine and vetch produced equal, but lower N in leaves. Concentration of N increased as applied N rate increased. Corn fertilized at the 2 highest N rates, 150 and 200 kg N ha^{-1}, produced the highest N concentrations.

For P concentration in diagnostic leaf, an interaction between cropping history and N rate occurred, due to conflicting trends in P production in diagnostic leaves. Corn grown in history 1 produced highest P concentration when fertilized at 0 to 150 kg N ha^{-1}. Corn grown in cropping history 2 produced highest P when fertilized at rates 0, 100, 150, and 200 kg N ha^{-1}. Corn grown in history 3 produced highest P when fertilized at 100, 150, and 200 kg N ha^{-1}. Corn that was fertilized from 0 to 100 kg N ha^{-1} exhibited the same trend and produced equal and highest P in histories 1 and2. Corn that received N at 150 kg N ha^{-1} produced highest P in histories 1 and 2, while corn that received 200 kg N ha^{-1} produced highest P in history 2.

For K concentration in diagnostic leaf, differences ($p \leq 0.05$) were displayed due to cropping history as well as an interaction between N source and N rate, which was due to differing trends in K production. Corn that received lupine produced highest K when fertilized at 200 kg N ha^{-1}. When vetch was the N source, corn produced highest K when N rates were 150 and 200 kg N ha^{-1}. When corn received AN, highest K was produced at fertilization rates 0 to 150 kg N ha^{-1}. Corn fertilized at rates 100 and 200 kg N ha^{-1} exhibited similar trends, with corn receiving lupine and vetch producing equal and highest concentrations of K. Corn fertilized at 0 kg N ha^{-1} produced equal K in when it received lupine and vetch and equal but lower K when N came from vetch and AN. Corn fertilized at 50 kg N ha^{-1} produced equal K with all 3 N sources. Finally, corn fertilized at 150 kg N ha^{-1} produced highest K when it received vetch, followed by histories lupine and AN, respectively.

Mineral Analysis: Soil for 2003

The same trend was exhibited by N and P concentrations in soil. Soil from cropping history 2 had the highest N and P concentrations, while soil from histories 1 and 3 had equal, but lower concentrations. No differences ($p>0.05$) in N or P concentrations were due to N source. The highest K concentrations were seen in soil from cropping histories 2 and 3. Differences ($p\leq0.05$) in K were due to N source, with lupine and vetch used as fertilizer in areas with the highest K. For Ca concentration, soil from cropping history 2 displayed the highest, followed by soil from histories 3 and 1, respectively. No differences ($p>0.05$) in Ca concentration were due to N source. Soil from history 2 displayed the highest Mg concentration, but no differences ($p>0.05$) were displayed due to N source.

An interaction occurred in soil pH, between cropping history and N source. Soil for each N source followed the same trend, with highest pH found in soil from histories 2 and 3. Soil from history 1 had highest pH when fertilized with vetch and AN, while soil from histories 2 and 3 had equal pH with each N source. Soil from cropping history 2 displayed the highest OM, followed by soil from histories 3 and 2, respectively. No differences (p>0.05) in soil OM were due to N source. Soil from history 2 also displayed the highest CEC. Again, no differences (p>0.05) in CEC were due to N source.

Yield: Ear for 2004

For number of fancy (>10.6 cm) ears produced, no interactions occurred, while N source and N rate were significant ($p \leq 0.05$). Corn that received AN as an N source produced the highest number of fancy ears. Corn that received lupine or vetch produced equal, but lower numbers of ears. Corn fertilized at rates 0 and 60 kg N ha^{-1} produced equal, but lowest, ears. Corn that received 120 and 180 kg N ha^{-1} of fertilizer produced higher, but equal, ears. Finally, corn that received 240 kg N ha^{-1} of fertilizer produced the highest number of ears. No interactions occurred for ears 12.7 to 15.2 cm in length, but cropping history displayed significant ($p \leq 0.05$) differences. Corn from histories 1 and 2 produced the highest numbers of ears, followed by history 3. No significant ($p \leq 0.05$) differences or interactions were displayed for ears 10.2 to 12.7 cm produced. For non-marketable (<10.6 cm) ears produced, no interactions were displayed, while N rate was significant ($p \leq 0.05$). The highest number of non-marketable ears was produced by corn that received 0 kg N ha^{-1}. The number of ears produced decreased as N rate increased, with the 2 highest N rates, 180 and 240 kg N ha^{-1}, used on corn that produced the lowest numbers of ears.

One interaction was displayed for number of total ears produced, between cropping history and N rate. This interaction was due to conflicting trends in ear production. Corn in cropping history 1 fertilized at rates 0, 120, 180, and 240 kg N ha^{-1} produced the highest number of ears. Corn in history 2 fertilized at rates 0 to 180 kg N ha^{-1} produced lowest numbers of ears, while corn receiving 240 kg N ha^{-1} produced the highest number of ears. Corn in history 3, corn that received 0, 120, 180, and 240 kg N ha^{-1} produced highest numbers of ears. Corn fertilized at 0, 60, and 120 kg N ha^{-1} produced equal ears for all 3 cropping histories. Corn fertilized at 180 kg N ha^{-1} produced highest ears in history 3, while corn fertilized at 240 kg N ha^{-1} produced highest ears in history 2. Source of nitrogen was also significant ($p \leq 0.05$), with AN used on corn that produced the highest number of ears.

For ear weight of fancy (>15.2 cm) ears, no interactions occurred, while N source and N rate displayed significant ($p \leq 0.05$). Corn that received AN produced greater ear weights than corn that received lupine or vetch. Corn that received 0 and 60 kg N ha^{-1} produced lowest ears weights, while corn fertilized at 120 and 180 kg N ha^{-1} produced increased, but equal ear weights. Corn that received 240 kg N ha^{-1} produced the highest ear weights. No interactions or differences ($p > 0.05$) were displayed for ear weight of ears 12.7 to 15.2 cm or ears 10.2 to 12.7 cm in length. For ear weight of non-marketable (<10.6 cm) ears, no interactions were displayed, while N source and N rate were significant ($p \leq 0.05$). Corn that received lupine and vetch both produced highest ear weights. Corn fertilized at rates 0 and 60 kg N ha^{-1} produced highest ear weights.

For ear weight of total ears produced, differences ($p \leq 0.05$) due to N source and an interaction between cropping history and N rate were displayed. The interaction was due to differing trends in ear weight production. Corn fertilized with AN produced the highest ear weights. Corn grown in cropping histories 1 and 3 that received 120, 180, and 240 kg N ha^{-1} produced highest ear weights. Corn in cropping history 2 that received 240 kg N ha^{-1} produced highest ear weights. Corn that was fertilized at rates 0, 60, and 120 kg N ha^{-1} exhibited similar trends, producing equal ear weights in each cropping history. Corn fertilized at 180 and 240 kg N ha^{-1} produced highest ear weights in histories 2 and 3.

Yield: Diagnostic Leaf for 2004

No interactions occurred for diagnostic leaf area, while cropping history and N rate displayed differences ($p \leq 0.05$). Leaves from histories 2 and 3 had the largest area. Corn fertilized at rates 0 and 60 kg N ha^{-1} produced leaves with the smallest area, followed by corn fertilized at 60 and 120 kg N ha^{-1}, which produced leaves with equal, but increased area. Finally, corn that received 120, 180, and 240 kg N ha^{-1} produced leaves with the largest area. For diagnostic leaf dry weight, only cropping history and N rate displayed significant ($p \leq 0.05$) differences. Corn grown in histories 2 and 3 produced leaves with the highest dry weights. Corn fertilized at rates 180 and 240 kg N ha^{-1} produced leaves with the highest dry weights. Dry weights of leaves then decreased as N rate decreased.

Three interactions occurred for N concentration in diagnostic leaf. The first was between cropping history and N source and was due to conflicting trends in N production in diagnostic leaf. Corn grown in cropping histories 1 and 3 followed similar trends in N production, with highest N produced with AN as an N source. Corn from history 2 produced equal N with all 3 N sources. Corn that received vetch and AN produced equal N in all 3 cropping histories. Corn grown in histories 2 and 3 that received lupine produced highest N. The second interaction occurred between cropping history and N rate and was due to differing trends in N production in leaves. Diagnostic leaves from histories 1 and 3 followed a similar trend, with N concentration remaining equal when corn received 0 to 180 kg N ha^{-1} and then increasing as N increased to 240 kg N ha^{-1}. Leaves from history 2 did not follow this trend, increasing in N as N rate increased from

0 to 180 kg N ha^{-1} and then decreasing at 240 kg N ha^{-1}. Corn fertilized at rates 0, 60, 120, and 240 kg N ha^{-1} all followed the same trend, producing equal N in diagnostic leaves in all 3 cropping histories. Corn that received 180 kg N ha^{-1} did not follow this trend, producing equal N in histories 1 and 2 and again in histories 1 and 3. The final interaction was between N source and N rate and occurred due to conflicting trends in N concentration production in diagnostic leaves. Corn fertilized with AN produced equal N in leaves at N rates 0 and 60 kg N ha^{-1}, equal but increased N at rates 60, 120, and 180 kg N ha^{-1}, and equal but increased N at rate 120, 180, and 240 kg N ha^{-1}. Corn that received vetch produced equal N in leaves from N rates 0 to 180 kg N ha^{-1} and increased N at rates 180 and 240 kg N ha^{-1}. Corn that received lupine produced equal N in leaves from N rates 0 to 60 kg N ha^{-1}, equal but increased N from rates 60 to 120 kg N ha^{-1}, and highest N at rate 180 kg N ha^{-1}. Corn fertilized at 0 kg N ha^{-1} produced equal N with all 3 N sources, while corn fertilized at 60 kg N ha^{-1} produced equal N with lupine and vetch and lupine and AN. Corn fertilized at rates 120 and 240 kg N ha^{-1} exhibited similar trends, highest N produced by corn that received AN. Finally, corn fertilized at 180 kg N ha^{-1} produced equal and highest N concentrations with lupine and AN as N sources.

Only 1 interaction was displayed for P concentration in diagnostic leaf, in addition to significant ($p \leq 0.05$) differences due to cropping history. Corn grown in cropping histories 1 and 2 producing highest P in diagnostic leaves. The interaction occurred between N source and N rate and was due to conflicting trends in P production in diagnostic leaves. Corn that received lupine produced equal P when fertilized from rates 0 to 120 kg N ha^{-1} and decreased, but equal P at rates 180 and 240 kg N ha^{-1}. Corn fertilized with vetch produced equal P concentrations with all 3 N sources. Corn that received AN produced highest P at N rates 0 and 60 kg N ha^{-1} and lowest at rates 120, 180, and 240 kg N ha^{-1}. Corn fertilized at rates 0 and 60 kg N ha^{-1} produced highest P concentrations with lupine and AN as N sources. Corn that received 120 kg N ha^{-1} produced highest P with lupine. Corn fertilized at rates 180 and 240 kg N ha^{-1} peaked in P production with vetch as an N source.

Significant ($p \leq 0.05$) differences were displayed for K concentration in diagnostic leaf due to cropping history. Corn grown in history 2 produced highest K. One interaction also occurred in K concentration in diagnostic leaf, between N source and N rate. This interaction was due to differing trends in K production in diagnostic leaves. Corn that received lupine peaked in K production at N rate 240 kg N ha^{-1}, while corn the received vetch produced highest K at both rates 180 and 240 kg N ha^{-1}. Corn fertilized with AN peaked in K production at rate 60 kg N ha^{-1}. Corn that received 0 kg N ha^{-1} peaked in K production when lupine and vetch were N sources. Corn fertilized at rates 60 and 120 kg N ha^{-1} produced equal K with all 3 N sources. Corn that received 180 and 240 kg N ha^{-1} produced highest K concentrations with lupine and vetch as N sources.

Mineral Analysis: Soil for 2004

For N concentration in soil, an interaction occurred between cropping history and N source, due to differing trends in N concentration. Soil from cropping histories 1 and 3 had equal N for all N sources. Soil from history 2 had higher N with lupine as an N source than with either vetch or AN. Soil that had received lupine and vetch followed similar trends in N concentrations, N being highest in soil from history 2. Soil that received AN had highest N from histories 2 and 3.

An interaction occurred for P concentration in soil, between cropping history and N source, due to conflicting trends in P concentration. Again, soil from cropping histories 1 and 3 followed the same trend and had equal P concentrations for all 3 N sources. Soil from history 2 had highest P with vetch and AN as N sources. Soil that received all 3 N sources followed the same trend in P concentrations, with soil from history 2 having highest P.

Neither cropping history nor N source displayed significant ($p>0.05$) differences for K concentration in soil. Cropping history was significant ($p\leq0.05$) for Ca concentration, with soil from history 2 highest in Ca. Nitrogen source was also significant ($p\leq0.05$), with soil that had received AN and lupine highest in Ca. For Mg concentration in soil, soil from history 2 had the highest concentration. Nitrogen source did not display any differences ($p>0.05$).

Cropping history and N source displayed significant ($p\leq0.05$) differences for soil pH. Soil from histories 2 and 3 had highest pH's while soil that received AN as an N source also had the highest pH. An interaction occurred for soil OM, between cropping history and N source. The soil from histories 1 and 3 behaved similarly, with equal OM from all 3 N sources. Soil from history 2 has highest OM when AN was the N source. Soil the received lupine had highest OM in histories 2 and 3, while soil that received vetch and AN had highest OM in history 2. An interaction between cropping history and N source also occurred in soil CEC. Again, soil from histories 1 and 3 behaved similarly, having equal CEC for all 3 N sources. Soil CEC was also highest in history 2 when AN was the N source. Soil that received lupine had highest CEC in histories 2 and 3, while soil that received vetch had equal CEC in all histories. Soil that received AN had highest CEC in history 2.

Summary

Cropping history 2 yielded the highest number of fancy (>15.2 cm) ears as well as the highest ear weight of fancy (>15.2 cm) ears in 2003, while in 2004, no difference among histories was displayed for fancy (>15.2 cm) ear production or weight. In terms of economic value, fancy (>15.2 cm) ears are the only ear size with marketable potential. Diagnostic leaves sampled in 2003 from all histories were not different in N concentration. An interaction for N concentration in diagnostic leaves occurred involving cropping history in 2004. Nitrogen is one of the most important limiting nutrients for plant growth and development. Mineral analysis of the diagnostic leaves indicated that macronutrients tested were well within, or even higher than, sufficiency ranges appropriate for sweet corn during the tasseling stage (Hochmuth, 1991; Mills and Jones, 1996). In 2003, N concentration in leaves was within suggested sufficiency ranges while P and K concentrations were slightly higher than the suggested ranges when organic fertilizers were used. In 2004, N and P concentrations were within suggested ranges while K concentration was again higher than suggested ranges when applied fertilizer was organic. Soil samples taken from history 2 directly following harvest of final sweet corn crop in 2003 were highest in N concentration of all 3 histories. In 2004, an interaction occurred involving cropping history for N concentration of soil.

In 2003, an interaction occurred for number of fancy (>15.2 cm) ears produced involving N source. In 2004, AN was used on corn that produced the highest number of fancy (>15.2 cm) ears. For both years of the study, AN-fertilized corn produced the highest fancy (>15.2 cm) weight, as well. Diagnostic leaves sampled in 2003 were highest in N concentration when corn received AN. An interaction occurred for N concentration in leaves involving N source in 2004.

An interaction occurred involving N rate for number of fancy (>15.2 cm) ears produced in 2003. Corn that received fertilizer at 240 kg N ha^{-1} produced the highest number of fancy (>15.2 cm) ears in 2004. In both 2003 and 2004, corn that produced the highest ear weight for fancy (>15.2 cm) ears produced received fertilizer at 240 kg ha^{-1}. Corn that received N at both 180 and 240 kg ha^{-1} produced the highest N concentrations in diagnostic leaves in 2003. In 2004, an interaction occurred involving N rates for N concentration in leaves.

For production of sweet corn in a no-till multiple cropping system, a previous history involving cowpea and Austrian winter pea appears to be well suited. Of the cropping histories tested, the system including these 2 legumes prior to sweet corn produced the most, as well as largest, marketable ears. The soil from this history also had the highest N concentration, which could be due to N contributions from the residue of the 2 consecutive legume crops planted immediately prior to the corn. The third cropping history also included 2 legumes grown prior to the final sweet corn, but the residue from the first crop, sunn hemp, was not left on the field, which could explain why ear production and soil health was not as high.

For our tests, the inorganic fertilizer, AN, gave best results as an N source for sweet corn grown in a no-till multiple cropping system. The organic sources, lupine and vetch, could not compete with the inorganic N at the rates applied. The organic sources cannot offer the same immediate supply of N that the AN can provide. The legumes must begin to break down in order for N to become available, whereas with the chemical formulation, N is available for crops right away. In addition, not all of the N that organic mulches contain can become available; in a previous study, only a portion of the total N contained in organic legume mulches were recovered by subsequent crops (Eylands, 1984). Legume mulches have been found to contribute up to 50% of their N contained to a following crop (Sullivan, 2003). Although inorganic fertilizers might be more economical, organic fertilizers offer benefits that inorganic fertilizers cannot. Organic fertilizers can improve soil moisture conservation, soil organic matter, provide other plant mineral elements, and reduce erosion in addition to reducing the threat of chemical leaching.

The highest rates of applied N of those tested, 240 and 180 kg ha^{-1}, produced corn with the highest yields and best production. As the applied N rate increased, production of fancy (>15.2 cm) ears also increased, and the production of non-marketable (<10.6 cm) ears decreased. Economically, the lower of the 2 rates, 180 kg ha^{-1}, would be preferable if the same results can be achieved as with the higher rate.

Table 6-1. Analysis of variance for a split-split plot experimental design with main treatments in a CRD experimental design.

Source of variation	Description	df
Total (1)	Total for overall experiment (5*3*3*5) = 225-1=	224
Total (2)	Total cropping histories (5*3) = 15-1 =	14
Main (A)	Cropping histories (3-1) =	2
Error a	Error main treatment (a)	12
Total (3)	Total nitrogen sources (5*3*3-1-14) =	30
Sub (B)	Nitrogen sources (3-1) =	2
A* B	A* B (3-1)* (3-1) =	4
Error b	Error sub treatment (b)	24
Total (4)	Total nitrogen rates: Total (1)-Total (2)-Total (3) =	180
Sub-sub (C)	Nitrogen rate (5-1) =	4
A* C	A*C (3-1)*(5-1) =	8
B* C	B*C (3-1)*(5-1) =	8
A* B* C	A*B*C (3-1)*(3-1)*(5-1) =	16
Error c	Error sub-sub treatment (c)	144

Table 6-2. Statistics key to treatment means and interactions in sweet corn for three cropping histories, three sources of nitrogen, and five nitrogen rates in 2003 and 2004.

	Cropping history 1†				Cropping history 2				Cropping history 3				Cropping history $\overline{X}$			
	——N source——				——N source——				——N source——				——N source——			
N rate	LP‡	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$
Kg ha-1	——Number of ears, total, m-2——															
0	h*s*r	h*s*r	h*s*r	H*R	h*s*r	h*s*r	h*s*r	H*R	h*s*r	h*s*r	h*s*r	H*R	S*R	S*R	S*R	**R**
60	h*s*r	h*s*r	h*s*r	H*R	h*s*r	h*s*r	h*s*r	H*R	h*s*r	h*s*r	h*s*r	H*R	S*R	S*R	S*R	**R**
120	h*s*r	h*s*r	h*s*r	H*R	h*s*r	h*s*r	h*s*r	H*R	h*s*r	h*s*r	h*s*r	H*R	S*R	S*R	S*R	**R**
180	h*s*r	h*s*r	h*s*r	H*R	h*s*r	h*s*r	h*s*r	H*R	h*s*r	h*s*r	h*s*r	H*R	S*R	S*R	S*R	**R**
240	h*s*r	h*s*r	h*s*r	H*R	h*s*r	h*s*r	h*s*r	H*R	h*s*r	h*s*r	h*s*r	H*R	S*R	S*R	S*R	**R**
$\overline{X}$	H*S	H*S	H*S		H*S	H*S	H*S		H*S	H*S	H*S		**S**	**S**	**S**	
$\overline{X}$ $\overline{X}$				**H**				**H**				**H**				

H (h) = Main treatments (Cropping history, 1 to 3)
S (s) = Sub treatment (Nitrogen source, 1 to 3)
R (r) = Sub-sub treatment (Nitrogen rate, 1 to 5)
H*S = Main treatment * Sub treatment interaction (Cropping history * Nitrogen source)
H*R = Main treatment * Sub-sub treatment interaction (Cropping history * Nitrogen rate)
S*R = Sub treatment * sub-sub treatment interaction (Nitrogen source * Nitrogen rate)
h*s*r = Main treatment * sub treatment * sub-sub treatment interaction (Cropping history * Nitrogen source * Nitrogen rate)

†History 1 = sweet corn/Austrian winter pea/sweet corn/sweet corn/Austrian winter pea/sweet corn.
History 2 = cowpea/Austrian winter pea/sweet corn/lima bean/Austrian winter pea/sweet corn.
History 3 = sunn hemp/Austrian winter pea/sweet corn/sunn hemp/Austrian winter pea/sweet corn.
‡LP = lupine, VT = vetch, AN = ammonium nitrate.

Table 6-3. Sweet corn ears (>15.2 cm in length) produced for three cropping histories, three sources of nitrogen, and five nitrogen rates in 2003.

	Cropping history 1†				Cropping history 2				Cropping history 3				Cropping history $\overline{X}$			
	——N source——				——N source——				——N source——				——N source——			
N rate	LP‡	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$
Kg ha^{-1}	——Number of ears >15.2 cm m^{-2}——															
0	1.26	0.70	0.98	0.98	1.32	0.96	1.44	1.24	0.72	0.68	0.44	0.61	**1.10**	**0.78**	**0.95**	0.94
50	1.14	1.06	1.80	1.33	1.56	1.64	2.70	1.97	1.36	1.02	2.00	1.46	**1.35**	**1.24**	**2.17**	1.59
100	2.12	1.90	1.90	1.97	1.74	2.48	3.48	2.57	1.88	1.78	4.06	2.57	**1.91**	**2.05**	**3.15**	2.37
150	2.34	2.12	2.34	2.27	2.88	2.56	3.84	3.09	2.34	2.46	2.80	2.53	**2.52**	**2.38**	**2.99**	2.63
200	2.06	2.18	4.18	2.81	3.26	2.96	4.24	3.49	3.48	2.60	4.04	3.37	**2.93**	**2.58**	**4.15**	3.22
$\overline{X}$	1.78	1.59	2.24		2.15	2.12	3.14		1.96	1.71	2.67		1.96	1.81	2.68	
$\overline{X}$ $\overline{X}$				1.87				2.47				2.11				

†History 1 = sweet corn/Austrian winter pea/sweet corn/sweet corn/Austrian winter pea/sweet corn.
History 2 = cowpea/Austrian winter pea/sweet corn/lima bean/Austrian winter pea/sweet corn.
History 3 = sunn hemp/Austrian winter pea/sweet corn/sunn hemp/Austrian winter pea/sweet corn.
‡LP = lupine; VT = vetch; AN = ammonium nitrate.

N source x N rate (highlighted) was significant at $p<0.05$. Differences among N sources within N rates were different at $p\leq0.05$ with LSD = 0.78. Differences among N rates within N sources were different at $p\leq0.05$ with LSD = 0.65.

Table 6-4. Sweet corn ears (12.7–15.2 cm in length) produced for three cropping histories, three sources of nitrogen, and five nitrogen rates in 2003.

	Cropping history 1†				Cropping history 2				Cropping history 3				Cropping history $\overline{X}$			
	——N source——				——N source——				——N source——				——N source——			
N rate	LP‡	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$
Kg ha^{-1}	——Number of ears, 12.7–15.2 cm m^{-2}——															
0	1.06	1.04	1.12	1.07	0.64	0.90	1.22	0.92	0.88	1.16	1.02	1.02	0.86	1.03	1.12	**1.00**
50	1.40	1.22	1.02	1.21	1.42	0.90	1.24	1.19	1.64	1.30	1.06	1.33	1.49	1.14	1.11	**1.24**
100	1.32	1.42	1.24	1.33	1.68	1.10	1.54	1.44	1.54	1.56	1.42	1.51	1.51	1.36	1.40	**1.42**
150	1.48	2.00	1.98	1.82	1.48	1.30	1.36	1.38	1.42	1.42	1.74	1.53	1.46	1.57	1.69	**1.58**
200	1.88	1.58	1.28	1.58	1.26	1.76	1.84	1.62	1.00	1.54	1.60	1.38	1.38	1.63	1.57	**1.53**
$\overline{X}$	1.43	1.45	1.33		1.30	1.19	1.44		1.30	1.40	1.37		1.34	1.35	1.38	
$\overline{X}\ \overline{X}$				1.40				1.31				1.35				

†History 1 = sweet corn/Austrian winter pea/sweet corn/sweet corn/Austrian winter pea/sweet corn.
History 2 = cowpea/Austrian winter pea/sweet corn/lima bean/Austrian winter pea/sweet corn.
History 3 = sunn hemp/Austrian winter pea/sweet corn/sunn hemp/Austrian winter pea/sweet corn.
‡LP = lupine; VT = vetch; AN = ammonium nitrate.

N rate (highlighted) significant at $p \leq 0.05$ with LSD = 0.22.

Table 6-5. Sweet corn ears (10.2–12.7 cm in length) produced for three cropping histories, three sources of nitrogen, and five nitrogen rates in 2003.

	Cropping history 1†				Cropping history 2				Cropping history 3				Cropping history $\overline{X}$			
	N source				N source				N source				N source			
N rate	LP‡	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$
Kg ha^{-1}	Number of ears, 10.2–12.7 cm m^{-2}															
0	0.94	0.68	1.14	0.92	0.84	1.04	1.12	1.00	1.70	1.22	0.70	1.21	1.16	0.98	0.99	1.04
50	1.28	0.94	0.68	0.97	1.22	1.08	1.20	1.17	0.74	1.16	0.96	0.95	1.08	1.06	0.95	1.03
100	1.14	1.14	1.14	1.14	0.86	1.18	0.90	0.98	1.12	1.04	1.08	1.08	1.04	1.12	1.04	1.07
150	0.96	1.04	1.00	1.00	0.90	1.28	0.68	0.95	0.68	0.70	0.82	0.73	0.85	1.01	0.83	0.90
250	1.38	0.94	0.70	1.01	1.00	1.06	1.02	1.03	0.66	0.76	0.74	0.72	1.01	0.92	0.82	0.92
$\overline{X}$	1.14	0.95	0.93		0.96	1.13	0.98		0.98	0.98	0.86		1.03	1.02	0.93	
$\overline{X}$ $\overline{X}$				1.01				1.03				0.94				

†History 1 = sweet corn/Austrian winter pea/sweet corn/sweet corn/Austrian winter pea/sweet corn.
History 2 = cowpea/Austrian winter pea/sweet corn/lima bean/Austrian winter pea/sweet corn.
History 3 = sunn hemp/Austrian winter pea/sweet corn/sunn hemp/Austrian winter pea/sweet corn.
‡LP = lupine; VT = vetch; AN = ammonium nitrate.

Table 6-6. Sweet corn ears (<10.2 cm in length) produced for three cropping histories, three sources of nitrogen, and five nitrogen rates in 2003.

	Cropping history 1†				Cropping history 2				Cropping history 3				Cropping history $\overline{X}$			
	——N source——				——N source——				——N source——				——N source——			
N rate	LP‡	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$
Kg ha^{-1}	——Number of ears, <10.2 cm, m^{-2}——															
0	1.72	1.60	1.70	1.67	1.30	2.06	1.60	1.65	1.36	1.72	1.44	1.51	1.46	1.79	1.58	**1.61**
50	1.36	1.30	0.60	1.09	2.60	3.02	1.36	2.33	0.94	1.88	1.18	1.33	1.63	2.07	1.05	**1.58**
150	0.82	0.42	0.98	0.74	1.48	1.00	0.88	1.12	0.36	0.92	0.68	0.65	0.89	0.78	0.85	**0.84**
100	0.82	0.90	0.86	0.86	1.54	1.36	1.12	1.34	0.42	0.78	0.40	0.53	0.93	1.01	0.79	**0.91**
250	0.62	0.68	0.56	0.62	1.00	0.58	0.70	0.76	0.86	1.10	0.54	0.83	0.83	0.79	0.60	**0.74**
$\overline{X}$	1.07	0.98	0.94		1.58	1.60	1.13		0.79	1.28	0.85		**1.15**	**1.29**	**0.97**	
$\overline{X}$ $\overline{X}$				**1.00**				**1.44**				**0.97**				

†History 1 = sweet corn/Austrian winter pea/sweet corn/sweet corn/Austrian winter pea/sweet corn.
History 2 = cowpea/Austrian winter pea/sweet corn/lima bean/Austrian winter pea/sweet corn.
History 3 = sunn hemp/Austrian winter pea/sweet corn/sunn hemp/Austrian winter pea/sweet corn.
‡LP = lupine; VT = vetch; AN = ammonium nitrate.

Cropping history (highlighted) significant at $p \leq 0.05$ with LSD = 0.30.
N source (highlighted) significant at $p \leq 0.05$ with LSD = 0.24.
N rate (highlighted) significant at $p \leq 0.05$ with LSD = 0.33.

Table 6-7. Total sweet corn ears produced for three cropping histories, three sources of nitrogen, and five nitrogen rates in 2003.

	Cropping history 1†				Cropping history 2				Cropping history 3				Cropping history $\overline{X}$			
	N source				N source				N source				N source			
N rate	LP‡	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$
Kg ha^{-1}	Number of ears, total, m^{-2}															
0	5.04	4.02	4.94	**4.67**	4.10	5.00	5.38	**4.83**	4.64	4.82	3.56	**4.34**	4.59	4.61	4.63	4.61
50	5.20	4.48	4.12	**4.60**	6.80	6.62	6.50	**6.64**	4.68	5.36	5.22	**5.09**	5.56	5.49	5.28	5.44
100	5.40	4.84	5.22	**5.15**	5.78	5.76	6.76	**6.10**	4.88	5.28	7.28	**5.81**	5.35	5.29	6.42	5.69
150	5.58	6.06	6.16	**5.93**	6.78	6.54	7.00	**6.77**	4.86	5.30	5.76	**5.31**	5.74	5.97	6.31	6.00
200	5.98	5.42	6.66	**6.02**	6.48	6.32	7.80	**6.87**	6.04	5.96	6.90	**6.30**	5.17	5.90	7.12	6.40
$\overline{X}$	5.44	4.96	5.42		6.00	6.05	6.69		5.02	5.34	5.74		**5.48**	**5.45**	**5.95**	
$\overline{X}$ $\overline{X}$				5.28				6.24				5.37				

†History 1 = sweet corn/Austrian winter pea/sweet corn/sweet corn/Austrian winter pea/sweet corn.
History 2 = cowpea/Austrian winter pea/sweet corn/lima bean/Austrian winter pea/sweet corn.
History 3 = sunn hemp/Austrian winter pea/sweet corn/sunn hemp/Austrian winter pea/sweet corn.
‡LP = lupine; VT = vetch; AN = ammonium nitrate.

N source (highlighted) significant at $p<0.05$ with LSD = 0.40.
Cropping history x N rate (highlighted) significant at $p<0.05$. Differences among cropping histories within N rates were different at $p \leq 0.05$ with LSD = 1.10. Differences among N rates within cropping histories were different at $p \leq 0.05$ with LSD = 0.75.

Table 6-8. Sweet corn ear (>15.2 cm in length) yield for three cropping histories, three sources of nitrogen, and five nitrogen rates in 2003, Gainesville, Florida.

	Cropping history 1†				Cropping history 2				Cropping history 3				Cropping history $\overline{X}$			
	N source				N source				N source				N source			
N rate	LP‡	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$
Kg ha^{-1}	Ear weight, g m^{-2} (Ears >15.2 cm)															
0	305	153	233	230	342	253	407	334	141	137	84	121	262	181	241	**228**
50	488	240	438	389	391	419	725	512	256	235	426	306	379	298	530	**402**
100	388	414	483	428	471	640	916	676	405	387	884	559	421	480	761	**554**
150	636	521	600	586	694	687	1003	795	484	512	703	566	605	573	769	**649**
200	537	543	1082	721	828	665	1031	841	787	629	787	734	717	612	967	**765**
$\overline{X}$	471	374	567		454	533	817		414	380	577		**477**	**429**	**654**	
$\overline{X}$ $\overline{X}$				471				632				457				

†History 1 = sweet corn/Austrian winter pea/sweet corn/sweet corn/Austrian winter pea/sweet corn.
History 2 = cowpea/Austrian winter pea/sweet corn/lima bean/Austrian winter pea/sweet corn.
History 3 = sunn hemp/Austrian winter pea/sweet corn/sunn hemp/Austrian winter pea/sweet corn.
‡LP = lupine; VT = vetch; AN = ammonium nitrate.

N source (highlighted) was significant at $p \leq 0.05$ with LSD = 156.
N rate (highlighted) was significant at $p \leq 0.05$ with LSD = 104.

Table 6-9. Sweet corn ear (12.7–15.2 cm in length) yield for three cropping histories, three sources of nitrogen, and five nitrogen rates in 2003.

	Cropping history 1†				Cropping history 2				Cropping history 3				Cropping history $\bar{X}$			
	——N source——				——N source——				——N source——				——N source——			
N rate	LP‡	VT	AN	$\bar{X}$	LP	VT	AN	$\bar{X}$	LP	VT	AN	$\bar{X}$	LP	VT	AN	$\bar{X}$
Kg ha^{-1}	——Ear weight, g m^{-2} (Ears 12.7–15.2 cm)——															
0	162	144	176	161	112	175	224	171	118	168	128	137	130	162	176	**156**
50	211	183	163	186	277	167	228	224	232	215	166	204	240	188	186	**205**
100	221	178	192	197	290	189	260	246	231	226	218	225	247	197	223	**223**
150	235	334	314	294	273	237	260	257	226	207	256	230	245	259	277	**260**
200	275	250	218	247	224	323	342	296	150	227	244	207	216	267	268	**250**
$\bar{X}$	221	218	213		235	218	263		191	208	202		216	215	226	
$\bar{X}$ $\bar{X}$				217				239				201				

†History 1 = sweet corn/Austrian winter pea/sweet corn/sweet corn/Austrian winter pea/sweet corn.
History 2 = cowpea/Austrian winter pea/sweet corn/lima bean/Austrian winter pea/sweet corn.
History 3 = sunn hemp/Austrian winter pea/sweet corn/sunn hemp/Austrian winter pea/sweet corn.
‡LP = lupine; VT = vetch; AN = ammonium nitrate.

N rates (highlighted) significant at $p \leq 0.05$ with LSD = 41.

Table 6-10. Sweet corn ear (10.2–12.7 cm in length) yield for three cropping histories, three sources of nitrogen, and five nitrogen rates in 2003.

	Cropping history 1†				Cropping history 2				Cropping history 3				Cropping history $\bar{X}$			
	——N source——				——N source——				——N source——				——N source——			
N rate	LP‡	VT	AN	$\bar{X}$	LP	VT	AN	$\bar{X}$	LP	VT	AN	$\bar{X}$	LP	VT	AN	$\bar{X}$
Kg ha^{-1}	——Ear weight, g m^{-2} (Ears 10.2–12.7 cm)——															
0	108	66	139	104	112	146	148	135	196	134	75	135	138	115	121	125
50	149	99	67	105	158	148	156	154	211	144	111	155	173	130	111	138
150	122	125	123	124	121	174	115	137	139	114	115	122	127	138	118	127
100	99	123	113	111	110	168	96	125	63	71	86	73	91	120	98	103
200	143	97	89	110	126	129	140	132	76	87	74	79	115	104	101	107
$\bar{X}$	124	102	106		125	153	131		137	110	92		129	122	110	
$\bar{X}$ $\bar{X}$				111				137				113				

†History 1 = sweet corn/Austrian winter pea/sweet corn/sweet corn/Austrian winter pea/sweet corn.
History 2 = cowpea/Austrian winter pea/sweet corn/lima bean/Austrian winter pea/sweet corn.
History 3 = sunn hemp/Austrian winter pea/sweet corn/sunn hemp/Austrian winter pea/sweet corn.
‡LP = lupine; VT = vetch; AN = ammonium nitrate.

Table 6-11. Sweet corn ear (<10.2 cm in length) yield for three cropping histories, three sources of nitrogen, and five nitrogen rates in 2003.

	Cropping history 1†				Cropping history 2				Cropping history 3				Cropping history $\overline{X}$			
	——N source——				——N source——				——N source——				——N source——			
N rate	LP‡	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$
Kg ha^{-1}	Ear weight, g m^{-2} (Ears <10.2 cm)															
0	89	99	108	**99**	128	155	107	**130**	97	130	97	**108**	105	128	104	112
50	89	87	41	**72**	190	250	132	**191**	62	141	79	**94**	114	159	84	118
100	56	29	69	**51**	130	94	72	**98**	28	61	52	**47**	71	61	64	66
150	61	67	62	**63**	129	125	111	**122**	31	55	37	**41**	73	82	70	75
200	41	50	43	**45**	90	63	69	**74**	60	79	41	**60**	63	64	51	60
$\overline{X}$	67	66	65		133	137	98		55	93	61		**85**	**99**	**75**	
$\overline{X}$ $\overline{X}$				66				123				70				

†History 1 = sweet corn/Austrian winter pea/sweet corn/sweet corn/Austrian winter pea/sweet corn.
History 2 = cowpea/Austrian winter pea/sweet corn/lima bean/Austrian winter pea/sweet corn.
History 3 = sunn hemp/Austrian winter pea/sweet corn/sunn hemp/Austrian winter pea/sweet corn.
‡LP = lupine; VT = vetch; AN = ammonium nitrate.

N source (highlighted) significant at $p \leq 0.05$ with LSD = 18.
Cropping history x N rate (highlighted) significant at $p \leq 0.05$. Differences among cropping histories within N rates were different at $p \leq 0.05$ with LSD = 41. Differences among N rates within cropping histories were different at $p \leq 0.05$ with LSD = 42.

Table 6-12. Total sweet corn ear yield for three cropping histories, three sources of nitrogen, and five nitrogen rates in 2003.

	Cropping history 1†				Cropping history 2				Cropping history 3				Cropping history $\overline{X}$			
	——N source——				——N source——				——N source——				——N source——			
N rate	LP‡	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$
Kg ha^{-1}	Ear weight, g m^{-2} (Ears total)															
0	663	461	656	593	693	728	887	770	551	569	384	501	636	586	642	**621**
50	937	609	709	572	1015	983	1241	1080	762	735	781	759	905	776	910	**864**
100	786	746	866	800	1011	1097	1364	1157	802	787	1268	852	866	877	1166	**970**
150	1031	1043	1088	1054	1205	1217	1471	1298	803	844	1082	910	1013	1035	1214	**1087**
200	995	941	1431	1123	1267	1180	1582	1343	1072	1021	1146	1080	1111	1048	1387	**1182**
$\overline{X}$	882	760	950		1039	1042	1309		798	791	932		**906**	**864**	**1064**	
$\overline{X}$ $\overline{X}$				864				1130				840				

†History 1 = sweet corn/Austrian winter pea/sweet corn/sweet corn/Austrian winter pea/sweet corn.
History 2 = cowpea/Austrian winter pea/sweet corn/lima bean/Austrian winter pea/sweet corn.
History 3 = sunn hemp/Austrian winter pea/sweet corn/sunn hemp/Austrian winter pea/sweet corn.
‡LP = lupine; VT = vetch; AN = ammonium nitrate.

N source (highlighted) significant at $p \leq 0.05$ with LSD = 306.
N rate (highlighted) significant at $p \leq 0.05$ with LSD = 105.

Table 6-13. Diagnostic leaf (5th leaf from top) area for three cropping histories, three sources of nitrogen, and five nitrogen rates in 2003.

	Cropping history 1†				Cropping history 2				Cropping history 3				Cropping history $\overline{X}$			
	—N source—				—N source—				—N source—				—N source—			
N rate	LP‡	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$
Kg ha^{-1}	—Fifth leaf area leaf^{-1} (cm^2)—															
0	426	465	480	457	523	559	555	546	483	487	480	483	477	504	505	**496**
50	485	485	461	477	570	582	613	588	528	535	498	521	528	534	523	**529**
100	545	506	480	510	621	580	676	626	545	524	574	548	571	536	577	**561**
150	547	519	528	531	677	639	638	652	513	517	539	523	579	559	568	**569**
200	533	526	534	534	616	618	645	626	545	555	566	556	565	566	585	**572**
$\overline{X}$	507	500	498		602	596	625		523	523	531		544	540	552	
$\overline{X}$ $\overline{X}$				**502**				**608**				**526**				

†History 1 = sweet corn/Austrian winter pea/sweet corn/sweet corn/Austrian winter pea/sweet corn.
History 2 = cowpea/Austrian winter pea/sweet corn/lima bean/Austrian winter pea/sweet corn.
History 3 = sunn hemp/Austrian winter pea/sweet corn/sunn hemp/Austrian winter pea/sweet corn.
‡LP = lupine; VT = vetch; AN = ammonium nitrate.

Cropping history (highlighted) significant at $p \leq 0.05$ with LSD = 59.
N rate (highlighted) significant at $p \leq 0.05$ with LSD = 23.

Table 6-14. Diagnostic leaf (5th leaf from top) weight for three cropping histories, three sources of nitrogen, and five nitrogen rates in 2003.

	Cropping history 1†				Cropping history 2				Cropping history 3				Cropping history $\bar{X}$			
	N source				N source				N source				N source			
N rate	LP‡	VT	AN	$\bar{X}$	LP	VT	AN	$\bar{X}$	LP	VT	AN	$\bar{X}$	LP	VT	AN	$\bar{X}$
Kg ha^{-1}	Fifth leaf dry weight leaf^{-1} (g)															
0	14.4	16.1	16.4	15.6	18.8	19.0	18.8	18.9	17.6	16.5	16.8	17.0	16.9	17.2	17.3	**17.1**
50	17.0	16.6	16.3	16.6	19.9	20.6	22.3	20.9	18.1	18.5	17.6	18.1	18.3	18.6	18.7	**18.5**
100	18.5	17.7	17.3	17.8	21.8	20.7	22.4	21.6	18.7	18.5	20.7	19.3	19.6	19.0	20.1	**19.6**
150	19.0	17.8	18.6	18.5	22.5	22.8	23.4	22.9	18.2	18.5	19.3	18.7	19.9	19.7	20.4	**20.0**
200	19.8	19.4	19.2	19.5	21.9	21.8	23.3	22.3	18.4	20.0	20.4	19.6	20.1	20.4	21.0	**20.5**
$\bar{X}$	17.7	17.5	17.6		21.0	21.0	22.0		18.2	18.4	19.0		19.0	19.0	19.5	
$\bar{X}$ $\bar{X}$				**17.6**				**21.3**				**18.5**				

†History 1 = sweet corn/Austrian winter pea/sweet corn/sweet corn/Austrian winter pea/sweet corn.
History 2 = cowpea/Austrian winter pea/sweet corn/lima bean/Austrian winter pea/sweet corn.
History 3 = sunn hemp/Austrian winter pea/sweet corn/sunn hemp/Austrian winter pea/sweet corn.
‡LP = lupine; VT = vetch; AN = ammonium nitrate.

Cropping history (highlighted) significant at $p \leq 0.05$ with LSD = 2.1.
N rates (highlighted) significant at $p \leq 0.05$ with LSD = 0.9.

Table 6-15. Nitrogen concentration of diagnostic leaf (5th leaf from top) for three cropping histories, three sources of nitrogen, and five nitrogen rates in 2003.

	Cropping history 1†				Cropping history 2				Cropping history 3				Cropping history $\bar{X}$			
	——N source——				——N source——				——N source——				——N source——			
N rate	LP‡	VT	AN	$\bar{X}$	LP	VT	AN	$\bar{X}$	LP	VT	AN	$\bar{X}$	LP	VT	AN	$\bar{X}$
Kg ha^{-1}	——N concentration in fifth leaf (g kg^{-1})——															
0	16.2	16.9	17.2	16.8	14.7	15.6	14.9	15.1	16.1	14.1	16.6	15.6	15.7	15.5	16.3	**15.8**
60	17.4	17.3	19.7	18.1	16.7	15.4	18.8	17.0	18.1	16.0	19.2	17.8	17.4	16.2	19.2	**17.6**
120	19.8	21.2	22.0	21.0	18.3	18.1	21.6	19.3	19.6	20.9	23.1	21.2	19.2	20.0	22.2	**20.5**
180	21.4	20.4	22.7	21.5	20.9	19.6	23.7	21.4	21.4	24.0	22.3	22.6	21.3	21.3	22.9	**21.8**
240	21.8	21.8	25.0	22.9	21.0	21.0	23.1	21.7	23.7	22.5	23.1	23.1	22.2	21.8	23.7	**22.6**
$\bar{X}$	19.3	19.5	21.3		18.3	17.9	20.4		19.8	19.5	20.9		**19.1**	**19.0**	**20.9**	
$\bar{X}$ $\bar{X}$				20.1				18.9				20.1				

†History 1 = sweet corn/Austrian winter pea/sweet corn/sweet corn/Austrian winter pea/sweet corn.
History 2 = cowpea/Austrian winter pea/sweet corn/lima bean/Austrian winter pea/sweet corn.
History 3 = sunn hemp/Austrian winter pea/sweet corn/sunn hemp/Austrian winter pea/sweet corn.
‡LP = lupine; VT = vetch; AN = ammonium nitrate.

N source (highlighted) significant at $p \leq 0.05$ with LSD = 1.0.
N rate (highlighted) significant at $p \leq 0.05$ with LSD = 1.0.

Table 6-16. Phosphorus concentration of diagnostic leaf (5th leaf from top) for three cropping histories, three sources of nitrogen, and five nitrogen rates in 2003.

	Cropping history 1†				Cropping history 2				Cropping history 3				Cropping history $\overline{X}$			
	——N source——				——N source——				——N source——				——N source——			
N rate	LP‡	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$
Kg ha^{-1}	P concentration in fifth leaf (g kg^{-1})															
0	4.49	4.09	4.44	**4.34**	4.57	4.40	4.28	**4.42**	3.92	3.47	3.85	**3.75**	4.33	3.99	4.19	4.16
50	4.41	4.19	4.34	**4.31**	4.22	4.19	4.46	**4.29**	3.92	3.40	3.72	**3.68**	4.18	3.93	4.17	4.09
100	4.26	4.11	4.35	**4.24**	4.41	4.47	4.60	**4.49**	3.91	3.86	3.89	**3.89**	4.19	4.15	4.28	4.21
150	4.36	4.12	4.28	**4.25**	4.43	4.37	4.67	**4.49**	3.89	4.14	3.95	**3.99**	4.23	4.21	4.30	4.24
200	4.34	4.24	3.88	**4.15**	4.36	4.33	4.64	**4.44**	3.89	3.87	3.95	**3.90**	4.19	4.15	4.16	4.17
$\overline{X}$	4.37	4.15	4.26		4.40	4.35	4.53		3.91	3.75	3.87		**4.22**	**4.08**	**4.22**	
$\overline{X}$ $\overline{X}$				4.26				4.43				3.84				

†History 1 = sweet corn/Austrian winter pea/sweet corn/sweet corn/Austrian winter pea/sweet corn.
History 2 = cowpea/Austrian winter pea/sweet corn/lima bean/Austrian winter pea/sweet corn.
History 3 = sunn hemp/Austrian winter pea/sweet corn/sunn hemp/Austrian winter pea/sweet corn.
‡LP = lupine; VT = vetch; AN = ammonium nitrate.

N sources (highlighted) significant at $p \leq 0.05$ with LSD = 0.23.
Cropping history x N rate (highlighted) significant at $p \leq 0.05$. Differences among cropping histories within N rates were different at $p \leq 0.05$ with LSD = 0.33. Differences among N rates within cropping histories different at $p \leq 0.05$ with LSD = 0.18.

Table 6-17. Potassium concentration of diagnostic leaf (5th leaf from top) for three cropping histories, three sources of nitrogen, and five nitrogen rates in 2003.

	Cropping history 1†				Cropping history 2				Cropping history 3				Cropping history $\bar{X}$			
	——N source——				——N source——				——N source——				——N source——			
N rate	LP‡	VT	AN	$\bar{X}$	LP	VT	AN	$\bar{X}$	LP	VT	AN	$\bar{X}$	LP	VT	AN	$\bar{X}$
Kg ha^{-1}	——K concentration in fifth leaf (g kg^{-1})——															
0	29.2	27.5	27.5	28.1	27.6	27.3	25.4	26.8	25.3	24.0	24.9	24.7	**27.4**	**26.3**	**25.9**	26.5
50	29.2	28.2	28.3	28.6	26.3	27.9	26.7	27.0	26.3	25.9	26.0	26.1	**27.3**	**27.3**	**27.0**	27.2
100	30.5	30.9	27.1	29.6	28.9	29.1	27.0	28.3	26.1	26.4	24.4	25.6	**28.5**	**28.8**	**26.2**	27.8
150	29.8	31.8	27.9	29.9	27.8	29.7	25.5	27.7	26.6	29.0	24.2	26.6	**28.1**	**30.1**	**25.9**	28.0
200	30.7	31.0	26.7	29.5	30.7	30.6	26.8	29.4	28.2	26.5	23.6	26.1	**29.9**	**29.3**	**25.7**	28.3
$\bar{X}$	29.9	29.9	27.5		28.3	28.9	26.3		26.5	26.4	24.6		28.2	28.4	26.1	
$\bar{X}$ $\bar{X}$				**29.1**				**27.8**				**25.8**				

†History 1 = sweet corn/Austrian winter pea/sweet corn/sweet corn/Austrian winter pea/sweet corn.
History 2 = cowpea/Austrian winter pea/sweet corn/lima bean/Austrian winter pea/sweet corn.
History 3 = sunn hemp/Austrian winter pea/sweet corn/sunn hemp/Austrian winter pea/sweet corn.
‡LP = lupine; VT = vetch; AN = ammonium nitrate.

Cropping history (highlighted) significant at $p \leq 0.05$ with LSD = 1.1.
N source x N rate (highlighted) significant at $p \leq 0.05$. Differences among N sources within N rates were different at $p \leq 0.05$ with LSD = 1.2. Differences among N rates within N sources were different at $p \leq 0.05$ with LSD = 0.05.

Table 6-18. Soil analysis for three cropping histories and three nitrogen sources in 2003.

N source	History 1†	History 2	History 3	$\overline{X}$
	Mineral concentration, mg kg^{-1}			
		N		
Lupine	541	719	503	588
Vetch	494	715	491	567
Amm. Nitrate	473	661	491	542
$\overline{X}$	**503**	**699**	**495**	
Cropping history (highlighted) significant at $p \leq 0.05$ with LSD = 117.				
		P		
Lupine	61	150	71	94
Vetch	48	156	79	94
Amm. Nitrate	56	154	57	89
$\overline{X}$	**55**	**153**	**69**	
Cropping history (highlighted) significant at $p \leq 0.05$ with LSD = 46.				
		K		
Lupine	52	77	56	**61**
Vetch	55	79	53	**62**
Amm. Nitrate	43	65	48	**52**
$\overline{X}$	**50**	**73**	**52**	
Cropping history (highlighted) significant at $p \leq 0.05$ with LSD = 21. N source (highlighted) significant at $p \leq 0.05$ with LSD = 7.				
		Ca		
Lupine	641	1710	1098	1150
Vetch	610	1734	1189	1178
Amm. Nitrate	727	1660	927	1105
$\overline{X}$	**660**	**1701**	**1071**	
Cropping history (highlighted) significant at $p \leq 0.05$ with LSD = 371.				
		Mg		
Lupine	41	58	41	47
Vetch	40	58	41	46
Amm. Nitrate	38	58	40	45
$\overline{X}$	**40**	**58**	**41**	
Cropping history (highlighted) significant at $p \leq 0.05$ with LSD = 11.				
		pH		
Lupine	**6.2**	**7.0**	**6.9**	6.7
Vetch	**6.3**	**7.0**	**7.0**	6.8
Amm. Nitrate	**6.5**	**7.0**	**6.8**	6.8
$\overline{X}$	6.3	7.0	6.9	

Cropping history x N source (highlighted) significant at $p \leq 0.05$. Differences among cropping histories within N sources different at $p \leq 0.05$ with LSD = 0.28. Differences among N sources with cropping histories different at $p \leq 0.05$ with LSD = 0.20.

Table 6-18. Continued.

N source	History 1†	History 2	History 3	$\overline{X}$
	OM, g kg^{-1}			
Lupine	13.7	16.1	16.6	15.5
Vetch	14.0	17.1	16.5	15.9
Amm. Nitrate	13.6	17.6	16.0	15.7
$\overline{X}$	**13.8**	**16.9**	**16.4**	
Cropping history (highlighted) significant at $p \leq 0.05$ with LSD = 0.13.				
	CEC, cmol kg^{-1}			
Lupine	4.97	10.24	6.75	7.32
Vetch	4.53	10.18	7.10	7.27
Amm. Nitrate	5.25	9.97	5.98	7.07
$\overline{X}$	**4.92**	**10.13**	**6.61**	
Cropping history (highlighted) significant at $p \leq 0.05$ with LSD = 2.0.				

†History 1 = sweet corn/Austrian winter pea/sweet corn/sweet corn/Austrian winter pea/sweet corn.

History 2 = cowpea/Austrian winter pea/sweet corn/lima bean/Austrian winter pea/sweet Corn.

History 3 = sunn hemp/Austrian winter pea/sweet corn/sunn hemp/Austrian winter pea/sweet corn.

Table 6-19. Sweet corn ears (>15.2 cm in length) produced for three cropping histories, three sources of nitrogen, and five nitrogen rates in 2004.

	Cropping history 1†				Cropping history 2				Cropping history 3				Cropping history $\overline{X}$			
	N source				N source				N source				N source			
N rate	LP‡	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$
Kg ha^{-1}	Number of ears >15.2 cm m^{-2}															
0	1.82	1.04	1.52	1.46	1.66	2.16	2.16	1.99	1.70	1.94	2.78	2.14	1.73	1.71	2.15	**1.86**
60	1.68	1.92	1.74	1.78	2.32	2.66	2.72	2.57	2.06	1.84	2.48	2.13	2.02	2.14	2.31	**2.16**
120	1.58	2.04	3.04	2.22	2.60	2.64	3.38	2.87	2.66	2.30	3.86	2.94	2.28	2.33	3.43	**2.68**
180	2.28	2.42	3.08	2.59	2.50	2.72	3.26	2.83	2.86	2.68	4.64	3.39	2.55	2.61	3.66	**2.94**
240	2.34	2.52	3.76	2.87	3.48	3.44	4.46	3.79	2.72	3.30	5.52	3.51	2.85	3.09	4.25	**3.39**
$\overline{X}$	1.94	1.99	2.63		2.51	2.72	3.20		2.40	2.41	3.66		**2.28**	**2.38**	**3.16**	
$\overline{X}$ $\overline{X}$				2.19				2.81				2.82				

†History 1 = sweet corn/Austrian winter pea/sweet corn/sweet corn/Austrian winter pea/sweet corn.
History 2 = cowpea/Austrian winter pea/sweet corn/lima bean/Austrian winter pea/sweet corn.
History 3 = sunn hemp/Austrian winter pea/sweet corn/sunn hemp/Austrian winter pea/sweet corn.
‡LP = lupine; VT = vetch; AN = ammonium nitrate.

N source (highlighted) significant at $p \leq 0.05$ with LSD = 0.36.
N rate (highlighted) significant at $p \leq 0.05$ with LSD = 0.34.

Table 6-20. Sweet corn ears (12.7–15.2 cm in length) produced for three cropping histories, three sources of nitrogen, and five nitrogen rates in 2004.

	Cropping history 1†				Cropping history 2				Cropping history 3				Cropping history $\overline{X}$			
	——N source——				——N source——				——N source——				——N source——			
N rate	LP‡	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$
Kg ha^{-1}	——Number of ears, 12.7–15.2 cm m^{-2}——															
0	1.34	1.24	1.66	1.41	0.96	1.32	1.02	1.10	1.08	0.88	0.80	0.92	1.13	1.15	1.16	1.14
60	1.06	0.92	1.22	1.07	0.80	1.16	1.20	1.05	0.92	0.82	1.22	0.99	0.93	0.97	1.21	1.04
120	1.26	1.26	1.10	1.21	0.76	0.94	1.22	0.97	0.92	0.90	1.02	0.95	0.98	1.03	1.11	1.04
180	1.18	1.08	1.44	1.23	0.98	0.84	1.14	0.99	1.42	1.02	0.94	1.13	1.19	0.98	1.17	1.12
240	1.54	1.10	1.06	1.23	1.04	1.20	1.54	1.26	0.84	0.66	1.00	0.83	1.14	0.99	1.20	1.11
$\overline{X}$	1.28	1.12	1.30		0.91	1.09	1.22		1.04	0.86	1.00		1.07	1.02	1.17	
$\overline{X}$ $\overline{X}$				**1.23**				**1.08**				**0.96**				

†History 1 = sweet corn/Austrian winter pea/sweet corn/sweet corn/Austrian winter pea/sweet corn.
History 2 = cowpea/Austrian winter pea/sweet corn/lima bean/Austrian winter pea/sweet corn.
History 3 = sunn hemp/Austrian winter pea/sweet corn/sunn hemp/Austrian winter pea/sweet corn.
‡LP = lupine; VT = vetch; AN = ammonium nitrate.

Cropping history (highlighted) significant at $p \leq 0.05$ with LSD = 0.20.

Table 6-21. Sweet corn ears (10.2–12.7 cm in length) produced for three cropping histories, three sources of nitrogen, and five nitrogen rates in 2004.

	Cropping history 1†				Cropping history 2				Cropping history 3				Cropping history $\overline{X}$			
	——N source——				——N source——				——N source——				——N source——			
N rate	LP‡	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$
Kg ha^{-1}	——Number of ears, 10.2–12.7 cm, m^{-2}——															
0	0.98	0.86	0.90	0.91	0.62	0.78	0.96	0.79	0.62	0.82	0.70	0.71	0.74	0.82	0.85	0.80
60	0.64	0.84	0.84	0.77	0.76	0.46	0.68	0.63	0.52	0.86	0.84	0.74	0.64	0.72	0.79	0.71
120	0.74	0.76	0.88	0.79	0.58	0.74	0.70	0.67	0.70	0.50	0.48	0.56	0.67	0.67	0.68	0.68
180	0.66	0.52	0.38	0.52	0.62	0.70	0.70	0.67	1.02	0.64	0.46	0.71	0.77	0.62	0.51	0.63
240	0.78	0.74	0.74	0.75	0.50	0.74	0.72	0.65	0.28	0.60	0.60	0.49	0.52	0.69	0.69	0.63
$\overline{X}$	0.76	0.74	0.75		0.62	0.68	0.75		0.63	0.68	0.62		0.67	0.70	0.71	
$\overline{X}$ $\overline{X}$				0.75				0.68				0.64				

†History 1 = sweet corn/Austrian winter pea/sweet corn/sweet corn/Austrian winter pea/sweet corn.
History 2 = cowpea/Austrian winter pea/sweet corn/lima bean/Austrian winter pea/sweet corn.
History 3 = sunn hemp/Austrian winter pea/sweet corn/sunn hemp/Austrian winter pea/sweet corn.
‡LP = lupine; VT = vetch; AN = ammonium nitrate.

Table 6-22. Sweet corn ears (<10.2 cm in length) produced for three cropping histories, three sources of nitrogen, and five nitrogen rates in 2004.

	Cropping history 1†				Cropping history 2				Cropping history 3				Cropping history $\overline{X}$			
	——N source——				——N source——				——N source——				——N source——			
N rate	LP‡	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$
Kg ha^{-1}	——Number of ears, <10.2 cm, m^{-2}——															
0	1.30	1.36	1.50	1.39	1.80	1.28	1.18	1.42	1.64	1.96	1.78	1.79	1.58	1.53	1.49	**1.53**
60	1.56	1.40	1.10	1.35	1.08	1.20	1.16	1.15	1.66	1.86	0.94	1.49	1.43	1.49	1.07	**1.33**
120	1.14	1.44	0.92	1.17	0.90	0.52	0.56	0.66	1.54	1.78	0.76	1.36	1.19	1.25	0.75	**1.06**
180	0.26	1.06	0.86	0.73	0.74	0.96	0.70	0.80	0.98	1.14	0.44	0.85	0.66	1.05	0.67	**0.79**
240	0.50	0.84	0.90	0.75	0.70	0.86	0.68	0.75	1.32	0.80	0.34	0.82	0.84	0.83	0.64	**0.77**
$\overline{X}$	0.95	1.22	1.06		1.04	0.96	0.86		1.43	1.51	0.85		1.14	1.23	0.92	
$\overline{X}$ $\overline{X}$				1.08				0.96				1.26				

†History 1 = sweet corn/Austrian winter pea/sweet corn/sweet corn/Austrian winter pea/sweet corn.
History 2 = cowpea/Austrian winter pea/sweet corn/lima bean/Austrian winter pea/sweet corn.
History 3 = sunn hemp/Austrian winter pea/sweet corn/sunn hemp/Austrian winter pea/sweet corn.
‡LP = lupine; VT = vetch; AN = ammonium nitrate.

N source (highlighted) significant at $p \leq 0.05$ with LSD = 0.07.

Table 6-23. Total sweet corn ears produced for three cropping histories, three sources of nitrogen, and five nitrogen rates in 2004.

	Cropping history 1†				Cropping history 2				Cropping history 3				Cropping history $\bar{X}$			
	——N source——				——N source——				——N source——				——N source——			
N rate	LP‡	VT	AN	$\bar{X}$	LP	VT	AN	$\bar{X}$	LP	VT	AN	$\bar{X}$	LP	VT	AN	$\bar{X}$
Kg ha^{-1}	——Number of ears, total, m^{-2}——															
0	5.42	4.50	5.60	**5.17**	5.06	5.56	5.34	**5.32**	5.08	5.58	6.06	**5.57**	5.19	5.21	5.67	5.36
60	4.98	5.04	4.92	**4.98**	4.94	5.48	5.80	**5.41**	5.20	5.40	5.46	**5.35**	5.04	5.31	5.39	5.25
120	4.72	5.52	5.94	**5.39**	4.82	4.82	5.88	**5.17**	5.84	5.46	6.12	**5.81**	5.13	5.27	5.98	5.46
180	4.40	5.10	5.74	**5.08**	4.78	5.24	5.78	**5.27**	6.32	5.42	6.50	**6.08**	5.17	5.25	6.01	5.48
240	5.14	5.22	6.50	**5.62**	5.72	6.24	7.42	**6.46**	5.12	5.36	6.46	**5.65**	5.33	5.61	6.79	5.91
$\bar{X}$	4.93	7.08	5.74		5.06	5.47	6.04		5.51	5.44	6.12		**5.17**	**5.33**	**5.97**	
$\bar{X}$ $\bar{X}$				5.25				5.53				5.69				

†History 1 = sweet corn/Austrian winter pea/sweet corn/sweet corn/Austrian winter pea/sweet corn.
History 2 = cowpea/Austrian winter pea/sweet corn/lima bean/Austrian winter pea/sweet corn.
History 3 = sunn hemp/Austrian winter pea/sweet corn/sunn hemp/Austrian winter pea/sweet corn.
‡LP = lupine; VT = vetch; AN = ammonium nitrate.

N source (highlighted) significant at $p \leq 0.05$ with LSD = 0.40.
Cropping history x N rate (highlighted) significant at $p \leq 0.05$. Differences among cropping histories within N rates different at $p \leq 0.05$ with LSD = 0.77. Differences among N rates within cropping histories different at $p \leq 0.05$ with LSD = 0.55.

Table 6-24. Sweet corn ear (>15.2 cm in length) yield for three cropping histories, three sources of nitrogen, and five nitrogen rates in 2004.

	Cropping history 1†				Cropping history 2				Cropping history 3				Cropping history $\overline{X}$			
	——N source——				——N source——				——N source——				——N source——			
N rate	LP‡	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$
Kg ha^{-1}	——Ear weight, g m^{-2} (Ears >15.2 cm) ——															
0	474	216	364	351	404	504	514	474	438	435	553	475	439	385	477	**433**
60	396	423	431	417	560	648	664	624	523	433	605	520	493	501	567	**520**
120	367	497	732	532	639	674	811	708	697	592	1011	766	568	588	851	**669**
180	580	560	564	568	692	741	787	740	727	702	1308	913	666	668	887	**740**
240	453	605	911	565	937	932	1227	1032	705	882	1247	645	699	806	1128	**878**
$\overline{X}$	454	460	600		646	700	801		618	609	945		**573**	**590**	**782**	
$\overline{X}$ $\overline{X}$				504				716				724				

†History 1 = sweet corn/Austrian winter pea/sweet corn/sweet corn/Austrian winter pea/sweet corn.
History 2 = cowpea/Austrian winter pea/sweet corn/lima bean/Austrian winter pea/sweet corn.
History 3 = sunn hemp/Austrian winter pea/sweet corn/sunn hemp/Austrian winter pea/sweet corn.
‡LP = lupine; VT = vetch; AN = ammonium nitrate.

N source (highlighted) significant at $p \leq 0.05$ with LSD = 96.
N rate (highlighted) significant at $p \leq 0.05$ with LSD = 105.

Table 6-25. Sweet corn ear (12.7–15.2 cm in length) yield for three cropping histories, three sources of nitrogen, and five nitrogen rates in 2004.

	Cropping history 1†				Cropping history 2				Cropping history 3				Cropping history $\overline{X}$			
	——N source——				——N source——				——N source——				——N source——			
N rate	LP‡	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$
Kg ha^{-1}	——Ear weight, g m^{-2} (Ears 12.7–15.2 cm)——															
0	174	161	228	188	135	199	146	160	161	122	120	135	157	161	165	161
60	166	108	189	155	117	179	176	157	136	111	176	141	140	133	180	151
120	182	181	144	169	117	133	194	148	150	145	161	152	150	153	166	156
180	167	136	190	164	171	128	169	156	218	154	135	169	185	139	164	163
240	206	155	144	168	165	173	245	194	124	99	159	127	165	142	182	163
$\overline{X}$	179	148	179		141	162	186		158	126	150		159	146	172	
$\overline{X}$ $\overline{X}$				169				163				145				

†History 1 = sweet corn/Austrian winter pea/sweet corn/sweet corn/Austrian winter pea/sweet corn.
History 2 = cowpea/Austrian winter pea/sweet corn/lima bean/Austrian winter pea/sweet corn.
History 3 = sunn hemp/Austrian winter pea/sweet corn/sunn hemp/Austrian winter pea/sweet corn.
‡LP = lupine; VT = vetch; AN = ammonium nitrate.

Table 6-26. Sweet corn ear (10.2–12.7 cm in length) yield for three cropping histories, three sources of nitrogen, and five nitrogen rates in 2004.

	Cropping history 1†				Cropping history 2				Cropping history 3				Cropping history $\overline{X}$			
	——N source——				——N source——				——N source——				——N source——			
N rate	LP‡	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$
Kg ha^{-1}	——Ear weight, g m^{-2} (Ears 10.2–12.7 cm)——															
0	102	90	85	92	66	97	97	87	74	86	79	80	81	91	87	86
60	157	79	80	105	87	50	73	70	60	96	98	85	101	75	84	86
120	136	266	83	162	64	76	83	74	82	58	52	64	94	133	73	100
180	65	47	41	51	59	82	76	72	118	73	52	81	81	68	57	68
240	68	74	74	72	56	88	86	77	33	67	63	54	52	76	75	68
$\overline{X}$	106	111	73		66	79	83		73	76	69		82	89	75	
$\overline{X}$ $\overline{X}$				97				76				73				

†History 1 = sweet corn/Austrian winter pea/sweet corn/sweet corn/Austrian winter pea/sweet corn.
History 2 = cowpea/Austrian winter pea/sweet corn/lima bean/Austrian winter pea/sweet corn.
History 3 = sunn hemp/Austrian winter pea/sweet corn/sunn hemp/Austrian winter pea/sweet corn.
‡LP = lupine; VT = vetch; AN = ammonium nitrate.

Table 6-27. Sweet corn ear (<10.2 cm in length) yield for three cropping histories, three sources of nitrogen, and five nitrogen rates in 2004.

	Cropping history 1†				Cropping history 2				Cropping history 3				Cropping history $\overline{X}$			
	——N source——				——N source——				——N source——				——N source——			
N rate	LP‡	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$
Kg ha^{-1}	——Ear weight, g m^{-2} (Ears <10.2 cm)——															
0	80	62	90	77	119	91	72	94	88	133	118	113	96	95	93	**95**
60	87	86	63	79	63	85	83	77	117	121	65	101	89	98	71	**86**
120	77	87	52	72	62	37	40	46	98	130	63	97	79	85	52	**72**
180	35	66	50	51	48	64	49	54	68	83	32	61	51	71	44	**55**
240	28	59	51	46	56	71	44	57	99	59	22	60	61	63	39	**54**
$\overline{X}$	61	72	61		69	70	57		94	105	60		**75**	**82**	**60**	
$\overline{X}$ $\overline{X}$				65				66				87				

†History 1 = sweet corn/Austrian winter pea/sweet corn/sweet corn/Austrian winter pea/sweet corn.
History 2 = cowpea/Austrian winter pea/sweet corn/lima bean/Austrian winter pea/sweet corn.
History 3 = sunn hemp/Austrian winter pea/sweet corn/sunn hemp/Austrian winter pea/sweet corn.
‡LP = lupine; VT = vetch; AN = ammonium nitrate.

N source (highlighted) significant at $p \leq 0.05$ with LSD = 15.
N rates (highlighted) significant at $p \leq 0.05$ with LSD = 16.

Table 6-28. Total sweet corn ear yield for three cropping histories, three sources of nitrogen, and five nitrogen rates in 2004.

	Cropping history 1†				Cropping history 2				Cropping history 3				Cropping history $\bar{X}$			
	N source				N source				N source				N source			
N rate	LP‡	VT	AN	$\bar{X}$	LP	VT	AN	$\bar{X}$	LP	VT	AN	$\bar{X}$	LP	VT	AN	$\bar{X}$
Kg ha^{-1}	Ear weight, g m^{-2} (Ears total)															
0	826	529	767	**708**	724	891	828	**814**	761	776	870	**802**	771	732	821	775
60	806	696	763	**755**	827	962	996	**928**	835	760	945	**847**	823	806	901	843
120	762	1031	1011	**935**	882	920	1128	**977**	1026	925	1287	**1079**	890	959	1142	997
180	847	809	845	**834**	969	1015	1081	**1022**	1132	1011	1528	**1224**	982	945	1151	1026
240	755	893	1179	**942**	1214	1263	1602	**1360**	962	1107	1491	**1187**	977	1088	1424	1163
$\bar{X}$	800	792	913		923	1010	1127		943	916	1124		**889**	**906**	**1088**	
$\bar{X}$ $\bar{X}$				835				1020				1028				

†History 1 = sweet corn/Austrian winter pea/sweet corn/sweet corn/Austrian winter pea/sweet corn.
History 2 = cowpea/Austrian winter pea/sweet corn/lima bean/Austrian winter pea/sweet corn.
History 3 = sunn hemp/Austrian winter pea/sweet corn/sunn hemp/Austrian winter pea/sweet corn.
‡LP = lupine; VT = vetch; AN = ammonium nitrate.

N source (highlighted) significant at $p \leq 0.05$ with LSD = 87.
Cropping history x N rate (highlighted) significant at $p \leq 0.05$. Differences among cropping histories within N rates different at $p \leq 0.05$ with LSD = 285. Differences among N rates within cropping histories different at $p \leq 0.05$ with LSD = 172.

Table 6-29. Diagnostic leaf (5th leaf from top) area for three cropping histories, three sources of nitrogen, and five nitrogen rates in 2004.

	Cropping history 1†				Cropping history 2				Cropping history 3				Cropping history $\overline{X}$			
	N source				N source				N source				N source			
N rate	LP‡	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$
Kg ha^{-1}	Fifth leaf area leaf^{-1} (cm^3)															
0	574	395	408	459	445	484	477	469	461	476	527	488	493	452	471	**472**
60	475	415	465	452	481	524	501	502	521	513	523	519	492	484	497	**491**
120	443	521	482	482	508	514	506	509	525	513	539	526	492	516	509	**506**
180	505	482	484	490	547	537	481	521	543	528	549	540	531	516	505	**517**
240	474	513	470	486	550	631	528	536	532	536	557	542	519	527	518	**521**
$\overline{X}$	494	465	462		506	518	499		517	513	539		506	499	500	
$\overline{X}$ $\overline{X}$				**474**				**508**				**523**				

†History 1 = sweet corn/Austrian winter pea/sweet corn/sweet corn/Austrian winter pea/sweet corn.
History 2 = cowpea/Austrian winter pea/sweet corn/lima bean/Austrian winter pea/sweet corn.
History 3 = sunn hemp/Austrian winter pea/sweet corn/sunn hemp/Austrian winter pea/sweet corn.
‡LP = lupine; VT = vetch; AN = ammonium nitrate.

Cropping history (highlighted) significant at $p \leq 0.05$ with LSD = 34.
N rate (highlighted) significant at $p \leq 0.05$ with LSD = 23.

Table 6-30. Diagnostic leaf (5th leaf from top) weight for three cropping histories, three sources of nitrogen, and five nitrogen rates in 2004.

	Cropping history 1†				Cropping history 2				Cropping history 3				Cropping history $\overline{X}$			
	——N source——				——N source——				——N source——				——N source——			
N rate	LP‡	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$
Kg ha^{-1}	——Fifth leaf dry weight leaf^{-1} (g) ——															
0	13.1	11.4	11.6	12.1	12.9	14.9	14.2	14.0	12.7	15.0	16.8	14.9	13.0	13.8	14.2	**13.6**
60	13.5	12.4	14.9	13.6	14.6	16.2	16.2	15.7	15.8	16.2	16.9	16.3	14.6	14.9	16.0	**15.2**
120	13.6	16.6	14.4	14.8	16.5	16.2	16.7	16.5	16.7	16.7	18.0	17.1	15.6	16.5	16.4	**16.1**
180	15.2	15.6	15.0	15.3	17.4	18.1	16.8	17.5	17.0	18.3	18.1	17.8	16.5	17.3	16.7	**16.8**
240	15.7	15.3	14.3	15.1	18.3	18.1	17.4	18.0	17.8	18.7	18.8	18.5	17.3	17.4	16.9	**17.2**
$\overline{X}$	14.2	14.2	14.0		16.0	16.7	16.3		16.0	17.0	17.7		15.4	16.0	16.0	
$\overline{X}$ $\overline{X}$				**14.2**				**16.3**				**16.9**				

†History 1 = sweet corn/Austrian winter pea/sweet corn/sweet corn/Austrian winter pea/sweet corn.
History 2 = cowpea/Austrian winter pea/sweet corn/lima bean/Austrian winter pea/sweet corn.
History 3 = sunn hemp/Austrian winter pea/sweet corn/sunn hemp/Austrian winter pea/sweet corn.
‡LP = lupine; VT = vetch; AN = ammonium nitrate.

Cropping history (highlighted) significant at $p \leq 0.05$ with LSD = 1.1.
N rate (highlighted) significant at $p \leq 0.05$ with LSD = 0.6.

Table 6-31. Nitrogen concentration of diagnostic leaf (5th leaf from top) for three cropping histories, three sources of nitrogen, and five nitrogen rates in 2004.

N rate	Cropping history 1†				Cropping history 2				Cropping history 3				Cropping history $\overline{X}$			
	N source				N source				N source				N source			
	LP‡	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$
Kg ha^{-1}	N concentration in fifth leaf (g kg^{-1})															
0	18.2	20.6	20.4	**19.8**	17.1	18.9	19.4	**18.5**	18.9	18.7	19.3	**19.0**	**18.1**	**19.4**	**19.7**	19.1
60	18.5	18.8	22.5	**20.0**	21.2	19.7	22.4	**21.1**	19.8	19.0	20.5	**19.8**	**19.8**	**19.2**	**21.8**	20.3
120	18.9	21.3	25.1	**21.8**	23.1	20.7	22.6	**22.1**	19.4	16.0	22.3	**19.2**	**20.5**	**19.3**	**23.3**	21.1
180	20.5	22.5	24.9	**22.6**	31.9	21.9	23.2	**25.6**	20.7	19.6	24.1	**21.4**	**24.3**	**21.3**	**24.1**	23.2
240	21.3	24.1	28.6	**24.7**	18.9	22.7	24.3	**22.0**	21.9	21.6	24.1	**22.5**	**20.7**	**22.8**	**25.7**	23.1
$\overline{X}$	**19.5**	**21.5**	**24.3**		**22.4**	**20.8**	**22.4**		**20.1**	**19.0**	**22.1**		20.7	20.4	22.9	
$\overline{X}$ $\overline{X}$				21.8				21.9				20.4				

†History 1 = sweet corn/Austrian winter pea/sweet corn/sweet corn/Austrian winter pea/sweet corn.
History 2 = cowpea/Austrian winter pea/sweet corn/lima bean/Austrian winter pea/sweet corn.
History 3 = sunn hemp/Austrian winter pea/sweet corn/sunn hemp/Austrian winter pea/sweet corn.
‡LP = lupine; VT = vetch; AN = ammonium nitrate.

Cropping history x N source (highlighted) significant at $p \leq 0.05$. Differences among cropping histories among N sources different at $p \leq 0.05$ with LSD = 2.6. Differences among N sources within cropping histories different at $p \leq 0.05$ with LSD = 2.0.
Cropping history x N rate (highlighted) significant at $p \leq 0.05$. Differences among cropping histories within N rates different at $p \leq 0.05$ with LSD = 3.0. Differences among N rates within cropping histories different at $p \leq 0.05$ with LSD = 2.5.
N source x N rate (highlighted) significant at $p \leq 0.05$. Differences among N sources within N rates different at $p \leq 0.05$ with LSD 2.5. Differences among N rates within N sources different at $p \leq 0.05$ with LSD = 2.5.

Table 6-32. Phosphorus concentration of diagnostic leaf (5th leaf from top) for three cropping histories, three sources of nitrogen, and five nitrogen rates in 2004.

	Cropping history 1†				Cropping history 2				Cropping history 3				Cropping history $\overline{X}$			
	N source				N source				N source				N source			
N rate	LP‡	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$
Kg ha^{-1}	P concentration in fifth leaf (g kg^{-1})															
0	4.2	3.9	4.1	4.0	4.4	4.4	4.5	4.4	3.9	3.7	4.1	3.9	**4.1**	**4.0**	**4.2**	4.1
60	4.0	3.8	4.1	4.0	4.6	4.3	4.3	4.4	4.1	3.7	3.9	3.9	**4.2**	**4.0**	**4.1**	4.1
120	4.3	3.7	3.8	3.9	4.3	4.4	3.9	4.2	3.8	3.9	3.8	3.8	**4.2**	**4.0**	**3.8**	4.0
180	4.0	4.1	3.9	4.0	4.2	4.2	4.1	4.1	3.6	3.9	3.6	3.7	**4.0**	**4.1**	**3.9**	4.0
240	3.9	4.2	3.9	4.0	4.2	4.4	3.9	4.2	3.8	3.7	3.6	3.7	**4.0**	**4.1**	**3.8**	4.0
$\overline{X}$	4.1	3.9	4.0		4.3	4.3	4.1		3.9	3.8	3.8		4.1	4.0	4.0	
$\overline{X}$ $\overline{X}$				**4.0**				**4.3**				**3.8**				

†History 1 = sweet corn/Austrian winter pea/sweet corn/sweet corn/Austrian winter pea/sweet corn.
History 2 = cowpea/Austrian winter pea/sweet corn/lima bean/Austrian winter pea/sweet corn.
History 3 = sunn hemp/Austrian winter pea/sweet corn/sunn hemp/Austrian winter pea/sweet corn.
‡LP = lupine; VT = vetch; AN = ammonium nitrate.

Cropping history (highlighted) significant at $p \leq 0.05$ with LSD = 0.03.
N source x N rate (highlighted) significant at $p \leq 0.05$. Differences among N sources within N rates different at $p \leq 0.05$ with LSD = 0.19. Differences among N rates within N sources different at $p \leq 0.05$ with LSD = 0.20.

Table 6-33. Potassium concentration of diagnostic leaf (5th leaf from top) for three cropping histories, three sources of nitrogen, and five nitrogen rates in 2004.

	Cropping history 1†				Cropping history 2				Cropping history 3				Cropping history $\overline{X}$			
	N source				N source				N source				N source			
N rate	LP‡	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$	LP	VT	AN	$\overline{X}$
Kg ha^{-1}	K concentration in fifth leaf (g kg^{-1})															
0	24.4	25.5	27.5	25.8	28.6	30.5	31.0	30.0	23.6	24.1	26.3	24.6	**25.5**	**26.7**	**28.3**	26.8
60	25.5	28.3	29.6	27.8	33.0	32.3	32.7	32.7	26.8	26.4	27.2	26.8	**28.4**	**29.0**	**29.9**	29.1
120	28.4	27.2	29.7	28.5	33.7	33.9	28.0	31.9	27.7	27.4	26.1	27.0	**29.9**	**29.5**	**27.9**	29.1
180	29.0	33.1	29.5	30.5	34.1	30.9	28.5	31.2	27.4	33.0	25.8	28.7	**30.2**	**32.4**	**27.9**	30.1
240	31.3	32.1	27.5	30.3	37.3	36.5	27.5	33.8	30.6	30.8	23.8	28.4	**33.0**	**33.1**	**26.3**	30.8
$\overline{X}$	27.7	29.2	28.8		33.3	32.8	29.5		27.2	28.3	25.8		29.4	30.1	28.1	
$\overline{X}\ \overline{X}$				**28.6**				**31.9**				**27.1**				

†History 1 = sweet corn/Austrian winter pea/sweet corn/sweet corn/Austrian winter pea/sweet corn.
History 2 = cowpea/Austrian winter pea/sweet corn/lima bean/Austrian winter pea/sweet corn.
History 3 = sunn hemp/Austrian winter pea/sweet corn/sunn hemp/Austrian winter pea/sweet corn.
‡LP = lupine; VT = vetch; AN = ammonium nitrate.

Cropping history (highlighted) significant at $p \leq 0.05$ with LSD = 0.8.
N source x N rate (highlighted) significant at $p \leq 0.05$. Differences among N sources within N rates different at $p \leq 0.05$ with LSD = 2.7. Differences among N rates within N sources different at $p \leq 0.05$ with LSD = 2.6.

Table 6-34. Soil analysis for three cropping histories and three nitrogen sources in 2004.

N source	History 1†	History 2	History 3	$\overline{X}$
	Mineral concentration, mg kg^{-1}			
			N	
Lupine	**468**	**754**	**548**	590
Vetch	**510**	**685**	**541**	579
Amm. nitrate	**469**	**670**	**557**	565
$\overline{X}$	483	703	548	
Cropping history x N source (highlighted) significant at $p \leq 0.05$. Differences among cropping histories within N sources different at $p \leq 0.05$ with LSD = 120. Differences among N sources within cropping histories different at $p \leq 0.05$ with LSD = 58.				
			P	
Lupine	**75**	**155**	**75**	102
Vetch	**74**	**161**	**66**	100
Amm. nitrate	**59**	**181**	**79**	106
$\overline{X}$	69	166	73	
Cropping history x N source (highlighted) significant at $p \leq 0.05$. Differences among cropping histories within N sources different at $p \leq 0.05$ with LSD = 43. Differences among N sources within cropping histories different at $p \leq 0.05$ with LSD = 24.				
			K	
Lupine	47	50	45	47
Vetch	36	48	41	42
Amm. Nitrate	35	51	35	41
$\overline{X}$	39	50	40	
			Ca	
Lupine	705	1501	870	**1025**
Vetch	733	1281	801	**938**
Amm. Nitrate	692	1963	930	**1195**
$\overline{X}$	**710**	**1582**	**867**	
Cropping history (highlighted) significant at $p \leq 0.05$ with LSD = 540. N source (highlighted) significant at $p \leq 0.05$ with LSD = 201.				
			Ma	
Lupine	60	82	65	69
Vetch	53	87	61	67
Amm. Nitrate	53	91	63	69
$\overline{X}$	**55**	**87**	**63**	
Cropping history (highlighted) significant at $p \leq 0.05$ with LSD = 17.				
	pH			
Lupine	6.8	7.3	7.2	**7.1**
Vetch	6.8	7.3	7.2	**7.1**
Amm. Nitrate	7.0	7.2	7.4	**7.2**
$\overline{X}$	**6.9**	**7.3**	**7.3**	
Cropping history (highlighted) significant at $p \leq 0.05$ with LSD = 0.1. N source (highlighted) significant at $p \leq 0.05$ with LSD = <0.1.				

Table 6-34. Continued.

N source	History 1†	History 2	History 3	$\overline{X}$
	OM, g kg^{-1}			
Lupine	**1.24**	**1.59**	**1.45**	1.43
Vetch	**1.30**	**1.67**	**1.51**	1.49
Amm. Nitrate	**1.21**	**1.81**	**1.48**	1.50
$\overline{X}$	1.25	1.69	1.48	
Cropping history x N source (highlighted) significant at $p \leq 0.05$. Differences among cropping histories within N sources different at $p \leq 0.05$ with LSD = 0.15. Differences among N sources within cropping histories different at $p \leq 0.05$ with LSD = 0.12.				
	CEC, cmol kg^{-1}			
Lupine	**5.17**	**9.03**	**6.27**	6.82
Vetch	**5.06**	**7.98**	**5.77**	6.27
Amm. Nitrate	**4.73**	**11.63**	**6.46**	7.61
$\overline{X}$	4.99	9.55	6.17	
Cropping history x N source (highlighted) significant at $p \leq 0.05$. Differences among cropping histories within N sources different at $p \leq 0.05$ with LSD = 3.2. Differences among N sources within cropping histories different at $p \leq 0.05$ with LSD = 1.8.				

†History 1 = sweet corn/Austrian winter pea/sweet corn/sweet corn/Austrian winter pea/sweet corn.

History 2 = cowpea/Austrian winter pea/sweet corn/lima bean/Austrian winter pea/sweet Corn.

History 3 = sunn hemp/Austrian winter pea/sweet corn/sunn hemp/Austrian winter pea/sweet corn.

CHAPTER 7
PLANT-PARASITIC NEMATODE POPULATION CHANGES ASSOCIATED WITH CROPPING HISTORIES

Introduction

One way in which sustainable agriculture can be achieved is by utilizing several available management practices that benefit the environment. Not only can the practice of multiple cropping benefit the environment in improving soil and crop fertility and many other aspects, it can also be a very effective tool in nematode management. The concept of a cropping system is particularly useful in nematode control because it includes not only crop rotation, but also other critical features that can affect nematode populations, such as continuous monoculture, continuous cropping, non-crop periods, season, weeds, and spatial arrangement of crops (McSorley, 2001). Multiple cropping as a means of nematode control is also considered a viable option due to the decline of nematicide-based technologies as of late.

Several plant-parasitic nematodes are serious and endemic problems in the production of many crops grown in the southeastern United States (McSorley and Gallaher, 1991). Root-knot nematodes (*Meloidogyne* spp.) have been identified as the key nematode pests in many cropping systems in north and central Florida (McSorley and Gallaher, 1991). Multiple cropping can aid in reducing nematode numbers, while the limitations of a 1 cover crop rotation cycle are the resurgence of nematode populations at the end of the subsequent crops prone to nematode damage (McSorley, 1999). Nematode populations, particularly plant-parasitic nematodes, will rise or fall in a site depending on the sequence of crops planted (McSorley and Gallaher, 1992). The design of cropping sequences that can minimize plant-parasitic nematode buildup and damage has received increased interest (McSorley and Gallaher, 1992; Noe, 1988) due to the success of rotating crops for the management of nematodes in the southeastern U.S. (Johnson, 1982).

The rotation or sequence of crops in multiple cropping can determine the severity of nematode problems in subsequent crops. Some crops are good hosts to nematodes and can increase populations while others are proven suppressors and can bring numbers down. In order to plan effective and profitable systems, it is very important that the effects of different crops, as well as cropping histories, on the population densities of plant-parasitic nematodes are determined.

Corn (*Zea mays* L.) is an important grain and forage crop adapted to cropping systems in the southeast region of the U.S. (Gallaher and Horner, 1983), therefore its effect on nematode populations is very pertinent information. Cultivars of field, sweet, and tropical corn have been found to be good hosts for many different species of nematodes. In a study conducted in north Florida, plant-parasitic nematode populations, including *M. incognita* (Kofoid & White) Chitwood and *Pratylenchus* spp., increased more than tenfold during the growth period of several corn cultivars (Gallaher et al., 1991). In another experiment that took place in Florida, populations of both *M. incognita* and *Criconemella* spp. nematodes increased greatly on summer crops of corn (McSorley and Gallaher, 1992). Corn, although apparently tolerant of some *M. incognita* infection (McSorley and Gallaher, 1991), will increase rather than decrease nematode populations when used as a cover crop or rotation crop (McSorley and Gallaher, 1992).

Another crop that is well adapted for use in cropping systems in the South is cowpea (*Vigna unguiculata* [L.] Walp.). Cowpea has been shown to be an effective cover crop for plant-parasitic nematode management (McSorley and Gallaher, 1992), but the effect depends on cowpea cultivar. Some cultivars of this legume are known to be suppressive to plant-parasitic nematodes ('Iron Clay') while others have proven to be very susceptible to nematode damage ('White Acre'). In a study conducted in north Florida, 'Iron Clay' performed as well as sunn hemp (*Crotalaria juncea* L.) and other summer crops in reducing *M. incognita* as compared to a corn crop (Wang et al., 2002a). During an experiment conducted in summer of 2001, 'Iron Clay' cowpea suppressed *M. incognita* to a level equal to that in fallow soil (Wang et al., 2003). A field experiment conducted on sandy soils in Florida resulted in the lowest population densities of *M. incognita* following cultivars 'California Blackeye #5' and 'Mississippi Silver' (Gallaher and McSorely, 1993). If an appropriate cultivar were selected, cowpea would be a very beneficial addition to a cropping system because of its nematode management properties, as well as its ability to improve available N.

An additional legume that is often used in crop rotations is lima bean (*Phaseolus lunatus* L.). As a legume, lima bean can bring the benefit of N improvement to a cropping system, but the effect of this crop on nematode levels must also be taken into consideration. In a field test conducted in Florida, lima bean had very high population densities (average of 338 100 cm^{-3} of soil) of *M. incognita* at harvest compared to cowpea and turnip (*Brassica rapa* L.) (Wang et al., 2003). Similar findings from other studies support the conclusion that lima bean is very susceptible to *M. incognita*, which is the key nematode pest in Florida cropping systems.

Sunn hemp is a legume that is receiving increased attention due to its efficient green manure properties, its ability to fix N, its rapid production of biomass, and its capabilities to suppress several different types of plant-parasitic nematodes (Marshall, 2002; Wang et al., 2002b). Suppression of plant-parasitic nematodes by *Crotalaria* spp. has been known for decades (Huang et al., 1981), but recently, several studies demonstrated that sunn hemp suppressed *Meloidogyne* spp. better than nematicides, because it continued to suppress the nematode population development after a host was planted (Wang et al., 2002b). In several studies conducted in Florida, *M. incognita* populations were found to be lower by as much as 47% on vegetable crops fertilized with sunn hemp as opposed to those fertilized with ammonium nitrate (NH_4NO_3) (Marshall, 2002).

Sunn hemp has proven to be a poor host to many important plant-parasitic nematodes, by producing an allelopathic compound that is toxic to nematodes and by enhancing nematode-antagonistic microorganisms (Wang et al., 2002b). *Crotalaria* spp., including sunn hemp, also contain monocrotaline, which is a substance known to suppress root-knot and other plant-parasitic nematode infestations (Rodriguez-Kabana et al., 1992; Marshall, 2002). Sunn hemp would be an excellent candidate for plant-parasitic nematode control in cropping systems.

In order to investigate the effects of specified cropping histories on nematode communities, a 2-yr experiment was conducted at the University of Florida. Nematode populations were examined after several different cropping histories were completed, each taking place over the course of 1 year. Our objective was to determine which cropping histories resulted in low nematode population densities. Our null hypothesis was that year and the various cropping histories would not have any effect on nematode populations.

Materials and Methods

This study took place from August 2002 to June 2004 in Gainesville, FL on a loamy siliceous semiactive hyperthermic Grossarenic Paleodults (USDA-NRCS, 2003).

Nematode Populations Following Final Sweet Corn, 2003 and 2004

A split-plot experimental design was used to examine nematode populations following the final sweet corn crop of each year of the study. Main effects, analyzed as a completely randomized design (CRD), were 3 different multiple cropping histories (histories 1, 2, and 3) that were grown during the first year of the test and then repeated during the second. History 1 consisted of sweet corn followed by Austrian winter pea (*Pisum arvense* L.), and then sweet corn in 2003, and the same multiple cropping sequence repeated in 2004. History 2 consisted of cowpea followed by Austrian winter pea and then sweet corn in 2003, and lima bean followed by Austrian winter pea and then sweet corn in 2004. History 3 consisted of sunn hemp followed by Austrian winter pea followed by sweet corn in 2003, and the same multiple cropping sequence repeated again in 2004. The sub-effects were 3 different N sources [lupine (*Lupinus angustifolius* L.), vetch (*Vicia villosa* [L.] Roth), and ammonium nitrate (AN)] used on the final sweet corn crop in the 3 cropping histories each year. Data from each year were analyzed by analysis of variance (ANOVA).

Pi and Pf Nematode Populations for Final Sweet Corn, 2003 and 2004

A CRD was used to examine nematode populations directly before and after the final sweet corn crop for each year of the 2 yr study. This study examined populations of nematodes before (Pi) planting the sweet corn and at the end (Pf) of the sweet corn crop.

The three cropping histories described above were the treatments. Data from each year were analyzed separately by ANOVA.

Pi and Pf Nematode Populations for Austrian Winter Pea, 2003 and 2004

A CRD was also used to examine Pi and Pf of nematodes associated with the Austrian winter pea crop for each year of the study. Cropping histories were again the treatments as described above. Data from each year were analyzed separately by ANOVA.

Nematode Analysis

Nematode population information was ascertained by collecting 6 soil cores (2.5 cm diameter x 20 cm deep) obtained from each subplot (history x N source test) or main plot (Pi/Pf studies on final sweet corn crop or Austrian winter pea crop) of the test area. The 6 soil cores comprising each sample were mixed, and nematodes were extracted from 100 cm^3 of soil from each of the samples using a modified sieving and centrifugal-flotation method (Jenkins, 1964). Nematodes were identified and counted, and populations for each genus were subjected to statistical analysis.

Statistical Analysis

Nematode data was recorded in Quattro Pro (Anonymous, 1987) spreadsheets and transferred to MSTAT 4.0 (Anonymous, 1985) for analysis of variance (ANOVA) with the appropriate model for the experimental design. Numbers were compared using ANOVA followed by mean separation using LSD (Gomez and Gomez, 1984). Analysis of variance tables giving breakdown of df and level of significance for each variable tested is given in Tables 7-1 to 7-3.

Results

Nematode Populations Following Final Sweet Corn, 2003 and 2004

When examining nematode populations following each year of the cropping history experiment on the final sweet corn, no interactions between cropping history and N source occurred for any of the nematode populations in either 2003 or 2004 (Table 7-4). Statistical ($p \leq 0.10$ in 2003 and $p \leq 0.05$ in 2004) differences were found among cropping histories for root-knot (*Meloidogyne* spp.) nematodes, which were most abundant in history 2 and least in history 3 in 2004, but no differences occurred among N sources (Table 7-4). No significant differences were found for spiral (*Helicotylenchus* spp.) populations in either 2003 or 2004 (Table 7-4). Stubby-root (*Paratrichodorus* spp.) numbers were highest in history 2 (significantly different at $p \leq 0.05$) in 2003, and in 2004, both cropping history and N source affected ($p \leq 0.05$) stubby-root nematode numbers (Table 7-4). Lesion nematode (*Pratylenchus* spp.) numbers were highest ($p \leq 0.05$) in history 1 in both years but N source was not significantly different in either 2003 or 2004 (Table 7-4). Ring nematode (*Criconemella* spp.) populations were consistently most abundant in cropping history 1, but were unaffected by N sources (Table 7-4) in both 2003 and 2004.

Pi and Pf Nematode Populations for Final Sweet Corn, 2003 and 2004

When the Pi and Pf nematodes associated with the final sweet corn crop of 2003 and 2004 were examined, root knot did not display any significant ($p \leq 0.05$) differences among cropping histories for Pi but was significantly different ($p \leq 0.10$) for Pf in 2003 (Table 7-5). In 2004, both the populations prior to and following the corn were greatest ($p \leq 0.001$) in cropping history two and least ($p \leq 0.001$) in history 3 (Table 7-5). The only significant ($p \leq 0.05$) differences among cropping histories displayed by spiral nematode populations for 2003 and 2004 were those prior to the sweet corn crop ($p \leq 0.05$) or following sweet corn crop ($p \leq 0.10$) in 2003 (Table 7-5). Stubby-root nematodes were most abundant ($p \leq 0.05$) in history 1 prior to planting sweet corn in 2003, but were most abundant ($p \leq 0.05$) in history 2 and least abundant ($p \leq 0.05$) in history 1 following sweet corn in both years (Table 7-5). Again, both lesion and ring nematode populations displayed significant ($p \leq 0.05$) differences among cropping histories prior to and following the sweet corn crop in both 2003 and 2004, with highest numbers consistently present in history 1 (Table 7-5).

Pi and Pf Nematode Populations for Austrian Winter Pea, 2003 and 2004

During the examination of nematode populations directly prior to and following the Austrian winter pea crop in 2003 and 2004, root-knot nematode numbers differed ($p \leq 0.05$) among cropping histories prior to planting. They remained highest ($p \leq 0.001$) in cropping history 2, following harvest in 2004, but not in 2003 (Table 7-6). Spiral nematode populations prior to and following harvest were greatest ($p \leq 0.05$) in cropping history 1 in 2003, but no significant ($p \leq 0.05$) differences were found in 2004 (Table 7-6). Stubby root nematodes were always greatest ($p \leq 0.05$) in cropping history 1 and least ($p \leq 0.10$) in cropping history 3, both prior to and after the Austrian winter pea crop (Table 7-6). Both lesion and ring nematode populations were more abundant ($p \leq 0.05$) in cropping history 1 than in histories 2 and 3 both prior to and following the Austrian winter pea crop in 2003 and 2004 (Table 7-6).

Discussion and Conclusion

Of the nematodes sampled, root-knot was not only the most prevalent but is also known to be the most problematic. *Meloidogyne* spp. can cause major damage to almost any vegetable crop and are considered to be the key nematode pest in crop production.

Root-knot nematodes are so widespread in tropical and subtropical crop production that frequently they are taken to represent “nematodes” in general and other economically important species are often overlooked (Netscher, 1990).

The hypothesis that year and cropping history would not affect nematode populations cannot be supported. The 2 different years did have an effect on nematode numbers. The 2 yr of cropping histories each had different influences. The cropping systems grown in 2004 had the influence of the same cropping histories from the year prior. The systems from 2003 did not have this influence. When cropping histories were examined, history 3, the cropping system utilizing sunn hemp, was found to decrease root-knot nematode populations drastically, especially in 2004, after the cropping histories had been grown successively for 2 yr. The data indicate that to gain optimum nematode control benefits from this crop, at least 2 successive years of sunn hemp should be planted. A single crop of this plant can reduce nematodes (Wang, 2002b), but was not found to have such great effect on the sampled populations in the current study. Spiral nematode populations tend to build up during the growth of field corn, and similar effects could be expected on sweet corn, but numbers proved inconsistent. Stubby root numbers had increased by the end of the second year, possibly because the plants of the second year were healthier and could sustain higher numbers of nematodes. Lesion nematodes were basically unaffected over both years and ring nematodes, which also tend to build up on corn crops, built up in history 1 (sweet corn) during both years.

When the final sweet corn crop was examined, the strong effects of the cropping histories and specifically sweet corn, were again apparent. After 2004 and 2 yr of the cropping systems, sweet corn consistently increased root-knot nematode numbers, proving to be a good host. Populations of spiral and stubby root nematodes were inconsistent. Ring nematodes increased in 2003, but decreased in 2004.

When the effect of the winter crop, Austrian winter pea, was examined, root-knot nematodes were again affected greatly by sunn hemp. The history including sunn hemp, history 3, was seen to result in the lowest numbers of root-knot nematodes in both 2003 and 2004. Austrian winter pea was also found to decrease nematode numbers, which is important information, since not many winter legumes are known to do so.

History 1 had the highest nematode counts for almost every nematode sampled, again displaying the effect of sweet corn and its ability to build up nematodes. Spiral and stubby root numbers were inconsistent. Lesion and ring numbers were extremely low, except in cropping history 1, demonstrating the ability of sweet corn to increase these nematodes.

In summary, year effects were inconsistent while cropping history effects were consistent. Also, any effect of the various N sources proved inconsistent. Sunn hemp and Austrian winter pea were found to decrease the most important and damaging nematode, root-knot, while sweet corn was found to increase its numbers. Also, sunn hemp (summer/fall) and Austrian winter pea (winter) growing seasons encompass 2 different times in the year. This equates to both warm and cool season suppression, or 2 seasons of nematode control.

Table 7-1. Nematodes following spring planted sweet corn for three cropping histories and three nitrogen sources analysis of variance.

Source of variation	df	2003	2004
		Root-knot	
Cropping history (CH)	2	+	***
Error A	12	—	—
N source (NS)	2	ns†	ns
CH x NS	4	ns	ns
Error B	24	—	—
Total	44	—	—
		Spiral	
Cropping history (CH)	2	ns	ns
Error A	12	—	—
N source (NS)	2	ns	ns
CH x NS	4	ns	ns
Error B	24	—	—
Total	44	—	—
		Stubby-root	
Cropping history (CH)	2	***	*
Error A	12	—	—
N source (NS)	2	ns	***
CH x NS	4	ns	ns
Error B	24	—	—
Total	44	—	—
		Lesion	
Cropping history (CH)	2	*	***
Error A	12	—	—
N source (NS)	2	ns	ns
CH x NS	4	ns	ns
Error B	24	—	—
Total	44	—	—
		Ring	
Cropping history (CH)	2	***	***
Error A	12	—	—
N source (NS)	2	ns	ns
CH x NS	4	ns	ns
Error B	24	—	—
Total	14	—	—

+ Significant at the 0.10 level.
* Significant at the 0.01 level.
** Significant at the 0.05 level.
*** Significant at the 0.001 level.
†ns = not significant.

Table 7-2. Analysis of variance for nematodes prior to and following spring planted sweet corn for three cropping histories.

Source of variation	df	2003 Pi‡	2003 Pf	2004 Pi	2004 Pf
		Root-knot			
Cropping history	2	ns†	+	***	***
Error A	12	—	—	—	—
Total	14				
		Spiral			
Cropping history	2	*	+	ns	ns
Error A	12	—	—	—	—
Total	14				
		Stubby-root			
Cropping history	2	*	***	+	*
Error A	12	—	—	—	—
Total	14				
		Lesion			
Cropping history	2	*	*	***	***
Error A	12	—	—	—	—
Total	14				
		Ring			
Cropping history	2	***	***	*	***
Error A	12	—	—	—	—
Total	14				

+ Significant at the 0.10 level.
* Significant at the 0.01 level.
** Significant at the 0.05 level.
*** Significant at the 0.001 level.
†ns = not significant.
‡Pi = nematode population prior to planting of sweet corn.
Pf = nematode population following harvest of sweet corn.

Table 7-3. Analysis of variance for nematodes prior to and following winter planted cover crop of Austrian winter pea for three cropping histories.

		2003		2004	
Source of variation	df	Pi‡	Pf	Pi	Pf
		Root-knot			
Cropping history	2	***	ns†	***	***
Error A	12	—	—	—	—
Total	14	—	—	—	—
		Spiral			
Cropping history	2	***	*	+	ns
Error A	12	—	—	—	—
Total	14	—	—	—	—
		Stubby-root			
Cropping history	2	**	*	**	+
Error A	12	—	—	—	—
Total	14	—	—	—	—
		Lesion			
Cropping history	2	**	*	***	***
Error A	12	—	—	—	—
Total	14	—	—	—	—
		Ring			
Cropping history	2	***	***	***	*
Error A	12	—	—	—	—
Total	14	—	—	—	—

+ Significant at the 0.10 level.
* Significant at the 0.01 level.
** Significant at the 0.05 level.
*** Significant at the 0.001 level.
†ns = not significant.
‡Pi = nematode population prior to planting of Austrian winter pea.
Pf = nematode population following harvest of Austrian winter pea.

Table 7-4. Nematodes following spring planted sweet corn crop for three cropping histories and three nitrogen sources.

N source	2003				2004			
	Cropping history				Cropping history			
	1¶	2	3	$\overline{X}$	1	2	3	$\overline{X}$
	Number of nematodes, 100 cm^{-3} soil							
				Root-knot				
Lupine	891	394	672	652 ns†	234	300	57	197 ns
Vetch	699	693	1367	920	214	372	56	214
AN	1167	619	907	898	243	401	56	233
$\overline{X}$	919 a§	567 b	982 a		230 b	357 a	56 c	
				Spiral				
Lupine	48	9	1	19 ns	9	22	1	11 ns
Vetch	46	41	3	30	11	9	2	7
AN	34	23	3	20	9	37	1	15
$\overline{X}$	42 ns	24	2		9 ns	22	1	
				Stubby root				
Lupine	1	15	17	11 ns	8	8	12	9 y‡
Vetch	2	19	7	9	7	5	7	6 y
AN	5	26	6	12	8	18	19	15 x
$\overline{X}$	3 b	20 a	10 b		7 b	11 a	13 a	
				Lesion				
Lupine	23	0	0	8 ns	19	1	0	6 ns
Vetch	3	0	0	1	18	0	1	6
AN	16	0	0	6	18	0	0	6
$\overline{X}$	14 a	0 b	0 b		18 a	0 b	0 b	
				Ring				
Lupine	64	25	19	36 ns	14	5	7	9 ns
Vetch	88	14	19	41	16	3	5	8
AN	97	55	35	62	15	9	12	12
$\overline{X}$	83 a	32 b	25 b		15 a	6 b	7 b	

†ns = not significant.
‡Values in columns among N sources not followed by the same letter (x,y,z) are significantly different ($p \leq 0.05$) according to LSD.
§Values in rows among cropping histories not followed by the same letter (a,b,c) are significantly different ($p \leq 0.05$) according to LSD.
¶History 1 = sweet corn/Austrian winter pea/sweet corn/sweet corn/Austrian winter pea/sweet corn.
History 2 = cowpea/Austrian winter pea/sweet corn/lima bean/Austrian winter pea/sweet corn.
History 3 = sunn hemp/Austrian winter pea/sweet corn/sunn hemp/Austrian winter pea/sweet corn.

Table 7-5. Nematodes prior to and following spring planted sweet corn crop for three cropping histories.

Cropping history	2003 Pi¶	2003 Pf	2004 Pi	2004 Pf
	Number of nematodes, 100 cm^{-3} soil			
		Root-knot		
1§	8	919 a‡	37 b	230 b
2	15	567 b	342 a	358 a
3	30	982 a	5 b	56 c
	ns†	+	***	***
		Spiral		
1	29 a	42 a	43	9
2	4 b	24 b	56	22
3	1 b	2 c	4	1
	*	+	ns	ns
		Stubby root		
1	13 a	3 b	23 a	7 b
2	2 b	20 a	24 a	11 a
3	2 b	10 a	7 b	12 a
	*	***	+	*
		Lesion		
1	7 a	14 a	12 a	18 a
2	0 b	0 b	0 b	0 b
3	0 b	0 b	0 b	0 b
	*	*	***	***
		Ring		
1	34 a	83 a	29 a	15 a
2	0 b	32 b	7 b	6 b
3	3 b	25 b	4 b	8 b
	***	***	*	**

+ Significant at the 0.10 level.
* Significant at the 0.01 level.
** Significant at the 0.05 level.
*** Significant at the 0.001 level.
†ns = not significant.
‡Values in columns not followed by the same letter are significantly different according to LSD at the designated level of probability.
§History 1 = sweet corn/Austrian winter pea/sweet corn/sweet corn/Austrian winter pea/sweet corn.
History 2 = cowpea/Austrian winter pea/sweet corn/lima bean/Austrian winter pea/sweet corn.
History 3 = sunn hemp/Austrian winter pea/sweet corn/sunn hemp/Austrian winter pea/sweet corn.
¶Pi = nematode population prior to planting of sweet corn.
Pf = nematode population following harvest of sweet corn.

Table 7-6. Nematodes prior to and following winter planted cover crop of Austrian winter pea for three cropping histories.

Cropping history	2003		2004	
	Pi¶	Pf	Pi	Pf
	Number of nematodes, 100 cm^{-3} soil			
		Root-knot		
1§	62 a	8	239 b‡	37 b
2	10 b	15	887 a	342 a
3	1 b	3	8 b	5 b
	**	ns†	***	***
		Spiral		
1	45 a	29 a	59 a	43
2	1 b	4 b	22 b	56
3	1 b	1 b	3 b	4
	***	*	+	ns
		Stubby root		
1	12 a	13 a	8 a	23 a
2	1 b	2 b	5 a	24 a
3	1 b	2 b	0 b	7 b
	**	*	**	+
		Lesion		
1	21 a	7 a	44 a	12 a
2	1 b	0 b	0 b	0 b
3	1 b	0 b	0 b	0 b
	**	*	***	***
		Ring		
1	58 a	34 a	36 a	29 a
2	1 b	0 b	2 b	7 b
3	1 b	3 b	5 b	4 b
	***	***	***	*

+ Significant at the 0.10 level.
* Significant at the 0.01 level.
** Significant at the 0.05 level.
*** Significant at the 0.001 level.
†ns = not significant.
‡Values in columns not followed by the same letter are significantly different according to LSD at the designated level of probability.
§History 1 = sweet corn/Austrian winter pea/sweet corn/sweet corn/Austrian winter pea/sweet corn.
History 2 = cowpea/Austrian winter pea/sweet corn/lima bean/Austrian winter pea/sweet corn.
History 3 = sunn hemp/Austrian winter pea/sweet corn/sunn hemp/Austrian winter pea/sweet corn.
¶Pi = nematode population prior to planting of sweet corn.
Pf = nematode population following harvest of sweet corn.

CHAPTER 8
SUMMARY

The results of these experiments demonstrate the need for more research regarding the use of no-tillage practices, the use of organic N sources, and multiple cropping using the appropriate crops. Utilizing multiple cropping when the climate is conducive can be extremely beneficial, not only for a grower, but for the environment. These agricultural techniques all promote sustainable agriculture, which can help to preserve and maintain natural resources and ensure their use by future generations.

Valuable information was obtained on the crops tested and the conditions best for their production in no-till cropping systems in Florida. Two sweet corn varieties were found to be superior hybrid choices for fall production of sweet corn in central Florida, 'Silver Queen' and '8102R'. The management of N fertilizer (ammonium nitrate) for sweet corn should be split into at least 2 applications, in order to reduce the risk of leaching. The number of split applications should be economically based.

For production in Florida as part of a cropping system or for use as organic mulch, the cowpea variety 'Iron Clay' would make the strongest choice. This variety of cowpea has the capacity to provide extra N, P, and K for succeeding crops, when used in a system. 'Iron Clay' can also reduce infestations of the extremely harmful plant-parasitic nematode, *M. incognita*, which poses a problem in crop production in Florida. 'California Blackeye #5' is a variety of cowpea that would make a good candidate for a very different situation, that is one of consumption. Its high pod production and high pod mineral content make it most suitable as a food crop. The lima bean variety most suited for production, possibly as a food crop, in Florida is 'Fordhook'.

Sunn hemp would make an excellent choice for inclusion in a multiple cropping system in Florida. It can be harvested and utilized as a green manure in order to increase soil OM, add minerals, especially N, and suppress nematodes. The portion of the sunn hemp not harvested could be maintained for continual clipping and production of mulch. The mulch could be used for weed control, soil moisture conservation, and the slow release of additional N and other minerals.

No-till planted Austrian winter pea performed well as a cover crop in all systems in this study. Its residue contributed a significant quantity of minerals, especially N, for subsequent crops. This legume also would aid in soil conservation and nematode population management.

A previous history involving cowpea and Austrian winter pea appeared to be best suited for production of sweet corn in a no-till multiple cropping system in Florida. The system including these 2 legumes prior to sweet corn produced the most, as well as largest, marketable ears and had the healthiest soil. Ammonium nitrate gave best results as an N source for sweet corn grown in a no-till multiple cropping system when compared with lupine and vetch. Although inorganic fertilizers might be more economical, organic fertilizers offer benefits that inorganic fertilizers cannot. Organic fertilizers or mulches can be used to improve soil moisture conservation, increase soil organic matter, provide N and other plant minerals, reduce weed competition, and reduce erosion in addition to eliminating the threat of chemical leaching.

When nematode populations were examined after 2 yr of cropping systems had been produced, year effects were inconsistent while cropping history effects were consistent. Sunn hemp and Austrian winter pea were found to decrease the most important and damaging nematode, root-knot nematode, while sweet corn was found to increase its numbers. Also, growing sunn hemp (summer/fall) and Austrian winter pea (winter) consecutively would encompass 2 different times in the year, which equates to both warm and cool season suppression, or 2 seasons of nematode control.

All of these cropping systems had very positive results. Much needed information was gathered on several different types of crops and the conditions necessary for the successful production of each within no-till cropping systems. Several varieties were proven more appropriate than others and some N management techniques were more efficient than others. Positive results such as these should encourage the use of no-tillage and multiple cropping and the continued investigation of organic fertilizers.

LIST OF REFERENCES

Adams, F., and C.E. Evans. 1962. A rapid method for measuring lime requirement of red-yellow podzolic soils. Soil Sci. Soc. Am. J. 26:355-357.

Aguiar, J., J. Ehlers, W. Graves, B. Matthews, P. Roberts, and V. Samons. 1999. Coachella Valley cover crop research. Botany and Plant Sci. Dept., Sustainable Agric. Res. and Educ. Prog. Univ. of California, Riverside.

Allison, F.E. 1965. Organic carbon. p. 367-1378. *In* C.A. Black, D.D. Evans, J.L.White, L.E. Ensminger, and F.E. Clark (ed.). Methods of Soil Analysis, Part II. Am. Soc. Agron., Madison, WI.

Anderson, J.R., N.L. Hubbard, F.D. Shaw, and F.W. Smith. 1990. Managing winter-annual legumes as N sources for no-tillage corn on sandy coastal plain soils. p. 104-107. *In*: Mueller, J.P. and M.G. Wagger (ed.). Proc. Southern Region Conserv. Tillage Conf., 1990. Raleigh, NC. NCSU Special Bulletin 90-1. North Carolina State Univ., Raleigh.

Anonymous. 1987. Manual for Quattro Pro, Ver 4.0. Getting started. Borland Int'l., Inc. Scotts Valley, California.

Anonymous. 1985. Users guide to MSTAT, Ver 4.0. [Online]. Available at http://www.msu.edu/~freed/mstatc.html (verified on 28 March 2005). Michigan State Univ., Lansing.

Beck, D.L., M.P. Hagny, and J.L. Miller. 1998. Principles and practices of no-till systems. Abstract, Amer. Soc. Agron. 90: 289.

Blade, S.F., S.V.R. Shetty, T. Terao, and B.B. Singh. 1997. Recent developments in cowpea cropping systems research. p. 114-128. *In*: B.B. Singh, D.R. Mohan Raj, K.E. Dashiell and L.E.N. Jackai (ed.). Int'l. Inst. of Tropical Agric. Ibadan, Nigeria.

Brady, K., and E. Buckman. 1969. The nature and properties of soils. 7th ed. The Macmillan Company, New York, NY.

Burnside, O.C., and J.H. Williams. 1968. Weed control methods for kinkaoil, kenaf, and crotalaria. Agron. J. 60:162-164.

Campbell, C.A., and R.P. Zentner. 1993. Soil organic matter as influenced by crop rotations and fertilization. Soil Sci. Soc. Am. J. 57:1034-1040.

Carsky, R.J., and S. Schultz. 1999. On-farm testing of mucuna and cowpea double cropping with maize in the Guinea savanna of Nigeria. Int'l. Inst. of Tropical Agric. Ibadan, Nigeria.

Davis, D.W., E.A. Oelke, E.S. Oplinger, J.D. Doll, C.V. Hanson, and D.H. Putnam. 1991. Cowpea [Online]. Available at http://www.hort.purdue.edu/newcrop/afcm/cowpea.html (verified 30 Sept 2003). Wisconsin Coop. Ext. Serv., Univ. of Wisconsin, Madison.

Delahaut, K.A., and T.J. Thiede. 2002. Sweet corn production in Wisconsin. Univ. of Wisconsin Press, Madison.

Doup, J. 2001. No-till farming remains popular choice [Online]. Available at http://news.uns.purdue.edu/UNS/html3month/010323.Evans.tillage.html (verified 23 Apr 2003). Purdue News, 23 March 2001.

Duke, J.A. 1981. Handbook of legumes of world economic importance. Plenum Press, New York, NY.

Ehlers, J. D., and H. E. Hall. 1997. Cowpea (*Vigna unguiculata* L. Walp.). Field Crops Res. 53:187-204.

Eylands, V.J. 1984. Corn and grain sorghum yield and mineral nutrition in multicropping systems. Ph.D. diss., Univ. of Florida, Gainesville.

Florida Agricultural Statistics Service. 2004. Vegetable summary [Online]. Available at http://www.nass.usda.gov/fl/facts/faf04/a22.html (verified on 12 Feb 2005). Florida Agric. Stats. Serv., Orlando.

Florida Automated Weather Network. 2005. FAWN results: Query results for Alachua, County, Florida [Online]. Available at http://fawn.ifas.ufl.edu/scripts/reportrequest.asp.html (verified 23 Feb 2005). Florida Auto. Weather Net., Alachua.

Florida Commodities. 2002. Sweet corn [Online]. Available at www.flag.com/commodities (verified 6 Jan 2003). Florida Dept. of Agric. and Consumer Serv., Orlando.

Food and Agriculture Organization (FAO) of the United Nations. 1984. Legume inoculants and their use. Food and Agric. Org. of the United Nations, Inc. Rome, Italy.

Fritz, F.A., G.W. Randall, and C.J. Rosen. 2001. Characterization and utilization of N contained in sweet corn silage waste. Agron. J. 93:627-633.

Gallaher, R.N. 1977. Soil moisture conservation and yield of crops no-till planted in rye. Soil Sci. Soc. Am. J. 41:145-147.

Gallaher, R. N. 1980. Value of residues, mulches, or sods in cropping systems. Multicropping Minimum Tillage 5, April 1980. Florida Coop. Ext. Serv., IFAS, Univ. of Florida, Gainesville.

Gallaher, R.N. 1983. Mulches, cover crops, crop residues, N-fixing legumes, etc. p. 43-46. *In*: J.F. Tompkins and R. Miles (ed.) Proc. Southeastern No-Till Systems Conf., 7th, Milan, TN. 21 July 1983. Univ. of Tennessee., Knoxville.

Gallaher, R.N., and M.B. Ferrer. 1987. Effect of no-tillage vs. conventional tillage on soil organic matter and N contents. Commun. in Soil Sci. Plant Anal. 18(9) 1061-1076.

Gallaher, R.N., and L. Hawf. 1997. Role of conservation tillage in production of a wholesome food supply. p 23-27. *In*: R.N. Gallaher and R. McSorley (ed.). Proc. Southern Conserv. Tillage Conf. for Sustainable Agric. Florida Coop. Ext. Serv., Univ. of Florida, Gainesville.

Gallaher, R.N., and E.S. Horner. 1983. Evaluation of late summer planted no-tillage corn. Agron. Res. Rep. AY-83-11. IFAS, Univ. of Florida, Gainesville.

Gallaher, R.N., and M.F. Laurent. 1983. Minimum tillage: pollution solution. Best Management Practices, SP 21. Florida Coop. Ext. Serv., IFAS, Univ. of Florida, Gainesville.

Gallaher, R.N., and R. McSorley. 1993. Population densities of *Meloidogyne incognita* and other nematodes following seven cultivars of cowpea. Nematropica 23:21-26.

Gallaher, R.N., and R. McSorley. 1998. No-tillage sweet corn hybrid response to Carbofuran (Furadan 4 F). p. 25-26. *In*: T. Keisling (ed.). Proc. Southern Conserv. Tillage Conf., Gainesville, FL, 1998. IFAS., Univ. of Florida, Gainesville.

Gallaher, R.N, R. McSorley, and D.W. Dickson. 1991. Nematode densities associated with corn and sorghum cropping systems in Florida. Supplement to the J. of Nem. 23(4S):668-672.

Gallaher, R.N., and D.E. Rieper. 1993. Influence of variety and plant population on cowpea yield in Gainesville, Florida. Agron. Res. Report AY-93-01. IFAS, Univ. of Florida, Gainesville.

Gallaher, R.N., C.O. Weldon, and J.G. Futral. 1975. An aluminum block digester for plant and soil analysis. Soil Sci. Soc. Am. J. 39:803-806.

Gibbs, A.J. 1983. Sunn hemp mosaic virus [Online]. Available at http://life.anu.edu.au/viruses/ICTVdB/71010010.html (verified on 6 Jan 2003). Australian Nat'l Univ., Sydney.

Gomez, K.A., and A.A. Gomez. 1984. Statistical procedures for agricultural research. 2nd ed. John Wiley and Sons Publishing, New York, NY.

Grant, C.A., L.D. Bailey, and M.C. Therrien. 1996. The effect of N, P, and KCl fertilizers on grain yield and Cd concentration of malting barley. Fert. Res. 45:153-161.

Grant, C.A., G.A. Peterson, and C.A. Constantine. 2002. Nutrient considerations for diversified cropping systems in the northern great plains. Agron. J. 94:186-198.

Griffin, T., M. Liebman, and J. Jemison, Jr. 2000. Cover crops for sweet corn production in a short-season environment. Agron. J. 92:144-151.

Hargrove, W.L., P.B. Ford, and Z.C. Somda. 1991. Crop residue decomposition under controlled and field conditions. p 99-108. *In*: Proc. Conf. Int'l. Soil Tillage Res. Org., 12th, Columbus. Ohio State Univ. Press, Columbus.

Hesse, P.R. 1972. A textbook of soil chemical analysis. Chemical Publishing Co., New York, NY.

Hochmuth, G., E. Hanlon, G. Synder, R. Nagata, and T. Schueneman. 1996. Fertilization of sweet corn, celery, romaine, escarole, endive, and radish on organic soils in Florida [Online]. Available at http://edis.ifas.ufl.edu/CV008#FOOTNOTE_2.html (verified on 20 March 2005). Univ. of Florida, Gainesville.

Hochmuth, G., D. Maynard, C. Vavrina, and E. Hanlon. 1991. Plant tissue analysis and interpretation for vegetable crops in Florida. Res. Rep. SS-VEC-42. Univ. of Florida.

Huang, C.S., R.C.V. Tenente, F.C.C. Da Silva, and J.A.R. Lara. 1981. Effect of *Crotalaria spectabilis* and two nematicides on numbers of *Meloidogyne incognita* and *Helicotylenchus dihystera*. Fitopathologia Brasileira 27:1-5.

Isse, A.A., A.F. MacKenzie, K. Stewart, D.C. Coultier, and D.L. Smith. 1999. Cover crops and nutrient retention for subsequent sweet corn production. Agron. J. 91: 934-939.

Jackson, M.L. 1958. Soil Chemical Analysis. Prentice-Hall, Inc., Englewood Cliffs, NJ.

Jenkins, W.R. 1964. A rapid centrifugal-flotation technique for separating nematodes from soil. Plant Disease Rep. 48:692.

Johnson, A.W. 1982. Managing nematode populations in crop production. p. 193-203. *In*: R.D. Riggs (ed.) Nematology in the Southern Region of the United States. Southern Coop. Ser. Bull. 276, Arkansas Agric. Exp. Stn., Fayetteville.

Kidder, G., and R.D. Rhue. 1983. Notes in soil science. Coop. Ext. Serv. Bulletin, No. 9. IFAS, Univ. of Florida, Gainesville.

Li, Y., H. Bryan, and T. Olczyk. 2000. Sunn hemp- a cover crop in Florida. Southwest Florida Res. and Educ. Center. IFAS, Univ. of Florida, Gainesville.

Lian, S. 1991. Efficiency of nitrogen fertilization on upland crops grown in multiple cropping systems in Taiwan. Dept. of Agric. Chem., Taiwan Agric. Res. Inst., Wufeng, Tainchung, Taiwan.

Lupwayi, N.Z., W.A. Rice, and G.W. Clayton. 1999. Soil microbial biomass and carbon dioxide flux under wheat as influenced by tillage and crop rotation. Can. J. Soil Sci. 79:273–280.

Luyindula, N., and R.W. Weaver. 1989. Nitrogen partitioning in cowpea as influenced by rhizobial strain and mineral nitrogen. Agron. J. 81:593-596.

Mahler, R.L., and D.L. Auld. 1989. Evaluation of the green manure potential of Austrian winter peas in northern Idaho. Agron. J. 81:258-264.

Mansoer, Z., D.W. Reeves, and C.W. Wood. 1997. Suitability of sunn hemp as an alternative late-summer legume cover crop. Soil. Sci. Soc. Am. J. 61:246-253.

Marshall, A.J. 2002. Sunn hemp (*Crotalaria juncea* L.) as an organic amendment in crop production. M.S. thesis. Univ. of Florida, Gainesville.

McSorley, R. 1999. Host suitability of potential cover crops for root-knot nematodes. Supp. to the J. of Nem. 31:619-623.

McSorley, R. 2001. Multiple cropping systems for nematode management: a review. Soil Crop Sci. Soc. of Florida. 60:132-142.

McSorley, R., and R.N. Gallaher. 1991. Cropping systems for management of plant-parasitic nematodes. p. 38-45. *In*: A.B. Bottcher, K.L. Campbell, and W.D. Graham (ed.). Proc. of the Conf. on Environmentally Sound Agric. Florida Coop. Ext. Serv., IFAS, Univ. of Florida, Gainesville.

McSorley, R., and R.N. Gallaher. 1992. Managing plant-parasitic nematodes in crop sequences. Soil Crop Sci. Soc. of Florida. 51:42-45.

Mehlich, A. 1953. Determination of P, Ca, Mg, K, Na, and NH_4^+. North Carolina Soil Test Div. (Mimeo, 1953). North Carolina State Univ., Raleigh.

Mills, H.A., and J.B. Jones, Jr. 1996. Plant analysis handbook II. Micro-Macro Publishing, Inc., Athens, GA.

Netscher, C., and R.A. Sikora. 1990. Nematode parasites of vegetables. p. 59. Plant parasitic nematodes in subtropical and tropical agriculture. CAB Int'l. Inst. of Parasitology. Wallingford, UK.

Noe, J.P. 1988. Theory and practice of the cropping systems approach to reducing nematode problems in the tropics. J. of Nem. 23:353-361.

Orzolek, M., G. Greaser, and J. Harper. 2003. Agricultural alternatives: sweet corn. College of Agric. Sci., Penn State Univ., PA.

Peachy, E., R. Dick, J. Luna, and R. Sattell. 1999. Cover crop weed suppression in annual rotations. Oregon Cover Crops, EM 8725. Oregon State Univ. Extension Service. Corvallis, OR.

Peech, M.F. 1965. Hydrogen-ion activity. Pp. 914-925. In C.A. Black, (ed.). Methods of soil analysis, Part II. Am. Soc. Agr., Madison, WI.

Reginelli, D.B, N.W. Beuhring, W.F. Jones, and J.J. Varco. 1990. Effects of legume cover crops and tillage on grain sorghum yield. p. 101-103. *In*: Mueller, J.P. and M.G. Wagger (ed.). Proc. of Southern Reg. Conserv. Tillage Conf. Raleigh, NC. NCSU Special Bulletin 90-1. North Carolina State Univ., Raleigh.

Rodriguez-Kabana, R., J. Pinochet, D.G. Robertson, C.F. Weaver, and P.S. King. 1992. Horsebean (*Canavalia ensiformis*) and Crotolaria (*Crotalaria spectabilis*) for the management of Meloidogyne spp. Nematropica 22:29-35.

Rotar, P.P., and R.J. Joy. 1983. 'Tropic sunn' sunn hemp (*Crotalaria juncea* L.). Res. and Ext. Serv. 36. Hawaii Inst. Tropical Agric. and Human Resources, Univ. of Hawaii, Honolulu.

SAS Institute, Inc. 2000. SAS/STAT User's guide. Release 8.02. SAS Inst., Cary, NC.

Sattell, R., T. Buford, R. Dick, D. McGrath, and H. Murray. 1999. Cover crop dry matter and N accumulation in western Oregon. OR Cover Crops, EM 8739. Ext. Serv. Oregon State Univ., Corvallis, OR.

Sullivan, P. 2003. Principles of sustainable weed management for croplands agronomy systems guide [Online]. Available at http://www.attra.org/attra-pub/weed.html (verified 28 Feb 2005). ATTRA, Fayetteville.

Thies, Judy, and Richard Fery. 1999. Root-knot nematodes: need for host plant resistance in cowpea [Online]. Available at http://www.nps.ars.usda.gov/publications.htm?SEQ_NO_115-12040 (verified 30 Sept 2002). USDA, Agric. Res. Serv.

Tisdale, S., and W. Nelson. 1975. Soil fertility and fertilizers, 3rd ed. Macmillan Publishing Co., Inc. New York, NY.

USDA. 1954. U.S. standards for grades of green corn. Source 19 FR 2221, 17 Apr redesignated at 42 FR 32514, 27 June 1977. United States Dept. of Agric., Food Safety and Quality Serv., Washington, DC.

USDA-CSREES. 1998. Field peas [Online]. Available at http://www.sare.org/handbook/mccp2/fieldpea.html (verified 9 Apr 2003). Sustainable Agric. Network, Washington, DC.

USDA-NRCS. 2003. Official soil series descriptions [Online]. Available at http://soils.usda.gov/technical/classification/osd/index.html (verified 04 Feb2005). USDA-NRCS, Washington, D.C.

Walkley, A. 1935. An examination of methods for determining carbon and nitrogen in soils. J. Agron. Soc. 25:598.

Wang, K.-H., R. McSorley, and R.N. Gallaher. 2003. Host status and amendment effects of cowpea on *Meloidogyne incognita* in vegetable cropping systems. Nematropica 33:215-224.

Wang, K-H., R. McSorley, R.N. Gallaher, and R. S. Tubbs. 2002. Effects of winter and fall cover crops on plant-parasitic nematode population development. p 152-155. *In*: E. van Santen (ed.) Making Conserv. Tillage Conv.: Building a Future on 25 Years of Res. Proc. Southern Conserv. Tillage Conf. for Sustainable Agric., 25th, Auburn, AL. 24-26 June 2002.

Wang, K-H., B.S. Sipes, and D.P. Schmitt. 2002a. Crotalaria as a cover crop for nematode management: a review. Nematropica 32:36-57.

Wang, K.-H., B.S. Sipes, and D.P. Schmitt. 2002b. Suppression of *Rotylenchulus reniformis* by *Crotolaria juncea*, *Brassica napus*, and *Tagetes erecta*. Nematropica 31:237-251.

Whitbread, A.M., G.J. Blair, and R.D.B. Lefroy. 1998. Managing residues and fertilizers to enhance the sustainability of wheat cropping systems. p. 827-835. *In*: D.L. Michalk, and J.E. Pratley (ed.). Proc. of Agron. Conf. of Australian Soc. Agron., 9th, Sydney, Australia.

Wild, A. 1998. Plant nutrients in soil: nitrogen. p. 652-694. *In*: A. Wild (ed.). Russell's Soil Conditions and Plant Growth. 11th ed. John Wiley and Sons, Inc. New York, NY.

Wood, C.W., D.G. Westfall, G.A. Peterson, and I.C. Burke. 1990. Impacts of cropping intensity on carbon and nitrogen mineralization under no-till dryland agroecosystems. Agron. J. 82:1115–1120.

BIOGRAPHICAL SKETCH

Kimberly A. Seaman was born 18 May 1980, to Jeffery and Karen Seaman, in Rochester Hills, MI. She graduated Columbia Academy Prepatory School (fourth in her class) in 1998. She then attended David Lipscomb University in Nashville, Tennessee, where she obtained a BS in Environmental Science in 2002. During her undergraduate studies she served as the university greenhouse manager and interned with the urban forestry department of the Tennessee Environmental Protection Agency.

In August 2002, she began an MS degree program at the University of Florida in the Agronomy Department. She was placed on an USDA-CREES grant entitled 'Effects of Management Practices on Pests, Pathogens, and Beneficials in Soil Ecosystems' and worked as a graduate research assistant. She is currently a member of the Gamma Sigma Delta Agricultural Honor Society, Crop Science Society of Florida, and the American Society of Agronomy.