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Cover Crops

Benefits of Vetch and Rye Cover Crops to Sweet Corn under No-Tillage

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ABSTRACT

Leguminous cover crops (CCs) may reduce N fertilizer requirements by fixing N biologically and storing leftover N-fertilizer applied in the previous year. The objective of this study was to determine the contribution of CCs [rye (*Secale cereal* L.) and hairy vetch (*Vicia villosa* Roth)] on plant N nutrition and weed suppression to the following sweet corn (*Zea mays* L.). The CCs were planted in the fall of 2003 and 2005, and sweet corn was planted in spring of 2004 and 2006. The experiment contained N rates and CC treatments. In 2004, two CC treatments were tested: none and a CC mixture consisting of 67% rye and 33% hairy vetch. In 2006 the experiment contained five CC treatments (100% rye; 100% vetch; 67% rye and 33% vetch; 33% rye and 67% vetch; and none). Nitrogen rates of 0, 67, and 133 kg ha^{-1} were split-applied at emergence, V3–4, and V9–10 growth stages. Two additional plots under non-CC treatment received N rates of 200 or 267 kg ha^{-1} to develop a N response curve. Sweet corn growth, N-accumulation, and yield were increased when CCs were presented for low-fertilizer inputs. The N contribution of CC to the sweet corn ranged between 35 and 75 kg ha^{-1}. Yield response to N-fertilizer application was fitted in a cubic model with optimum yield of 22 Mg ha^{-1} attained with 230 kg N ha^{-1}. Rye reduced weed biomass by 25% and 36% compared with non-CC and vetch. In conclusion, the potential CC yield benefits to sweet corn were greatest at lowest supplemental N rates.

In 2006, more than 13 million hectares of agricultural land in Florida was planted with sweet corn. This crop had a value of over 117 million dollars (USDA, 2008). Most sweet corn in Florida is produced on coarse-textured soils characterized by low inherent soil fertility and low organic matter levels (Carlisle et al., 1988). Owing to the low soil water holding capacity of these soils, poor irrigation management invariably results in inefficient N-fertilizer use, and farmers may opt to apply excessively high N rates to minimize the risk of yield reductions. However, excessive N-fertilizer rates increase the potential of nitrate leaching and groundwater pollution, especially in sweet corn production systems which require substantial inputs of nitrogen fertilizer. Moreover, N-fertilizer is one of the most energy-consuming components of corn production, involving economic and environmental costs (Ma and Dwyer, 1998). Reducing the dependence on fossil fuels is therefore desirable from both an ecological and economic perspective.

In general, crop N recommendation is the quotient of plant N requirement by the fertilizer use efficiency, while N efficiency can be defined as the product of capture (including interception and uptake efficiency) and conversion efficiencies (Giller et al., 2006). Crop N requirement is a physiological component, which is directly related to the genetic potential of the crop and to plant growth conditions. This component is determined by the overall crop N accumulation under optimum growing conditions. The fertilizer uptake efficiency for a specific production system depends on factors including environmental conditions, management, rate, timing, and source of nitrogen. The actual recommendation of N-fertilizer rate for mineral soils in Florida is 224 kg N ha^{-1}, with part of this N applied at planting followed of one or two sidedressings of the remaining N at the early part of the growth cycle (V6–V8 stage) (Hochmuth and Cordasco, 2000; Simonne et al., 2005). Approximately 28–55% of the N applied is taken up by the crop (Bundy and Andraski, 2005; Cherr, 2004). Fertilizer recovery typically decreases with an increase in N-application rate, and farmers incur economic loss by applying more N than is required to obtain a positive yield response (Macdonald et al., 1989). However, for high-value crops where N accounts for a small fraction of the total production cost, farmers may opt to apply excessive amounts of N as an insurance premium to minimize potential risk of yield reductions.

Cover crops may be included in rotation with cash crops to suppress weeds and increase soil moisture conservation, nutrient retention, soil organic matter, soil aggregation, and water infiltration. Hairy vetch as a leguminous CC and rye as a grass CC have shown benefits to several crop rotation systems (Fageria et al., 2005). Each CC plays different roles in the crop rotation systems. Rye provides earlier soil coverage, weed suppression, and reduction of soil erosion, while it can also scavenge and conserve residual soil inorganic N. Hairy vetch has an appreciable potential to fix the atmospheric N

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Abbreviations: ANR, apparent nitrogen recovery; CC, cover crop; DAE, days after emergence.

(Clark et al., 2007a; Griffin et al., 2000; Ranells and Wagger, 1997). Hairy vetch has been included in crop rotations as a CC to provide an important addition of N to the system (Cherr, 2004). The total accumulation of N for hairy vetch ranges between 58 and 257 kg N ha^{-1} (AbdulBaki et al., 1996; Guldan et al., 1996; Rochester and Peoples, 2005; Sainju and Singh, 2001; Singogo et al., 1996), with up to 90% of this N being derived from symbiotic N-fixation (Rochester and Peoples, 2005). The estimated contribution of hairy vetch to a succeeding corn crop ranges from 50 to 155 kg N ha^{-1} (Clark et al., 2007a; Clark et al., 1995; Ebelhar et al., 1984; Hargrove, 1986; Ranells and Wagger, 1996). However, in warm environments the N contained within the hairy vetch may be mineralized too quickly due to a C:N ratio between 8:1 and 15:1 (Wagger, 1989). Planting hairy vetch in combination with a grass CC may make the N more available to the following crop (McCracken et al., 1994). Rye is a very effective scavenger of residual inorganic N compared with vetch due to its rapid establishment of an extensive root system (McCracken et al., 1994). Moreover, the relatively high C:N ratio of its residues can also reduce N-leaching losses before N uptake by a subsequent crop. Some studies have shown the benefits of hairy vetch and crimson clover with rye in mixed culture as related to increased plant N content and decreased C:N ratio of rye (Ranells and Wagger, 1996; Sainju et al., 2005; Sullivan et al., 1991). Corn following rye and vetch mix had lower yields compared with corn after pure vetch, but greater than after pure rye or no CC (Clark et al., 1994; Clark et al., 1997). In addition, when both CCs are combined, the rye component serves to conserve residual N, while vetch component serves to supply N to the subsequent corn crop (Clark et al., 2007a).

Another potential benefit of the use of CCs is their capacity to suppress weeds since they compete for light, water, and nutrients, and also can release phytotoxins (Liebman and Davis, 2000). A complementary weed suppression mechanism exists when rye and hairy vetch are cultivated together. Weed suppression by rye has been attributed in part to allelopathy (Barnes et al., 1987; Chase et al., 1991), whereas in hairy vetch, weed suppression has been attributed primarily to shading (Teasdale, 1993; Teasdale and Daughtry, 1993).

Although a number of studies have assessed the benefits of CCs, few studies have looked at their effect of reducing supplemental crop N-fertilizer requirements as related to actual crop N uptake dynamics of a following sweet corn crop in no-tillage systems. The objectives of this research therefore were to (i) evaluate the effectiveness of rye and hairy vetch to reduce the external N-requirements of a subsequent sweet corn crop in terms of crop growth, marketable yield, and N uptake; (ii) measure the effects of CC use on weed suppression, and (iii) correlate chlorophyll meter reading with N-fertilizer rate and sweet corn yield for cover-cropped and non-cover-cropped areas.

MATERIALS AND METHODS

Field experiments were conducted at University of Florida, Plant Science Research and Education Unit, near Citra, FL. The dominant soil types at this site were a Candler fine sand (hyperthermic, uncoated Lamellic Quartzipsamments) containing 97% sand in the upper 100 to 200 cm of the soil profile (Carlisle et al., 1988). The measured soil bulk density was 1.42 and 1.57 Mg m^{-3} at the 0- to 5- and 5- to 30-cm depths, and soil water field capacity was 0.10 to 0.12 m^3 m^{-3} for the 0- to 30-cm soil depth. The field had cultivated under no-tillage systems since 2001, but previously had remained in long-term grass pasture (Cherr et al., 2007). Overhead irrigation was applied at germination and thereafter at 2-d intervals based on crop water requirements in the absence of rain. A weather station located within 500 m of the experimental site provided hourly temperature, relative humidity, and solar radiation. Thermal time was calculated as growing degree days (°Cd) using temperature base of 8°C (Muchow et al., 1990) using average air temperature.

In spring of 2004, a factorial experiment of CCs (Factor A) and N rates (Factor B) was established. The treatments consisted of sweet corn 'Saturn Yellow' planted either after intercropping mixture of hairy vetch and rye 'Florida 140', or after fallow, combined with N-fertilizer rates of 0 (FF_0), 67 (FF_{67}), and 133 (FF_{133}) kg ha^{-1} in a no-tillage system. In addition, N rate treatments of 200 (FF_{200}) and 267 (FF_{267}) kg ha^{-1} under fallow were established to determine sweet corn N-fertilizer response curve in the fallow system. The experimental design consisted of randomized complete blocks with four replicates, and individual plots sized 7.6 by 8.8 m.

On 13 Nov. 2003, a single mixture of CCs [at a rate of 53 kg ha^{-1} (67%) of rye and 25 kg ha^{-1} (33%) of vetch, $R^{67}V^{33}$] was planted with a rip-strip planter using a row spacing of 19 cm and planting depth of 13 mm. The same number of plots was maintained under fallow. The hairy vetch seeds were inoculated with *Rhizobium leguminosarum* and *Bradyrhizobium* spp. The CCs and fallow plots were mowed and sprayed on 29 Mar. 2004 with pendimethalin (3,4-dimethyl-2,6-dinitro-N-pentan-3-yl-aniline) at 65 g a.i. ha^{-1} and atrazine (1-chloro-3-ethylamino-5-isopropylamino-2,4,6-triazine) at 1.1 kg a.i. ha^{-1}. Sweet corn was planted on 14 Apr. 2004 using an in-row spacing of 18 cm, a between-row spacing of 76 cm (73,100 plants ha^{-1}), and a planting depth of 3 cm deep. Phosphorus and potassium were applied to all plots based on soil test recommendations (135 kg P_2O_5 ha^{-1} in a single application during planting and 167 kg K_2O ha^{-1} applied in three splits concurring with N applications). Sweet corn plants emerged on 21 Apr. 2004 and plants were harvested 70 d after emergence (DAE). Sweet corn cultivated after CC ($R^{67}V^{33}$) and fallow treatment were supplemented with 0, 67, and 133 kg N ha^{-1} (FF_0, FF_{67}, and FF_{133}, respectively). The fertilizer was applied as NH_4NO_3 in three equal applications at emergence: 21 and 49 DAE in 2004.

In 2006 the factorial experiment was repeated, including different proportions of rye and hairy vetch. The CC treatments (Factor A) consisted of single rye (R^{100}), single hairy vetch (V^{100}), 67% rye + 33% hairy vetch ($R^{67}V^{33}$), and 33% rye and 67% hairy vetch ($R^{33}V^{67}$), at total rate of 78 kg of seeds ha^{-1}. The CC treatments were combined with N rates of 0, 67, and 133 kg ha^{-1} (Factor B). Rye, hairy vetch, and mixtures were planted on 14 Nov. 2005, and plants were mowed on 26 Mar. 2006. The same variety of sweet corn was planted on 10 Apr. 2006 and final harvest occurred at 71 DAE. Again, N rate treatments of 200 and 267 kg ha^{-1} under fallow were established to determine sweet corn N-fertilizer response curve. The fertilizer was applied as NH_4NO_3 in three equal applications: at emergence, and 28 and 42 DAE.

Sweet corn plant biomass was determined at emergence and at 14, 28, 42, and 63 DAE, and also at final harvest (70 DAE) for both years. Sweet corn yield was determined for the inner plot area (11.5 m^2) and ears were graded using USDA standards (USDA, 1997). Biomass sampling was conducted outside of the inner area but away from the edges using 1 m of row representative of the entire plot in plant number, size, spacing and appearance. Weed biomass was determined by sampling between corn rows in an area of 31- x 76-cm per plot at final harvest in all treatment plots. Sweet corn and weed plant dry weights were determined for sample tissues after oven drying at 65°C for 96 h. Tissue samples were ground in a Wiley mill to pass through a 2-mm screen, and a thoroughly mixed 5-g portion of each sample was stored. Tissue material was digested using a modification of the aluminum block digestion procedure (Gallaher et al., 1975) and analyzed for total Kjeldahl N at the Analytical Research Lab – Univ. of Florida using USEPA Method 351.2 (Jones and Case, 1991). Nitrogen uptake by the plant was calculated by multiplying the weights of stems plus leaves and ear tissue by the corresponding N concentrations. The apparent nitrogen recovery (ANR) was calculated using the difference method where ANR_x = [(kg of N recovered at N_x treatment – kg of N recovered from 0-N)/kg N applied at N_x treatment] × 100, where x = N rate > 0. The control treatments amended with different N-fertilizer rates were used to generate a fertilizer response curve. This curve was then used to estimate the contribution of CC treatments to sweet corn N nutrition in NH_4NO_3-fertilizer equivalents. Weed suppression was evaluated by difference of weed biomass accumulated at fallow treatment and CC treatments.

The N status of the sweet corn crop was also measured by leaf light transmittance using a handheld Minolta SPAD chlorophyll 502 m (Konica Minolta, Ramsey, NJ). Readings were collected at the V8 corn growth stage (35 DAE). Readings were taken midway between the stalk and leaf tip, and midway between the midrib and leaf margin. Readings were taken from the uppermost leaf with the collar fully visible. Twenty-five plants were sampled per plot.

To monitor soil nitrate, soil samples were collected with a 5-cm-diam. soil auger every 2 wk before fertilization in the CC treatments under an N rate of 133 kg ha^{-1} and in the fallow treatments FF_0, FF_{133}, and FF_{267}. Soil samples from each treatment replicate were collected from two points located 10-cm from sweet corn row at the 0- to 30-, 30- to 60-, 60- to 90-, and 90- to 120-cm soil depths. Samples were analyzed for nitrate N using Cd reduction method (Elliott et al., 1989).

Regression analyses were conducted using linear and nonlinear SAS/STAT least-squares LIN and NLIN procedures describe the response curve of sweet corn yield to the N rate treatments. The model was then used to determine the N-contribution from each CC treatment to the sweet corn in equivalent of NH_4NO_3-fertilizer. The ANOVA procedure was used to determine the effect of CC treatments on marketable yield, N contribution from CCs, and weed suppression. For this comparison, only those treatments receiving 0, 67, and 133 kg N ha^{-1} were used for statistical analysis. Mean values for each CC treatment were compared using Duncan's multiple range test with $P \leq 0.05$. Sweet corn biomass, N accumulation, and soil nitrate concentration were analyzed using SAS/Proc Mixed procedures since the sampling dates were correlated over time. In this case, the statistical model included: cover-crop, N rate, sampling date, and the interaction between these factors. To compare the marketable yield, N uptake, and biomass accumulation from the use of CCs with N rates of 200 and 267 kg ha^{-1}, a second ANOVA was conducted with all treatments to make a post hoc pairwise contrast. The aim was to compare sweet corn cultivated in the fallow area and fertilized with chemical N at rates of 200 and 267 kg N ha^{-1} (N rates near to the recommended N rate for Florida by IFAS-University of Florida), against sweet corn followed by CC and fertilized with reduced N rate. The model included N rates, CC treatment, and interaction of these factors. To control the experiment-wise error rate, contrasted treatments were considered significantly different at level of $P \leq 0.05$.

RESULTS AND DISCUSSION

Precipitation and Temperature

Measured climatic parameters were similar during the 2004 and 2006 spring seasons (Fig. 1). For both years, average of daily air temperature was 24.1°C and cumulative growing degree days were 1014 and 1021°Cd, respectively, until 71 DAE. The average of maximum daily temperatures after 20 DAE exceeded 33°C for both years (Fig. 1A, 1B). The cumulative rainfall during the crop season in 2004 and 2006 was 192 and 136 mm, respectively. The irrigation application events ranged between 10 and 25 mm, depending on estimated crop need.

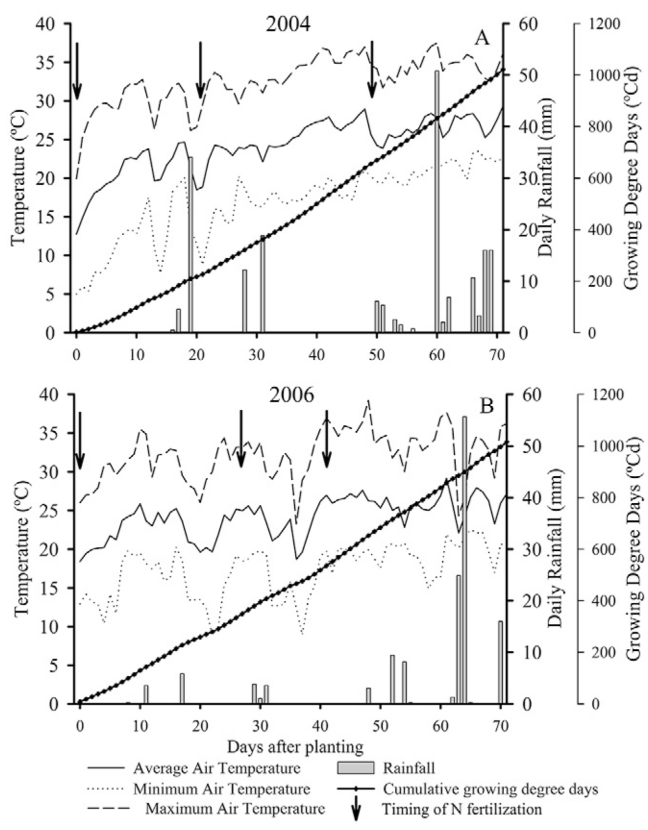

Fig. 1. Average, minimum and maximum daily temperatures, daily rainfall and growing degree days during spring of (A) 2004 and (B) 2006. Arrows indicate timing of N fertilization.

Table 1. Sweet corn above-ground biomass accumulation and plant N uptake as affected by previous cover crop (R = rye, V = hairy vetch) and N rates in 2004 and 2006.

Year	Cover crop treatment	N rate, kg ha^{-1} 0	67	133	200	267
		Biomass, Mg ha^{-1}				
2004	Fallow	1.53bC†‡	4.46aB	6.79aA	7.18A	6.44A
	$R^{67}V^{33}$	2.54aB§	4.86aA§	5.77aA	–	–
	CV, %				23.4	
2006	Fallow	2.24bC	4.56bB	9.76aA	9.81A	9.17A
	V^{100}	5.51aA§	6.95aA§	9.57aA	–	–
	$R^{33}V^{67}$	5.76aB§	8.15aA	7.34bAB	–	–
	$R^{67}V^{33}$	5.47aB§	8.12aA	8.77aA	–	–
	R^{100}	4.36aB§	5.56aA§	6.31cA§	–	–
	CV, %				21.2	
		N Uptake, kg ha^{-1}				
2004	Fallow	17bC	54aB	129aA	139A	122 A
	$R^{67}V^{33}$	25aC§	68aB§	105aA	–	–
	CV, %				20.6	
2006	Fallow	17bD	51cC	124aB	153A	152A
	V^{100}	49aC§	84abB§	129aA	–	–
	$R^{33}V^{67}$	53aB§	91aA§	110aA	–	–
	$R^{67}V^{33}$	60aC§	93aAB§	129aA	–	–
	R^{100}	48aB§	58bcA§	63bA§	–	–
	CV, %				22.7	

† Means within columns followed by the same lowercase letters are not significantly different at $P \leq 0.05$.

‡ Means within rows followed by the same uppercase letters are not significantly different at $P \leq 0.05$.

§ Means from cover crop treatments followed by § are significantly different from the FF_{200} and FF_{267} treatment, respectively.

Sweet Corn Growth and N Accumulation Patterns in Absence of Cover Crops (Control)

Sweet corn biomass increased with applied N rate in a quadratic manner in 2004 ($P \leq 0.001$, $R^2 = 0.95$) and in a cubic manner in 2006 ($P \leq 0.001$, $R^2 = 0.89$, data not shown). In both years, increase of N rate from 133 to 267 kg ha^{-1} did not result in an increase of end-of-season biomass (Table 1). The FF_{67} treatment accumulated 4.51 Mg ha^{-1} in both years, while the unfertilized treatment FF_0 accumulated between 1.53 and 2.24 Mg ha^{-1} (Table 1). Overall, plant N-accumulation followed a similar pattern as observed for biomass accumulation (Table 1), where FF_0 and FF_{67} accumulated less N ($P \leq 0.001$) than the treatments fertilized with N rates above 133 kg ha^{-1} under non-CC area (Table 1). There was no difference in N accumulation between the FF_{267}, FF_{200} and FF_{133} treatments in 2004, however, in 2006 FF_{267} and FF_{200} accumulated more N ($P \leq 0.05$) than FF_{133} (Table 1).

The application of N-fertilizer rate statistically increased soil NO_3–N availability compared to the unfertilized treatment (FF_0). At 18 DAE, soil NO_3–N concentration at the 0- to 30-cm depth at FF_{267} was 10.3 mg kg^{-1} and thus seven and three times higher than FF_0 and FF_{133}, respectively (Fig. 2G). Thus, the higher plant N uptake for the FF_{133}, FF_{200}, and FF_{267} treatments compared with the FF_0 and FF_{67} may be related to the initial availability of soil N, which increased plant growth. This in turn will increase root assimilate availability and potential N uptake (Tolleyhenry et

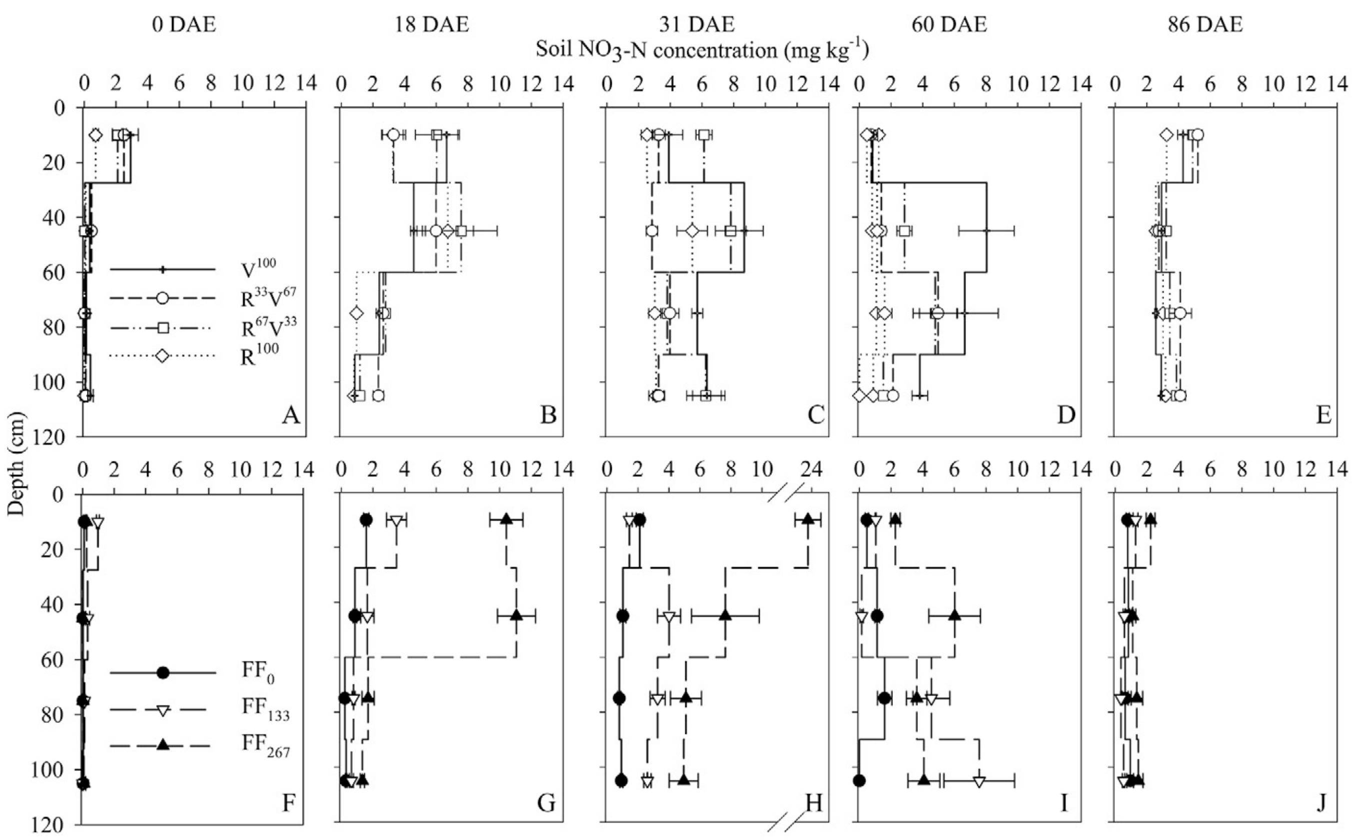

Fig. 2. Soil nitrate concentration (mg kg^{-1}) at 0, 18, 31, 60, and 86 d after emergence of sweet corn planted in 2006 after rye, vetch, and mixtures of rye and vetch amended with 133 kg N ha^{-1} (top row) and non-cover-crop treatments amended with N rates of 0, 133, and 267 kg ha^{-1} (bottom row). Error bars represent treatments standard error for *n* = 4.

al., 1988), while also augmenting sink capacity (Bassirirad, 2000), and thereby enhancing N uptake potential. In 2004, a slightly higher shoot N accumulation was observed for FF_{200} compared with FF_{267}, maybe because of greater N allocation to ears with the FF_{267} treatment (Fig. 3). In 2006, the FF_{200} and FF_{267} treatments accumulated equal amounts of N, about 152 kg N ha^{-1}, while N allocation between ears and stover was about even (Fig. 3). The different partitioning between ears and stover and reduced biomass and N accumulation in 2004 may be related to the timing of N-application. In that year, the second sidedress (one third of the N rate) occurred at 21 DAE, while in 2006 at 28 DAE, and the third sidedress (one third) occurred at 49 and 42 DAE, for 2004 and 2006, respectively. Also, during 2004, about 16 mm of rain occurred within 1 wk after the third fertilization, which may have contributed to the lower N availability of the N-fertilizer. According to Zotarelli et al. (2008), the maximum uptake rates for sweet corn occurred around 42 DAE. In addition, Plénet and Lemaire (1999) observed that, from the silking stage to maturity, about 65% of the 173 kg N ha^{-1} accumulated in the ears was remobilized from vegetative compartments and about 60 kg N ha^{-1} was taken up from the soil. The slight delay in third N application during 2004 thus may account for the difference in allocation patterns.

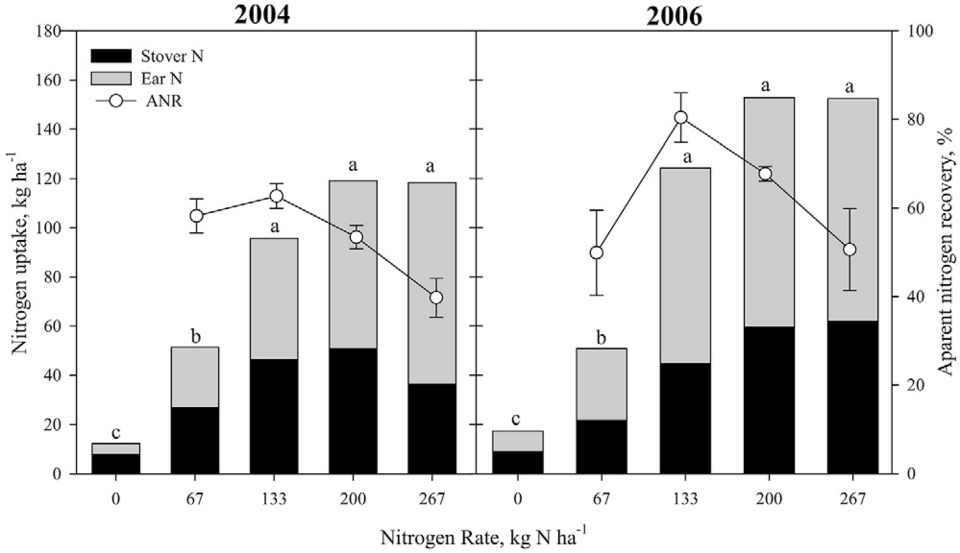

Fig. 3. The effect of N rates on sweet corn N uptake (bars) in ears and stover and apparent nitrogen recovery (ANR, dots and lines) in 2004 and 2006. Vertical bars labeled with different letters are significant at $P \leq 0.05$. Error bars represent treatments standard error for $n = 4$.

Sweet Corn Nitrogen Uptake Dynamics from Supplemental Fertilizer-Nitrogen

With an increase in N rate from 133 to 267 kg N ha^{-1}, the apparent N recovery (ANR), which is an estimate of fertilizer uptake efficiency, statistically decreased from 0.63 to 0.41 in 2004 while corresponding ANR values were 0.80 to 0.51 in 2006 (Fig. 3). There was no statistical difference between total crop N uptake from fertilizer with an increase of N rate from 133 to 267 kg N ha^{-1}. The plant N uptake ranged from 95 to 118 kg ha^{-1} and 124 to 152 kg N ha^{-1} in 2004 and 2006, respectively. The marginal crop N efficiency (kg additional yield per unit extra fertilizer) dropped from 104 to 73 and 113 to 70 kg of fresh sweet corn per kg of N, for 2004 and 2006, respectively, while N fertilizer rates increased from 133 to 267 kg ha^{-1}. This underlines that maximizing production will invariably result in less efficient fertilizer use. The ANR decreased with the increase of N rate. The low ANR values were associated to high NO_3–N concentrations in the deep soil depths (Fig. 2G, 2H, 2I). At 31 DAE (Fig. 2F), about 29 and 51 kg N ha^{-1} was found at the 60- to 120-cm soil depth in the FF_{133} and FF_{267} treatments, respectively; these values were statistically higher than FF_0. At 86 DAE, the amount of NO_3–N in the surface layer (0- to 30-cm) was 30 kg N ha^{-1} and differences between N rates were not detected (Fig. 2J). For the FF_{133} treatment, the amount of N not taken up by the crop ranged between 9 and 38 kg N ha^{-1}, and this amount increased to 115 to 150 kg N ha^{-1} for the highest N rate.

Sweet Corn Growth, N Accumulation and Weed Suppression in Cover-Crop-Based Systems

Interaction between CC and supplemental N rate affected total sweet corn plant dry weight, N accumulation, and chlorophyll meter readings ($P \leq 0.05$; Tables 1 and 2). The presence of CCs significantly ($P \leq 0.05$) enhanced sweet corn stover dry weight and N accumulation when N rates were 0 and 67 kg ha^{-1} in 2006 and only for 0 N rate in 2004. When no N-fertilizer was applied, sweet corn dry biomass ranged between 5.5 to 5.8 Mg ha^{-1} in 2006 and 2.5 Mg ha^{-1} in 2004 for the treatments where hairy vetch was included in the crop rotation (V^{100}, $R^{33}V^{67}$, $R^{67}V^{33}$) and only 4.4 Mg ha^{-1} when sweet corn was followed by R^{100} in 2006 (Table 1). At 35 DAE, chlorophyll meter readings were statistically higher in

Table 2. Chlorophyll meter reading and coefficient of variation of sweet corn at 35 d after emergence during spring of 2004 and 2006.

Year	Cover crop treatment†	N rate, kg ha^{-1} 0	67	133
		Marketable yield, Mg ha^{-1}		
2004	Fallow	31.5aB‡§	33.0aA	36.2aA
	$R^{67}V^{33}$	37.6bA	35.8aA	37.8aA
	CV, %			7.9
2006	Fallow	22.5dC	33.1cB	46.2abA
	V^{100}	34.9aA	44.4aA	42.7bA
	$R^{33}V^{67}$	33.8abB	43.5aA	49.9aA
	$R^{67}V^{33}$	30.4bcB	41.6abA	47.2abA
	R^{100}	27.2cC	37.1bB	44.8abA
	CV, %			8.2

† R = rye, V = hairy vetch.

‡ Means within columns followed by the same lowercase letters are not significantly different at $P \leq 0.05$.

§ Means within rows followed by the same uppercase letters are not significantly different at $P \leq 0.05$.

the 0-N CC treatments than the 0-N non-CC treatment, FF_0 (Table 2). Despite the positive effect of CCs on sweet corn biomass accumulation in 2006, the type or composition of CC mixture did not influence N accumulation in the unfertilized treatments (Table 1).

When compared with the 0-N treatment, the application of 67 kg N ha^{-1} increased plant biomass and plant N-uptake for both years. In terms of biomass accumulation in 2006, the mixture treatments ($R^{33}V^{67}$ and $R^{67}V^{33}$) accumulated on average 36% more biomass than R^{100} ($P \leq 0.05$) and 8% more than V^{100}. In 2004, there was no difference between $R^{67}V^{33}$ and FF_{67} for dry biomass and N-uptake. In 2006, there was an average increase of 33 kg N ha^{-1} uptake by sweet corn amended with 67 kg N ha^{-1} when hairy vetch was the previous CC. However, with the same N rate, sweet corn followed by pure rye (R^{100}) performed similarly to the FF_{67}, indicating that rye had a minimum impact on sweet corn N uptake. Increasing the supplemental N rate from 67 to 133 kg N ha^{-1} did not increase dry matter and N uptake of sweet corn for the R^{100} treatment (Table 1), and this treatment showed the lowest dry matter and N accumulation compared with the other treatments amended with 133 kg N ha^{-1}. There was no difference in dry weight and N accumulation between $V^{33}R^{67}$, $V^{67}R^{33}$, and V^{100} treatments complemented with 133 kg N ha^{-1} (Table 1).

Soil N availability impacted crop N uptake, dry matter accumulation, and yield for sweet corn (Kuo and Jellum, 2002). In this particular case, the application of 133 kg N ha^{-1} combined with CCs increased soil NO_3–N availability at the end of the growing season, compared with the FF_{133} (Fig. 2). The CCs were killed by herbicide application 3 wk before corn planting. At that time, the total N accumulation in the CC residues were 30, 71, 91, and 124 kg N ha^{-1} for R^{100}, $R^{67}V^{33}$, $R^{33}V^{67}$, and V^{100}, respectively. When sweet corn was planted, most of the CC residues remained on the soil surface. Soil samples were taken right after sowing, and the soil nitrate concentration at the 0- to 30-cm depth ranged from 2.1 to 2.9 mg N kg–1 in hairy vetch plots. These concentrations were higher than nitrate concentration in the R^{100} (0.6 mg N kg^{-1}) plot (Fig. 2A). For the 0- to 30-cm depth, there were no differences between treatments, and the average soil NO_3–N concentration was 0.3 mg kg^{-1} (Fig. 2A). Similar results were found by Ranells and Wagger (1997); rye as a monoculture or as part of the mixed culture resulted in lower soil inorganic N values compared with hairy vetch or crimson clover monocultures. At 18, 31, and 60 DAE, the overall NO_3–N concentration at the 0–60 cm depth layer decreased in order $V^{100} \geq R^{33}V^{67} \geq R^{67}V^{33} > R^{100}$ (Fig. 2). When the C:N ratio of plant residues increases above 25, the potential for soil N immobilization also increases (Allison, 1966). In our case, the C:N ratio of R^{100} ranged from 58 to 69 in 2004 and 2006, while the C:N ratio for V^{100} ranged from 13 to 14. When hairy vetch was grown with rye in mixed culture, the C:N ratio range from 17 to 21 in 2004 and 2006 for $R^{33}V^{67}$ and 25 for $R^{67}V^{33}$. In a residue decomposition study, Ruffo and Bollero (2003) reported that rye and rye in mixed culture with hairy vetch decomposed too slowly to be considered a reliable source of N for corn, while hairy vetch was a potential source of N for corn. In the present study, even with a higher accumulation of N in the V_{100}, possibly most of the N was released by time of the sowing of the corn due to warmer climatic conditions. In the same study, Ruffo and Bollero (2003) observed that at corn V6 stage, approximately 33 and 75% of the initial N content had been released from rye and hairy vetch residues, respectively. Although the application of 133 kg N ha^{-1} to the R^{100} treatment may reduce the potential of soil N immobilization by rye residues, this N rate was not enough to increase or maintain N uptake by sweet corn when compared with the sweet corn cultivated after no-CC and amended with 133 kg N ha^{-1} (Table 1).

Table 3. Effect of cover crop (R = rye, V = hairy vetch) and N rate treatment on weed biomass and coefficient of variation during sweet corn season in 2006.

Cover crop treatment	Weed biomass
	Mg ha^{-1}
Fallow	1.27ab†
V^{100}	1.49a
$R^{33}V^{67}$	0.88c
$R^{67}V^{33}$	1.05bc
R^{100}	0.92c
CV, %	38.1

† Means within columns followed by the same lowercase letters are not significantly different at $P \leq 0.05$.

The weed biomass accumulation at sweet corn harvest ranged between 0.80 and 1.66 Mg ha^{-1}. Rye residues, independently of the proportion utilized, significantly ($P \leq 0.05$) reduced weed biomass by 56% compared with the V^{100} treatment (Table 3). The better performance of rye on weed suppression was related to the soil coverage which was sustained until the sweet corn plants fully shade the ground. This is in agreement with reports that rye used as CC mulch effectively suppresses weed germination and establishment during commercial crops such as corn and cotton (Dhima et al., 2006; Vasilakoglou et al., 2006). There was no interaction between N-fertilizer rates and CC treatments, as well as there was no effect of applied N rates on weed suppression (data not shown). The overall accumulation of N by weeds ranged between 5 and 18 kg N ha^{-1}.

Use of Sweet Corn Yield Response to Assess Benefits from Cover-Crop-Based Systems

There were no differences between the FF_{200} and FF_{267} treatments for marketable sweet corn yield. Sweet corn cultivated on unfertilized CC area yielded three to six times more than absolute control (FF_0). Marketable ear yields for the FF_0 treatment were 0.12 and 0.22 Mg ha^{-1} for 2004 and 2006, respectively, while average marketable yields from CC with no-N-fertilizer yielded 3.80 and 3.44 Mg ha^{-1} for 2004 and 2006, respectively. In 2006, the statistical analysis showed that marketable yields were influenced by an interaction between CC and N rates treatments. When hairy vetch was included in the crop rotation, there was a positive marketable yield effect compared with the R^{100} treatment when no N-fertilizer was amended (Table 4). In fact, the N accumulation of hairy vetch CC treatments was at least three times greater than that of R^{100}. However, the mineralization of the residues may be poorly synchronized with the peak of sweet corn N demand (Zotarelli et al., 2008), thus potentially reducing the efficiency of N utilization from crop residues, as was evident from low biomass and N accumulation for unfertilized CC treatments

Table 4. **Sweet corn marketable fresh yield and coefficient of variation as affected by previous cover crop (R = rye, V = hairy vetch) in 2004 and 2006.**

Year	Cover crop treatment	N rate, kg ha^{-1} 0	67	133
		Marketable Yield, Mg ha^{-1}		
2004	Fallow	0.12bC†‡	5.18bB	14.23aA
	$R^{67}V^{33}$	3.80aC	9.35aB	14.69aA
	CV, %			25.6
2006	Fallow	0.22cC	3.23cB	14.45aA
	V^{100}	5.38aC	10.09aB	14.14aA
	$R^{33}V^{67}$	3.80aC	9.06abB	12.50abA
	$R^{67}V^{33}$	3.37aC	7.38bB	12.65abA
	R^{100}	1.21bB	3.70cB	11.48bA
	CV, %			20.1

† Means within columns followed by the same lowercase letters are not significantly different at $P \leq 0.05$.

‡ Means within rows followed by the same uppercase letters are not significantly different at $P \leq 0.05$.

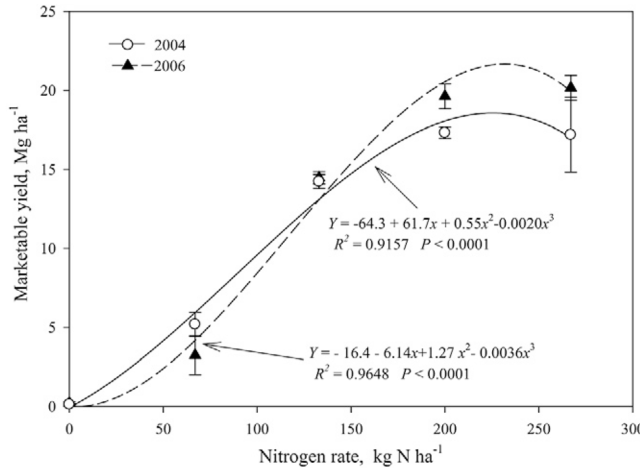

Fig. 4. Sweet corn marketable ears yield (*Y*) as a cubic function of supplemental N fertilizer rate in 2004 and 2006 for non-cover-crop based (control) systems.

(Table 1). Despite the fact that CC desiccation/mowing and sweet corn planting occurred within 2 or 3 wk, sweet corn germination did not occur until 1 wk afterward, while peak N demand only occurred at 40 to 50 DAE, thus reducing the potential benefits from the CC (Ruffo and Bollero, 2003). Early crop establishment of sweet corn was hampered by presence of crop residues on the soil surface which interfered with planting and resulted in uneven germination/initial crop establishment, as has also been reported by Dyck and Liebman (1994). Weather could also have triggered the loss of the early mineralized N, since the CC mowing occurred 2 wk earlier than the sweet corn sowing. For this period, the cumulative precipitation was 128 and 104 mm in 2004 and 2006, respectively. As a result, it could be argued that for CC system, the first N-application of supplemental N-fertilizer could be skipped.

The N contribution provided by CCs to sweet corn non-fertilized nutrition was estimated by regression (Fig. 4). In 2006, this contribution was equivalent to 35, 63, 64, and 75 kg N ha^{-1} of $NH_4NO_3$for R^{100}, $R^{67}V^{33}$, $R^{33}V^{67}$, and V^{100}, respectively, and in 2004, the $R^{67}V^{33}$ contribution was 47 kg N ha^{-1}. The better performance of sweet corn followed by CCs may be related to enhance nutrient retention of residual soil-N via initial immobilization and/or the more favorable soil microclimate underneath a mulch layer (Clark et al., 2007a, 2007b; Fageria et al., 2005). However, the benefit of CCs to sweet corn yield was drastically reduced when the N-fertilizer rate increased. When fertilized with 67 kg N ha^{-1}, the marketable yield of V^{100} and the mixtures of rye and hairy vetch yield between 7.4 to 10.1 Mg ha^{-1} while R^{100} yielded only 3.7 Mg ha^{-1} (Table 4). In addition, the chlorophyll meter reading for V^{100} and the CC mixtures ranged from 30 to 35 units for 0-N and from 42 to 44 units for the 67 kg N ha^{-1} treatment (Table 2). In the R^{100} treatment, the readings were lower, 27 and 37 for the 0 and 67 kg N ha^{-1} treatments, respectively (Table 2). The lower yield response of sweet corn in the R^{100} treatment clearly showed that rye residues required a higher supplemental N rate to increase yields and compensate soil N immobilization compared with other residue mixtures containing a higher vetch fraction. Similar results were observed by Clark et al. (2007b). When supplementing CC treatments with 133 kg N ha^{-1}, the different proportion of rye and vetch no longer affected yield or chlorophyll meter readings. This showed that in terms of N-requirements, CCs provide some benefits at low/intermediate fertilizer levels. For sandy soils, the rotation sweet corn and CCs required a supplementation of N-fertilizer > 133 kg ha^{-1} to achieve maximum yields. These findings are in accordance with the other experiments where different CCs were used in the crop rotation (Balkcom and Reeves, 2005; Cherr et al., 2007; Turgut et al., 2005), when CCs did not fully supply the spring crop N demands at high production levels.

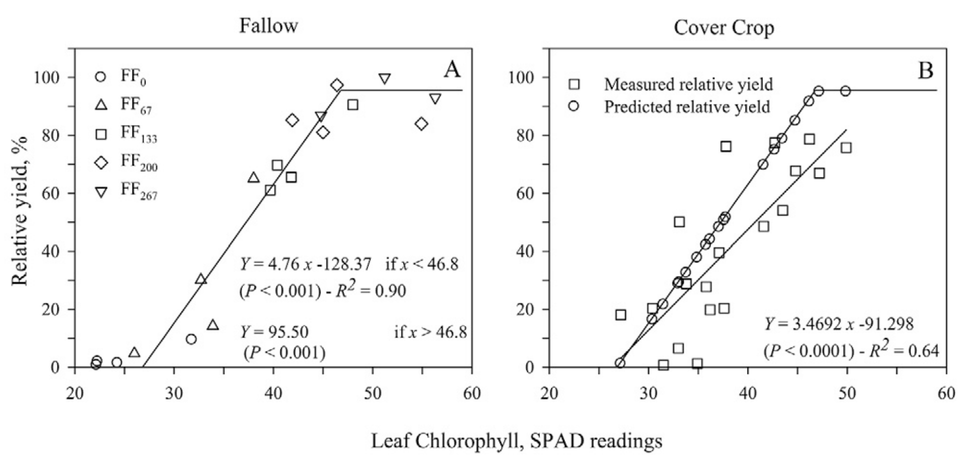

Fig. 5. Relative marketable yield of sweet corn function of leaf chlorophyll meter at 35 d after emergence (A) for sweet corn fertilized with 0, 67, 133, 200, and 267 kg N ha^{-1} and cultivated after fallow; and (B) for sweet corn cultivated with 0, 67, and 133 kg N ha^{-1} and cultivated after cover crops. Relative yields equal to measured yield divided by highest treatment mean. Relative marketable yield corresponded to the average from 2004 and 2006. Predicted yields values were obtained using the equation obtained in (A).

Chlorophyll meter readings and relative sweet corn yield were related ($P \leq 0.001$, $R^2 = 0.90$) at 35 d after emergence (Fig. 5A). Chlorophyll reading above 47 units showed that relative yields reached a plateau, which indicates that chlorophyll meter is a poor indicator of excess plant available N and luxury consumption at high N leaf concentration (Blackmer and Schepers, 1995) and/or when factors other than N could be limiting sweet corn yield (Hawkins et al., 2007). The marketable yield obtained for all CC treatments for both years were converted to relative yield based on the maximum measured yield in the experiment (Fig. 5B). The relationship obtained for sweet corn yield under N-fertilizer response curve for fallow was utilized to predict the relative yield under CC treatments. A linear relationship ($P \leq 0.0001$, $R^2 = 0.64$) between relative yield and chlorophyll meter readings was obtained for sweet corn for CC rotations (Fig. 5B). However, sweet corn yields in the CC treatments were slightly lower than yields predicted by chlorophyll meter readings. This confirmed the different N dynamic under CC system compared to non-cover-cropped area amended with N-fertilizer. In fact, CC and reduced N-fertilizer rate provided sufficient N for the initial plant development (Ruffo and Bollero, 2003); however, limited soil N availability due to the immobilization process may have occurred during the reproductive stage, even to the applied N rate of 133 kg ha^{-1} (Fig. 2D), where very low NO_3–N was observed at the top 30-cm depth for all cover-cropped treatments. As soil N testing is not recommended for sweet corn in Florida soils because of the very low N retention of sandy soils (Sartain, 2001; Simonne et al., 2005), a chlorophyll meter may still be used as a complementary in-season tool for detecting sweet corn N stress and to fine-tune supplemental N-fertilizer rate and/or timing. However, further studies are needed to assess optimal timing of supplemental N-fertilizer for CC-based systems. Use of decision support tools including the NDICEA model (van der Burgt et al., 2006) may be critical to provide a better insight in overall N release and to modify the timing of supplemental N applications to ensure more efficient N use in CC-based systems.

CONCLUSIONS

Cover-crop-based systems achieved higher initial growth rates, greater N accumulation, and ear yield in sweet corn systems in the absence of large quantities of supplemental N-fertilizer compared with no CC systems. However, CC based systems showed inferior performance in terms of both dry weight accumulation and plant growth compared with non-CC systems amended with 200 kg N ha^{-1}. Therefore, it is concluded that potential yield benefits from cover crops were greatest at lowest supplemental N rates and that their use may be only warranted if they provide additional benefits (including weed control and enhanced soil quality). Moreover, standard fertilizer recommendations may not apply to such systems, and in-season decision support systems may be required. For sweet corn under non-cover-crop systems , a positive correlation between chlorophyll meter reading and relative yield was observed for N rates ranging from 0 to 200 kg ha^{-1}. Chlorophyll meter was not sensitive indicator of plant N excess as occurred at N rate of 267 kg ha^{-1}. The assessment of sweet corn yield for cover-cropped areas through chlorophyll meter in early season was over estimated compared with the non-cover-cropped sweet corn. The inclusion of rye as a CC resulted in more effective weed suppression in a subsequent sweet corn crop compared with the use of hairy vetch CC.

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REFERENCES

AbdulBaki, A.A., J.R. Teasdale, R. Korcak, D.J. Chitwood, and R.N. Huettel. 1996. Fresh-market tomato production in a low-input alternative system using cover-crop mulch. Hortscience 31:65–69.

Allison, F.E. 1966. The fate of nitrogen applied to soils. Adv. Agron. 18:219–258.

Balkcom, K.S., and D.W. Reeves. 2005. Sunn-hemp utilized as a legume cover crop for corn production. Agron. J. 97:26–31.

Barnes, J.P., A.R. Putnam, B.A. Burke, and A.J. Aasen. 1987. Isolation and characterization of allelochemicals in rye herbage. Phytochemistry 26:1385–1390.

Bassirirad, H. 2000. Kinetics of nutrient uptake by roots: Responses to global change. New Phytol. 147:155–169.

Blackmer, T.M., and J.S. Schepers. 1995. Use of a chlorophyll meter to monitor nitrogen status and schedule fertigation for corn. J. Prod. Agric. 8:56–60.

Bundy, L.G., and T.W. Andraski. 2005. Recovery of fertilizer nitrogen in crop residues and cover crops on an irrigated sandy soil. Soil Sci. Soc. Am. J. 69:640–648.

Carlisle, V.W., F. Sodek III, M.E. Collins, and W.G. Harris. 1988. Characterization data for selected Florida soils. Soil Sci. Res. Rep. 88–1. Univ. of Florida Inst. of Food and Agric. Sci., Gainesville.

Chase, W.R., M.G. Nair, and A.R. Putnam. 1991. 2,2′-oxo-1,1′-azobenzene-selective toxicity of rye (*Secale cereale* L.) allelochemicals to weed and crop species: II. J. Chem. Ecol. 17:9–19.

Cherr, C.M. 2004. Improved use of green manure as a nitrogen source for sweet corn. MS thesis. Available at http://purl.fcla.edu/fcla/etd/UFE0006501 [verified 8 Dec. 2008]. Univ. of Florida, Gainesville.

Cherr, C.M., J.M.S. Scholberg, R. McSorley, and O.S. Mbuya. 2007. Growth and yield of sweet corn following green manure in a warm temperate environment on sandy soil. J. Agron. Crop Sci. 193:1–9.

Clark, A.J., A.M. Decker, and J.J. Meisinger. 1994. Seeding rate and kill date effects on hairy vetch cereal rye cover crop mixtures for corn production. Agron. J. 86:1065–1070.

Clark, A.J., A.M. Decker, J.J. Meisinger, F.R. Mulford, and M.S. McIntosh. 1995. Hairy vetch kill date effects on soil-water and corn production. Agron. J. 87:579–585.

Clark, A.J., A.M. Decker, J.J. Meisinger, and M.S. McIntosh. 1997. Kill date of vetch, rye, and a vetch-rye mixture: II. Soil moisture and corn yield. Agron. J. 89:434–441.

Clark, A.J., J.J. Meisinger, A.M. Decker, and F.R. Mulford. 2007a. Effects of a grass-selective herbicide in a vetch-rye cover crop system on nitrogen management. Agron. J. 99:36–42.

Clark, A.J., J.J. Meisinger, A.M. Decker, and F.R. Mulford. 2007b. Effects of a grass-selective herbicide in a vetch-rye cover crop system on corn grain yield and soil moisture. Agron. J. 99:43–48.

Dhima, K.V., I.B. Vasilakoglou, I.G. Eleftherohorinos, and A.S. Lithourgidis. 2006. Allelopathic potential of winter cereals and their cover crop mulch effect on grass weed suppression and corn development. Crop Sci. 46:345–352.

Dyck, E., and M. Liebman. 1994. Soil fertility management as a factor in weed-control—The effect of crimson clover residue, synthetic nitrogen-fertilizer, and their interaction on emergence and early growth of lambsquarters and sweet corn. Plant Soil 167:227–237.

Ebelhar, S.A., W.W. Frye, and R.L. Blevins. 1984. Nitrogen from legume cover crops for no-tillage corn. Agron. J. 76:51–55.

Elliott, C.L., G.H. Snyder, and J.L. Cisar. 1989. A modified AutoAnalyzer II method for the determination of NO_3-N in water using a hollow-Cd reduction coil. Commun. Soil Sci. Plant Anal. 20:1873–1879.

Fageria, N.K., V.C. Baligar, and B.A. Bailey. 2005. Role of cover crops in improving soil and row crop productivity. Commun. Soil Sci. Plant Anal. 36:2733–2757.

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

Giller, K.E., E.C. Rowe, N. de Ridder, and H. van Keulen. 2006. Resource use dynamics and interactions in the tropics: Scaling up in space and time. Agric. Syst. 88:8–27.

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

Guldan, S.J., C.A. Martin, J. CuetoWong, and R.L. Steiner. 1996. Dry-matter and nitrogen yields of legumes interseeded into sweet corn. Hortscience 31:206–208.

Hargrove, W.L. 1986. Winter legumes as a nitrogen-source for no-till grain-sorghum. Agron. J. 78:70–74.

Hawkins, J.A., J.E. Sawyer, D.W. Barker, and J.P. Lundvall. 2007. Using relative chlorophyll meter values to determine nitrogen application rates for corn. Agron. J. 99:1034–1040.

Hochmuth, G., and K. Cordasco. 2000. A summary of N, P, and K research with sweet corn in Florida. Vegetable nutrition management series. Available at http://edis.ifas.ufl.edu/CV235 [accessed 31 Aug. 2007; verified 8 Dec. 2008]. Hortic. Sci. Dep., Florida Cooperative Ext. Ser. no. HS758. Institute of Food and Agricultural Sci., Univ. of Florida.

Jones, J.B.J., and V.W. Case. 1991. Sampling, handling, and analyzing plant tissue samples. p. 289–427. *In* R.L. Westerman (ed.) Soil testing and plant analysis. 3rd ed. SSSAJ, Madison, WI.

Kuo, S., and E.J. Jellum. 2002. Influence of winter cover crop and residue management on soil nitrogen availability and corn. Agron. J. 94:501–508.

Liebman, M., and A.S. Davis. 2000. Integration of soil, crop and weed management in low-external-input farming systems. Weed Res. 40:27–47.

Ma, B.L., and L.M. Dwyer. 1998. Nitrogen uptake and use of two contrasting maize hybrids differing in leaf senescence. Plant Soil 199:283–291.

Macdonald, A.J., D.S. Powlson, P.R. Poulton, and D.S. Jenkinson. 1989. Unused fertilizer nitrogen in arable soils—Its contribution to nitrate leaching. J. Sci. Food Agric. 46:407–419.

McCracken, D.V., M.S. Smith, J.H. Grove, C.T. Mackown, and R.L. Blevins. 1994. Nitrate leaching as influenced by cover cropping and nitrogen-source. Soil Sci. Soc. Am. J. 58:1476–1483.

Muchow, R.C., Sinclair, T.R. and Bennett, J.M., 1990. Temperature and solar radiation effects on potential maize yield across locations. Agron. J. **82:**338–343.

Plénet, D., and G. Lemaire. 1999. Relationships between dynamics of nitrogen uptake and dry matter accumulation in maize crops. Determination of critical N concentration. Plant Soil 216:65–82.

Ranells, N.N., and M.G. Wagger. 1996. Nitrogen release from grass and legume cover crop monocultures and bicultures. Agron. J. 88:777–782.

Ranells, N.N., and M.G. Wagger. 1997. Winter annual grass-legume bicultures for efficient nitrogen management in no-till corn. Agric. Ecosyst. Environ. 65:23–32.

Rochester, I., and M. Peoples. 2005. Growing vetches (*Vicia villosa* Roth) in irrigated cotton systems: Inputs of fixed N, N fertiliser savings and cotton productivity. Plant Soil 271:251–264.

Ruffo, M.L., and G.A. Bollero. 2003. Modeling rye and hairy vetch residue decomposition as a function of degree-days and decomposition-days. Agron. J. 95:900–907.

Sainju, U.M., and B.P. Singh. 2001. Tillage, cover crop, and kill-planting date effects on corn yield and soil nitrogen. Agron. J. 93:878–886.

Sainju, U.M., W.F. Whitehead, and B.P. Singh. 2005. Biculture legume-cereal cover crops for enhanced biomass yield and carbon and nitrogen. Agron. J. 97:1403–1412.

Sartain, J.B. 2001. Soil Testing and Interpretation for Florida Turfgrasses. Soil and Water Sci. Dep., Florida Coop. Ext. Serv., Inst. of Food and Agricultural Sci., Univ. of Florida, Gainesville.

Simonne, E., G. Hochmuth, D.N. Maynard, C.S. Vavrina, W.M. Stall, S.M. Olson, S.E. Webb, T.G. Taylor, and S.A. Smith. 2005. Sweet corn production in Florida. p. 337–347. *In* S.M. Olson and E. Simonne (ed.) Vegetable Production Handbook for Florida 2005–2006. IFAS, Gainesville.

Singogo, W., W.J. Lamont, and C.W. Marr. 1996. Fall-planted cover crops support good yields of muskmelons. HortScience 31:62–64.

Sullivan, P.G., D.J. Parrish, and J.M. Luna. 1991. Cover crop contribution to N supply and water conservation in corn production. Am. J. Alt. Agric. 6:106–114.

Teasdale, J.R. 1993. Interaction of light, soil-moisture, and temperature with weed suppression by hairy vetch residue. Weed Sci. 41:46–51.

Teasdale, J.R., and C.S.T. Daughtry. 1993. Weed suppression by live and desiccated hairy vetch (*Vicia villosa*). Weed Sci. 41:207–212.

Tolleyhenry, L., C.D. Raper, and T.C. Granato. 1988. Cyclic variations in nitrogen uptake rate of soybean plants- effects of external nitrate concentration. J. Exp. Bot. 39:613–622.

Turgut, I., U. Bilgili, A. Duman, and E. Acikgoz. 2005. Effect of green manuring on the yield of sweet corn. Agron. Sust. Develop. 25:433–438.

USDA. 1997. United States standards for grades of sweet corn for processing. USDA, Washington, DC.

USDA. 2008. U.S. sweet corn statistics. http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1564 [accessed 9 Sept. 2008; verified 8 Dec. 2008]. National Agricultural Statistics Service, USDA, Washington, DC.

van der Burgt, G.J.H.M., G.J.M. Oomen, A.S.J. Habets, and W.A.H. Rossing. 2006. The NDICEA model, a tool to improve nitrogen use efficiency in cropping systems. Nutr. Cycl. Agroecosyst. 74:275–294.

Vasilakoglou, I., K. Dhima, I. Eleftherohorinos, and A. Lithourgidis. 2006. Winter cereal cover crop mulches and inter-row cultivation effects on cotton development and grass weed suppression. Agron. J. 98:1290–1297.

Wagger, M.G. 1989. Time of desiccation effects on plant composition and subsequent nitrogen release from several winter annual cover crops. Agron. J. 81:236–241.

Zotarelli, L., J.M. Scholberg, M.D. Dukes, and R. Muñoz-Carpena. 2008. Fertilizer residence time affects nitrogen uptake efficiency and growth of sweet corn. J. Environ. Qual. 37:1271–1278.