Effects of Cover Crops, Nitrogen, and Tillage on Sweet Corn

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ADDITIONAL INDEX WORDS. nitrogen fixation, *Vicia villosa*, *Secale cereale*, no-till vegetables, *Zea mays*

SUMMARY. Effects of tillage, inorganic N, and winter cover crops on sweet corn (*Zea mays*) were examined in 1994, 1995, and 1996. Tillage treatments were tillage or no tillage, and N treatments were the addition of inorganic N at 0 (N0) or 200 (N+) kg·ha^{-1} (0 or 179 lb/acre). Winter cover crops included hairy vetch (*Vicia villosa*), winter rye (*Secale cereale*), and a vetch/rye biculture. In the N0, rye treatment, the soil was N deficient in 1994 and highly N deficient in 1995 and 1996. When vetch shoot N content was ≥150 kg·ha^{-1} (134 lb/acre) (1994 and 1995), addition of inorganic N did not increase corn yields, and it only increased corn foliar N concentrations by 8%. Reductions in corn yields (29%) and foliar N concentrations (24%) occurred when vetch shoot N content was only 120 kg·ha^{-1} (107 lb/acre) (1996) and inorganic N was not supplied. In 1994, the vetch/rye biculture supplied sufficient N for maximum corn yields, but addition of inorganic N increased yields by more than 50% in 1995 and 1996. Under tilled conditions, the vetch N contribution to corn appeared to equal (1996) or exceed (1994 and 1995) 82 kg·ha^{-1} (73 lb/acre) of N supplied as ammonium nitrate, whereas a mean value of 30 kg·ha^{-1} (27 lb/acre) was obtained for the biculture cover crop (1995 and 1996). No significant effects of tillage on sweet corn population densities were detected following vetch, but no-tillage significantly reduced corn population densities following rye (17%) or biculture (35%) cover crops compared to tillage. No-tillage did not reduce yields from emerged seedlings (per plant basis) for any cover crops. Vetch appeared to be a satisfactory N source for sweet corn when vetch N content was ≥150 kg·ha^{-1}, and it could be used with no-tillage without yield reductions.

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This research was funded by a USDA., CSREES grant to Kentucky State University under agreement KY.X-10-94-21P.

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Concerns about effects of conventional agricultural practices on long-term productivity, environmental pollution, production costs, and health have discouraged the use of chemical fertilizers and promoted the use of sustainable farming methods (National Research Council, 1989). Such methods include the use of legume cover crops and no-tillage.

Much soil in the United States is being eroded more rapidly than it is being replaced naturally, especially in Kentucky, which is among the five states most affected by water erosion of soil (Cannell and Hawes, 1994). The United States contains 58 million ha (143 million acres) of highly erodible lands, including 46% of the cultivated land in Kentucky (Ditsch and Murdock, 1988; Moldenhauer and Blevins; 1995). The practice of no-tillage reduces soil erosion, while conserving water, improving soil structure, and reducing production costs (Cannell and Hawes, 1994; Johnson and Hoyt, 1999). Disadvantages of no-tillage include problems associated with seedling emergence, soil compaction, weeds, low soil temperatures, and possible yield reductions (Hoyt, 1999; Morse, 1999). However, no-tillage may be more profitable than conventional tillage due to lower production costs (Phillips et al., 1997). No-tillage is commonly used with agronomic crops such as field corn (*Zea mays)*, but evidence suggests it also may be applicable to vegetable crops (e.g., sweet corn), which normally possess less vigor than agronomic crops (Hoyt et al., 1994; Morse, 1999).

Use of legume winter cover crops can reduce inorganic N fertilizer requirements and production costs through symbiotic N_2 fixation (Frye et al, 1985). Amounts of fixed dinitrogen gas (N_2) often exceed 100 kg·ha^{-1} (89 lb/acre), but fixed N_2 is not as available to plants as inorganic N fertilizer since fixed N_2 must be mineralized before being absorbed by plants (Smith et al, 1987). The N_2 fixed by winter annual legumes normally must be supplemented with inorganic N fertilizer to obtain optimum yields of agronomic crops (Smith et al, 1987; Hanson et al., 1993). However, the seasonal dynamics of soil N availability and plant requirements are different for summer vegetables (e.g., sweet corn) than for common agronomic crops (e.g., field corn). Most vegetables have shorter maturation times and thus require N for a shorter time period. However, because most summer vegetables are irrigated, they tend to grow rapidly and require more N under dry summer conditions than common agronomic crops. For example, vetch/rye biculture residue has supplied sufficient N to no-till field corn without irrigation but not under irrigated conditions (Mitchell and Teel, 1977). Increased soil moisture from vegetable irrigation should also increase soil N availability by enhancing N mineralization of cover crop residue. Furthermore, summer vegetables are often planted later in the spring than many common agronomic crops, allowing for additional N_2 fixation by cover crops under optimal spring conditions (Clark et al. 1994, 1997a; Wagger, 1989).

Table 1. Planting schedule for field corn, vegetables, and winter cover crops at Frankfort, Ky., from 1993 to 1996.

	Crop	
Planting date	**Site 1**	**Site 2**
May 1993	Field corn	Field corn
September 1993	Cover crops	Cover crops
June 1994	Watermelon[z]	Sweet corn
September 1994	Cover crops	Cover crops
June 1995	Sweet corn	Watermelon
September 1995	Cover crops	Cover crops
June 1996	Watermelon	Sweet corn

[z]The watermelon experiment is not included in this report.

Compared to field corn, sweet corn is planted later and harvested earlier, plus it is often irrigated. Thus, in contrast to field corn, winter legumes may satisfy N requirements of sweet corn because there is 1) more time available for legume N_2 fixation, 2) a shorter growing season, and 3) enhanced legume N mineralization related to irrigation.

Hairy vetch is considered the superior winter annual legume in the central and southern U.S. (Smith et al, 1987). Vetch may supply sufficient N to some vegetables such as muskmelon (*Cucumis melo*), whereas tomato (Lycopersicon esculentum) may require supplemental N for optimum production (Abdul-Baki et al., 1997; Singogo et al., 1996). In Oregon, sweet corn and broccoli (*Brassica oleracea*) required additional N fertilizer for optimal yields following legume winter cover crops not including hairy vetch (Burkett et al., 1997). Winter rye is the most common small grain winter cover crop in the central U.S. (Bollero and Bullock, 1994).

Federal incentives and research have increased the use of no-tillage and legumes with agronomic crops (Cannell and Hawes, 1994; Smith et al, 1987), but research is needed to resolve uncertainties of vegetable growers about using these sustainable methods (Hoyt et al., 1994; Rutledge, 1999). Sweet corn is planted on more acres in Kentucky than any other vegetable and can be a supplemental crop to the leading cash crop, tobacco (*Nicotiana tabacum*), whose future is uncertain (USDA, 1999). The objectives were to 1) examine winter rye, hairy vetch, and a rye/vetch biculture as cover crop N sources for sweet corn and 2) determine effects of no-tillage on yields of sweet corn following these cover crops.

Materials and methods

Effects of tillage, inorganic N, and winter cover crops on 'Merit' sweet corn were examined in 1994, 1995, and 1996 in a 2 × 2 × 3 factorial, split-plot experiment. Main plots received tillage or no tillage. Subplot N treatments were the addition of inorganic N at 0 (N0) or 200 (N+) kg·ha^{-1} (0 or 179 lb/acre), and subplot winter cover crops included hairy vetch, winter rye, and a vetch/rye biculture. The six combinations of N and cover crop treatments were randomized within main plots, and all treatment combinations were replicated three times. Subplots were 5 m (16.4 ft) square and at least 1 m (3.3 ft) distant from bordering subplots. In 1994 and 1996, the experiment was conducted at a site containing Elk silt loam soil (fine-silty, mixed, mesic, Ultic Hapludalfs) with a pH of 6.4. An adjacent site with similar soil was used in 1995. As indicated in the cropping sequence described in Table 1, field corn was grown on all plots in 1993 without N fertilizer to reduce soil N availability. In 1995 and 1996, cover crops followed watermelon (*Citrillus lanatus*) that received N treatments similar to those for sweet corn in this study, except that addition of inorganic N in the N+ treatment was 30% lower for watermelon. Individual subplots received the same cover crop and N treatments (N0 or N+) in successive years regardless of which vegetable was grown.

Cover crops were drilled on 10, 20, and 25 Sept. 1994, 1995, and 1996, respectively. Vetch seed was inoculated with Rhizobium, and monoculture seeding rates for vetch and rye were 45 and 120 kg·ha^{-1} (40 and 107 lb/acre), respectively. Seeding rates of each cover crop were reduced by 50% in the biculture treatment. In mid-May, about 2 weeks before corn planting, cover crops were killed by moldboard plowing to a depth of 20 cm (7.9 inches) in tilled plots or by application of (a.i.) 0.35 kg·ha^{-1} (0.31 lb/acre) paraquat 8 d later in no-till plots, followed by rotary mowing. A minimum of 2 weeks is recommended between plowing and planting sweet corn to allow the soil to settle and cover crop toxins to decompose (Rowell et al., 1998). One to 2 d before kill dates, four subsamples of aboveground cover crops were removed from a total area of 0.5 m^2 (5.4 ft^2) in each subplot and combined. Vetch and rye were separated in the biculture treatment. After drying at 65 °C (149 °F) for 48 h, the samples were weighed and ground to a particle size ≤0.4 mm (0.016 inch). An N analyzer (model FP-228; Leco Corp., St Joseph, Mich.) was used to determine shoot N concentrations.

Inorganic N as ammonium nitrate (NH_4NO_3) was added manually at rates of 0 or 125 kg·ha^{-1} (112 lb/acre) in appropriate treatments before corn planting and sidedressed 4 weeks later at rates of 0 or 75 kg·ha^{-1} (67 lb/acre). Thus, factorial N0 and N+ treatments consisted of 0 or 200 kg·ha^{-1} (179 lb/acre) of total N, respectively. To obtain a N response curve, corn in two additional tilled, rye treatments received 25 or 75 kg·ha^{-1} (22 or 62 lb/acre) of N, including preplant and sidedress applications in proportion to those in the N+ treatment. All plots received 160 kg·ha^{-1} (143 lb/acre) of K and 12 kg·ha^{-1} (11 lb/acre) of Zn as K_2O and $ZnSO_4$, respectively. The soil was naturally high in P availability. In 1994 and 1995, fertilizer was applied less than 4 d before corn planting and rototilled into tilled plots. In 1996, fertilizer was applied 12 d prior to planting because planting was delayed to allow no-till cover crop surface debris to dry sufficiently for planting. Weeds were controlled in all treatments by preplant application of (a.i.) 1.12 kg·ha^{-1} (1.0 lb/acre) atrazine and (a.i.) 3.4 kg·ha^{-1} (3.0 lb/acre) alachlor.

Sweet corn was planted on 3, 7, and 17 June 1994, 1995, 1996, respectively using a Cole no-till planter (Powell Manufacturing Co., Bennettsville, S.C.) equipped with a Kinze planting unit (Kinze Manufacturing Inc., Williamsburg, Iowa) and a fluted coulter. Five rows were planted per subplot with a 0.9 m (3 ft) row spacing. Plant populations in tilled plots averaged 62,000 plants/ha (25,000 plants/acre) after 3 weeks. Drip irrigation was supplied as necessary in accordance with readings of tensiometers placed at soil depths of 15 and 45 cm (6 and 18 inches). Insects were controlled beginning at silking by repeated application of permethrin.

Plant populations in each subplot were determined 3 to 4 weeks after planting. At this time 1.5 to 2.0 m (4.9 to 6.6 ft) segments in each of the middle three rows containing six representative, evenly spaced plants were identified. Segments were >1 m from subplot borders. Ears from the selected plants were harvested at the milk stage. Numbers, fresh weights, lengths, and circumferences of ears were recorded as well as weights and numbers of culls. Marketable ears were defined as ears with lengths and circumferences exceeding 70% of the mean values obtained in the N+, rye treatment. Numbers of marketable ears with insect damage were determined visually. Corn foliar N was determined at silking in 1994 and four times each year in 1995 and 1996 on alternate weeks beginning about 3 weeks after planting. One recently mature corn leaf was collected from each of the three middle rows in each subplot. Leaf N concentrations were determined for the three combined leaves per subplot using methods described previously. The Statistical Analysis System was used to perform three-way analyses of variance and determine least significant differences ($P \leq 0.05$) among treatment means (SAS Institute, 1985).

Results and discussion

Interactions of tillage treatments with N and cover crop treatments were not significant for cover crop N content, sweet corn yields, or foliar N concentrations; thus, results were analyzed for combined tillage treatments.

WINTER COVER CROPS. In 1994 and 1995, shoot N content of hairy vetch was about 150 kg·ha^{-1} and within the range of 134 to 168 kg·ha^{-1} (120 to 150 lb/acre) of inorganic N recommended for sweet corn in Kentucky (Rowell et al., 1998) (Table 2). Vetch N content decreased to 120 kg·ha^{-1} in 1996 due to cold spring temperatures (Cline and Silvernail, 2001). Vetch N content was over twice as high as that of rye and tended to be similar to the N content of the biculture cover crop. Cover crop biomass production and N concentrations were similar to analogous cover crops following sweet corn and preceding watermelon each year at the adjacent site as described by Cline and Silvernail (2001). In the N+ treatment rye and biculture biomass production was similar and usually significantly greater than that of vetch, except in 1996. Vetch and biculture biomass production was normally similar in the N0 treatment, whereas rye biomass production was usually significantly lower. In both N treatments shoot N concentrations were significantly different among all three cover crops and ranged as follows in descending order of cover crops: vetch = 31 to 39 g·kg^{-1} (1 g·kg^{-1} = 0.1%), biculture = 13 to 33 g·kg^{-1}, and rye = 8 to 12 g·kg^{-1}.

COVER CROP EFFECTS ON CORN YIELDS. Sweet corn yields were determined from preselected plants (per plant basis), and thus do not include effects of tillage on corn plant population densities. Following field corn not receiving N in 1993, sweet corn yields in the 1994 rye treatment were significantly increased by 36% by addition of inorganic N, indicating the soil was N deficient (Fig. 1A). The soil became highly N deficient in 1995 and 1996 when corn yields were negligible in the N0, rye treatment (Fig. 1B and C).

In 1994, the vetch/rye biculture supplied sufficient N to produce maximum sweet corn yields (Fig. 1A), in agreement with results of Griffin et al. (2000) in short-term experiments using moderately N-deficient soil. Vetch/rye bicultures do not normally supply sufficient N to field corn, which has a longer growing season than sweet corn (Clark et al., 1994, 1997b; Sullivan et al., 1991). In 1995 and 1996, corn yields following biculture cover crops were more than 50% larger in the N+ treatment than in the N0 treatment (Fig. 1B and C) Thus, after several years without supplemental N, the biculture cover crop was unable to contribute adequate N to sweet corn. Additional N was also needed to obtain optimum yields of sweet corn following biculture cover crops containing rye and austrian pea (*Pisum sativum*) (Burket et al., 1997).

Corn yields following vetch were similar in N0 and N+ treatments in 1994 and 1995, indicating that vetch supplied sufficient N to the corn, even when the soil was highly N deficient in 1995 (Fig. 1A and B). However, 1996 corn yields following vetch were significantly reduced by 29% if inorganic N fertilizer was not supplied (Fig. 1C). Apparently, in highly N-deficient soil (1995), 150 kg·ha^{-1} of vetch N was sufficient to produce normal yields of sweet corn, but a 20% reduction in vetch N to 120 kg·ha^{-1} (1996) was insufficient (Table 2). In other studies with vetch, supplemental N was needed to obtain maximum yields of sweet corn (Hoyt, 1992) and field corn (Clark et al., 1994, 1997b; Smith et al., 1987), but vetch supplied sufficient N to field corn when vetch N content was high, i.e. about 300 kg·ha^{-1} (268 lb/acre) (Holderbaum et al., 1990).

Although the N contents of the vetch and biculture cover crops were similar in the N0 treatment (Table 2), corn yields in 1995 and 1996 were significantly greater following vetch than following the biculture cover crop (Fig. 1B and C). Similar results have been obtained with field corn (Clark et al., 1994, 1997b; Sullivan et al., 1991). Compared to vetch N, biculture N apparently is not as available to following crops due to microbial immobilization of N accompanying the decomposition of the rye component of the biculture cover crop (Allison, 1966; Clark et al., 1994).

NITROGEN FERTILIZER EQUIVALENTS. To estimate N contributions of vetch and biculture cover crops, N response curves were obtained each year for corn following rye using four rates of inorganic N fertilization (Smith et al., 1987) (Fig. 2). In 1996, the yield of tilled corn following vetch was 3.48 kg/subplot (7.66 lb/subplot), and it increased significantly if inor-

Table 2. Effects of prior N0 and N+ watermelon fertilization treatments on nitrogen (N) contents of winter cover crops preceding sweet corn at Frankfort, Ky. N0 and N+ = addition of N as ammonium nitrate (NH_4NO_3) at 0 or 140 kg·ha^{-1} (120 lb/acre), respectively.

	N content (kg·ha^{-1})[z]	
Cover crop	N0	N+
1994		
Rye	43 ± 5 b[y]	
Vetch	156 ± 7 a	
Biculture[x]	152 ± 10 a	
1995		
Rye	28 ± 4 b	64 ± 20 c
Vetch	148 ± 9 a	164 ± 12 a
Biculture	104 ± 19 a	141 ± 4 b
1996		
Rye	35 ± 3 b	43 ± 2 c
Vetch	120 ± 6 a	115 ± 5 b
Biculture	132 ± 24 a	149 ± 22 a

[z]1 kg·ha^{-1} = 0.89 lb/acre.
[y]Values are means ± SE (n = 6) summed over vegetable tillage treatments. For each year values in columns followed by different letters were significantly different ($P \leq 0.05$).
[x]Biculture = mixture of vetch and rye.

ganic N was added (Fig. 1C). By inserting 3.48 kg/subplot into the equation of the 1996 N response curve described in Fig. 2, the 1996 vetch N contribution in terms of inorganic N fertilizer equivalents (NFE) was calculated as 82 kg·ha^{-1} of N as NH_4NH_3. In 1994 or 1995 corn yields following vetch were not increased by addition of inorganic N. Consequently, vetch NFE could not be calculated from the N response curve in 1994 or 1995 because corn yields following vetch were not located in the range of the response curve in which the degree of slope was sufficient to accurately determine NFE. However, vetch NFE were probably >82 kg·ha^{-1} in 1994 and 1995 because vetch N contents were greater than in 1996 (Table 2). Also, vetch N was sufficient to produce yields similar to those obtained from the N+ treatment in 1994 and 1995, in contrast to 1996. Vetch NFE for field corn are typically ≤100 kg·ha^{-1} (Mitchell and Teel, 1977; Smith et al., 1987; Varco et al., 1989).

Biculture NFE were not determined in 1994 for reasons similar to

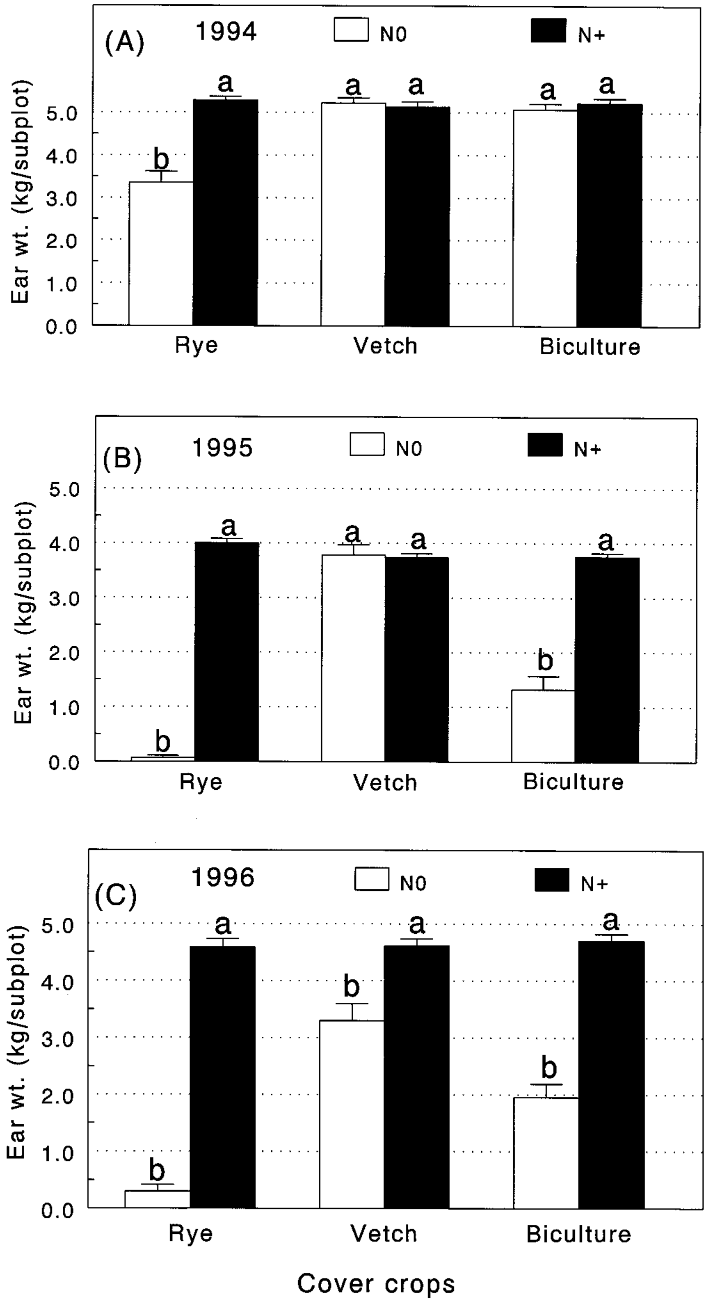
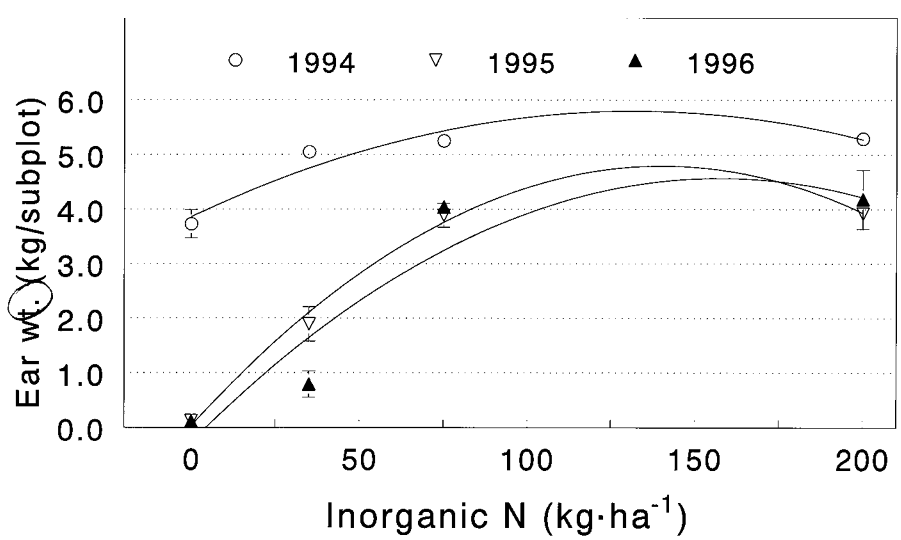


Fig. 1 (above). Effects of cover crops and inorganic nitrogen (N) fertilization on sweet corn yields in (A) 1994, (B) 1995, and (C) 1996. Values ±SE (n = 6) are summed over tillage. Within each bar pair different letters denote significant ($P \leq 0.05$) differences. N0 = no inorganic N applied. N+ = 200 kg·ha^{-1} (179 lb/acre) of inorganic N applied. Biculture = mixture of vetch and rye. Subplot = replicated experimental unit from which corn was harvested from 18 plants (6 plants in each of three rows); 1.0 kg = 2.2 lb.

Fig. 2 (below). Response of sweet corn following rye to inorganic nitrogen (N) fertilization under tilled conditions. Data points are means ±SE (n = 3). Regression lines and equations were determined using individual observations. 1994, $y = -0.000113x^2 + 0.0296x + 3.86$ ($r^2 = 0.78, P \leq 0.01$); 1995, $y = -0.000241x^2 + 0.0677x + 0.0320$ ($r^2 = 0.97, P \leq 0.01$); 1996, $y = -0.000195x^2 + 0.0614x - 0.266$ ($r^2 = 0.86, P \leq 0.01$). Subplot = replicated experimental unit from which corn was harvested from 18 plants (6 plants in each of three rows); 1 kg·ha^{-1} = 0.89 lb/acre, 1.0 kg = 2.2 lb.



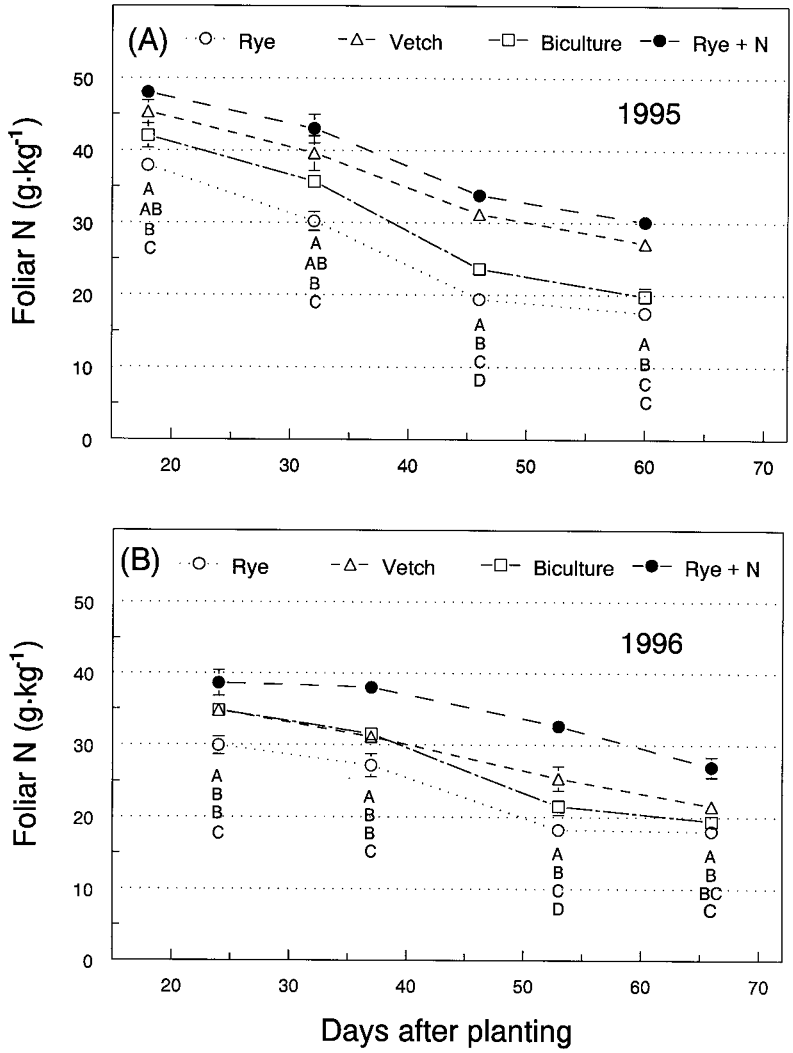


Fig. 3. Effects of cover crops and inorganic nitrogen (N) fertilization on sweet corn foliar N in (A) 1995 and (B) 1996. Values ±SE (n = 6) are summed over tillage. At each sampling date different letters denote significant ($P \leq 0.05$) differences. Biculture = mixture of vetch and rye. Rye + N = 200 kg·ha^{-1} (179 lb/acre) of inorganic N applied to sweet corn following rye; 1 g·kg^{-1} = 0.1%.

those given for vetch in 1994 and 1995. Tilled corn yields following the biculture cover crop in 1995 [1.59 kg/subplot (3.50 lb/subplot)] and 1996 [1.68 kg/subplot (3.70 lb/subplot)] responded to addition of inorganic N (Fig. 1B and C). Biculture N contributions were calculated as 25 kg·ha^{-1} (1995) and 36 kg·ha^{-1} (1996) (22 and 32 lb/acre, respectively) from equations for the 1995 and 1996 N response curves (Fig. 2).

COVER CROP EFFECTS ON CORN FOLIAR N. In 1995, corn foliar N concentrations in the N0, vetch treatment were consistently only 8% lower than N concentrations in the N+, rye treatment, although these differences were significant at the last two sampling dates (Fig. 3A). Corn foliar N concentrations following vetch were always significantly greater than N concentrations following biculture and rye cover crops, particularly at the last two sampling dates. These data were consistent with the effects of cover crops on corn yields attributed to N nutrition (Fig. 1B).

In 1996, corn N concentrations in the N0, vetch treatment were significantly lower (24%) than concentrations in the N+, rye treatment, and they were similar to N concentrations in the N0, biculture treatment (Fig. 3B). These data agreed with previous results indicating that neither vetch or biculture cover crops provided sufficient N to corn in 1996 (Fig. 1C).

Corn foliar N data also supported yield results from 1994. As with 1994 yields (Fig. 1A), foliar N concentrations at silking were similar among the

Table 3. Effects of nitrogen (N) and tillage treatments on sweet corn ear dimensions following rye, vetch, and biculture cover crops in 1995 and 1996 at Frankfort, Ky. Biculture = mixture of rye and vetch.

		Ear length (cm^z)			Ear circumference (cm^z)		
Year	Treatment	Rye	Vetch	Biculture	Rye	Vetch	Biculture
N effects							
1995	N0^y	3.1 ± 1.7 b^v	19.4 ± 0.2 a	14.2 ± 1.1 b	2.3 ± 1.3 b	14.9 ± 0.1 a	12.7 ± 0.1 b
	N+^{x}	19.9 ± 0.2 a	19.8 ± 0.2 a	20.0 ± 0.1 a	15.4 ± 0.1 a	14.9 ± 0.1 a	14.9 ± 0.2 a
1996	N0	6.3 ± 1.8 b	17.5 ± 0.8 b	17.5 ± 0.8 b	6.6 ± 1.6 b	15.2 ± 0.2 b	13.9 ± 0.9 b
	N+	19.6 ± 0.3 a	19.2 ± 0.3 a	19.2 ± 0.3 a	16.0 ± 0.2 a	16.2 ± 0.1 a	16.2 ± 0.1 a
Tillage effects							
1995	Tilled	19.7 ± 0.4 a^u	19.8 ± 0.2 a	19.9 ± 0.2 a	15.6 ± 0.2 a	14.9 ± 0.2 a	15.3 ± 0.2 a
	No-till	20.1 ± 0.2 a	19.9 ± 0.2 a	20.1 ± 0.4 a	15.2 ± 0.1 a	14.9 ± 0.2 a	14.6 ± 0.2 a
1996	Tilled	19.0 ± 0.3 a	18.5 ± 0.4 a	19.0 ± 0.3a	15.6 ± 0.3 a	16.0 ± 0.2 a	15.8 ± 0.2 a
	No-till	20.3 ± 0.3 a	20.0 ± 0.3 a	20.2 ± 0.3 a	16.5 ± 0.1 a	16.4 ± 0.2 a	16.5 ± 0.1 a

^{z}1.0 cm = 0.39 inch.
^{y}N0 = no inorganic N added.
^{x}N+ = addition of inorganic N at 200 kg·ha^{-1} (179 lb/acre).
^{v}Values are means ± SE (n = 6) summed over tillage. For each year values in columns followed by different letters were significantly different ($P \leq 0.05$).
^{u}Values are means ± SE (n = 3) for treatments receiving inorganic N (N+ treatment).

Table 4. Effects of nitrogen (N) treatments on marketable sweet corn yields following rye, vetch, and biculture cover crops in 1995 and 1996 at Frankfort, Ky. Biculture = mixture of rye and vetch.

Year	N treatment	Marketable ears (no. ears/subplot[z])			Marketable ears (wt, kg/subplot[y])		
		Rye	Vetch	Biculture	Rye	Vetch	Biculture
1995	N0[x]	2.1 ± 0.6 b[u]	17.4 ± 0.9 a	8.7 ± 1.2 b	0.18 ± 0.05 b	1.71 ± 0.08 a	0.80 ± 0.15 b
	N+[v]	18.0 ± 0.0 a	18.0 ± 0.0 a	18.0 ± 0.0 a	1.81 ± 0.04 a	1.70 ± 0.03 a	1.70 ± 0.03 a
1996	N0	5.4 ± 1.8 b	16.8 ± 0.3 b	12.0 ± 0.3 b	0.93 ± 0.33 b	3.60 ± 0.24 b	2.22 ± 0.27 b
	N+	17.8 ± 0.3 a	18.0 ± 0.0 a	18.0 ± 0.0 a	4.59 ± 0.15 a	4.52 ± 0.12 a	4.71 ± 0.12 a

[z]Subplot = replicated experimental unit from which corn was harvested from 18 plants (6 plants in each of three rows).
[y]1.00 kg = 2.21 lb.
[x]N0 = no inorganic N added.
[v]N+ = addition of inorganic N at 200 kg·ha^{-1} (179 lb/acre).
[u]Values are means ± SE from six subplots summed over tillage. For each year, values in columns followed by different letters were significantly different ($P \leq 0.05$).

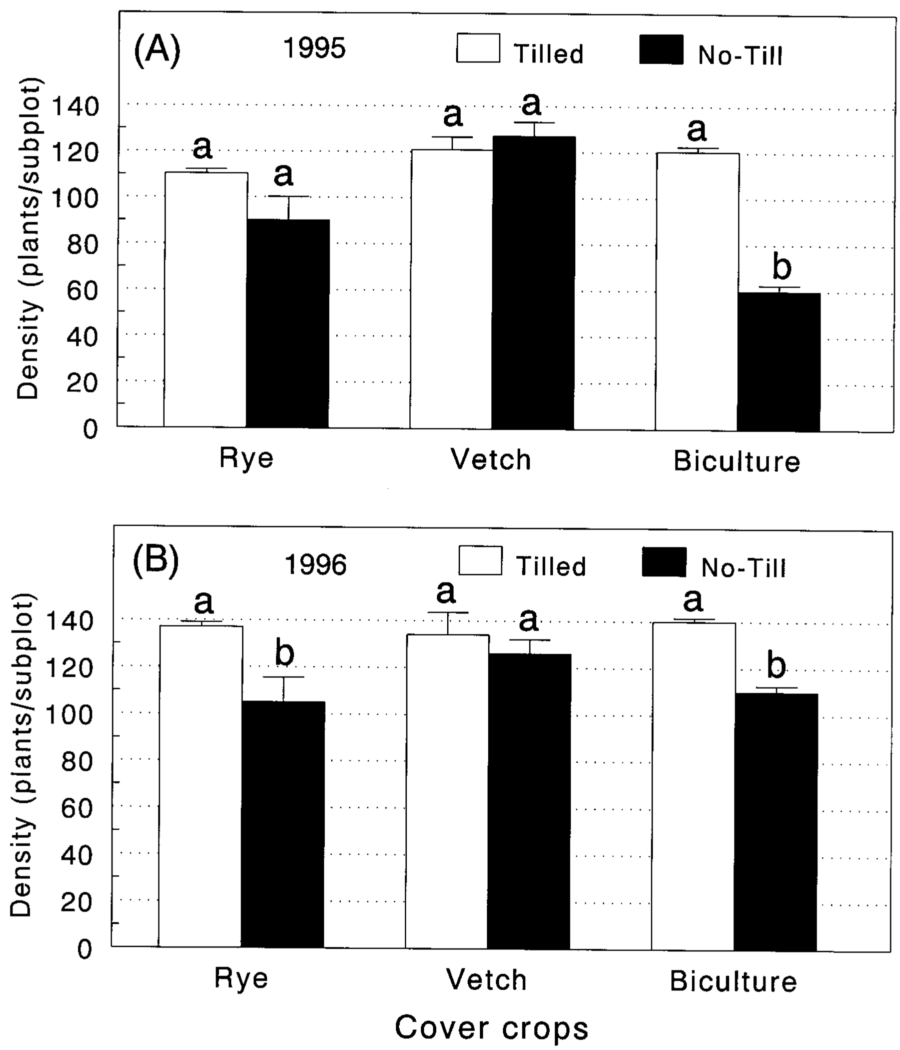
following treatment combinations: N0 + vetch (34 g·kg^{-1}), N0 + biculture (34 g·kg^{-1}), and N+ + rye (33 g·kg^{-1}). These N concentrations were significantly ($P > 0.05$) greater than those obtained in the N0, rye treatment (28 g·kg^{-1}).

In the N+ treatment corn foliar N concentrations tended to be greatest following vetch and lowest following rye. However, differences among all cover crops were always <2 mg·kg^{-1} and seldom significant (data not presented).

Cover crop effects on corn quality. Cover crop and N effects on ear dimensions and marketable ears (Tables 3 and 4) agreed with effects on total ear weights (Fig. 2). In 1995, ear lengths, circumferences, and yields of corn following vetch were not significantly increased by addition of inorganic N (Tables 3 and 4). Following rye or biculture cover crops, ear dimensions were significantly smaller in the absence of inorganic N fertilization. In 1996, ear lengths and circumferences plus numbers and weights of marketable ears of corn were all significantly reduced when inorganic N was not supplied in all cover crop treatments.

Tillage effects on corn. Tillage effects on corn were determined in the N+ treatment, in which total and marketable corn yields were similar. Following vetch, corn population densities in 1995 and 1996 were not affected by tillage (Fig. 4), in contrast with results obtained by Knavel and Herron (1986). However, in these years no-tillage reduced corn population densities following biculture and rye cover crops by an average of 35% and 21%, respectively. This reduction was significant for the biculture cover crop in both years and for rye in 1996. Petersen et al. (1986) and Rutledge (1999) also observed decreases in plant population densities for no-till sweet corn compared to tilled conditions. To successfully plant no-till corn, cover crop debris must be sufficiently dry or sparse to enable a coulter to cut through it and provide adequate seed–soil contact. It appeared to the authors that seed–soil contact was more easily obtained with vetch than with rye or biculture cover crops. Thus, low corn population densities in rye or biculture treatments may have been related to

Fig. 4. Effects of tillage and cover crops on mean plant population densities (±SE, n = 3) of sweet corn in the N+ treatment in (A) 1995 and (B) 1996. Within each bar pair different letters denote significant ($P \leq 0.05$) differences. N+ treatment = addition of 200 kg·ha^{-1} (179 lb/acre) of inorganic nitrogen. Biculture = mixture of vetch and rye. Subplot = replicated experimental unit from which corn was harvested from 18 plants (6 plants in each of three rows).



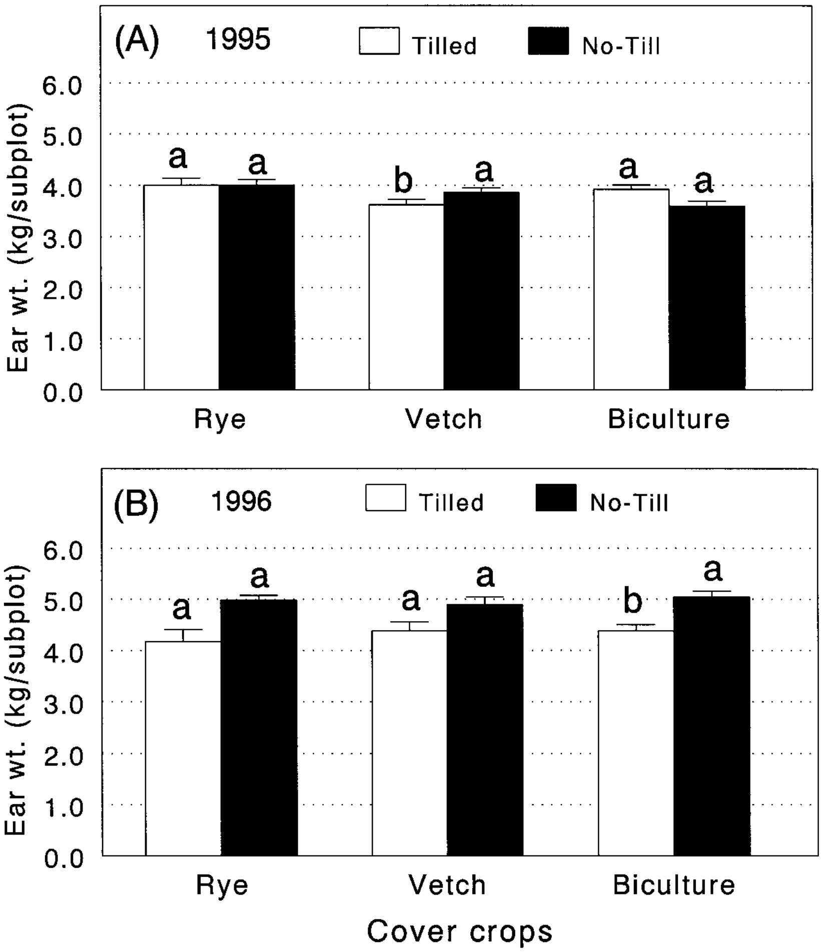


Fig. 5. Effects of tillage and cover crops on mean yields per plant (±SE, n = 3) of sweet corn in the N+ treatment in (A) 1995 and (B) 1996. Within each bar pair different letters denote significant ($P \leq 0.05$) differences. N+ treatment = addition of 200 kg·ha^{-1} (179 lb/acre) of inorganic nitrogen. Biculture = mixture of vetch and rye. Subplot = replicated experimental unit from which corn was harvested from 18 plants (6 plants in each of three rows); 1.0 kg = 2.2 lb.

mechanical limitations of the planting equipment. No-till planting problems may also occur if the soil is too dry (Rutledge, 1999). Plant population data in 1994 were not reliable due to plant damage in some no-till subplots not related to treatments.

Sweet corn yields were expressed on a per plant basis and excluded negative effects of no-tillage on plant population densities. For all cover crops, yields from no-till treatments exceeded or were not significantly different from yields obtained in tilled treatment (Fig. 5). Thus, if corn seedlings emerged through surface cover crop debris, they grew well under irrigated, no-till conditions in agreement with results of others for nonirrigated sweet corn (Knavel and Herron, 1986; Knavel et al., 1977). However, Petersen et al. (1985, 1986) reported that growth of established sweet corn plants was less with no-tillage than with tillage under various irrigation regimes. Differences were partially attributed to lower early season soil temperatures associated with no-tillage. Since sweet corn in that study was planted earlier (mid to late-May) and at a more northern latitude than in this study, lower early season soil temperatures probably had less effect in this study. In 1996, corn yields were greater in no-till than tilled treatments for all three cover crops, but the increase was only significant with the biculture cover crop (Fig. 5B). These increases were likely due to soil water conservation associated with no-tillage, particularly since the biculture cover crop produced the greatest corn yields and most mulch biomass (Cline and Silvernail, 2001). Use of no-tillage has increased maturation times of vegetables such as tomatoes (Abdul-Baki et al., 1996), but it did not increase maturation times of sweet corn in this study.

For all cover crops, fresh weight yields per plant were generally equivalent for tilled and no-till treatments (Fig. 5). Although significant differences in yields occurred between tillage treatments, they were small or inconsistent between years. Furthermore, sweet corn is normally sold in terms of numbers of ears, and more than 99% of corn plants receiving inorganic N produced marketable ears, regardless of tillage (Table 4). Therefore, tillage effects on sweet corn yields were proportional to treatment effects on sweet corn population densities described in Figure 4. For 1995 and 1996 combined, such no-till population densities were 79% (rye), 99% (vetch), and 65% (biculture) as large as population densities obtained using tillage (calculated from data of Fig. 4). Thus, vetch appeared to function well as a cover crop for no-till sweet corn in contrast to rye and biculture cover crops. Relative yield sizes of tilled and no-till field corn have varied in Kentucky, but no-till yields with rye cover crops have equaled or exceeded yields obtained using tillage (Cannell and Hawes, 1994; Ismail et al., 1994). Results of this study suggest that sweet corn may be less adaptable to no-tillage than field corn of other studies, unless a vetch cover crop is used. However, such differences might also be related to planting equipment, soils, weather, etc.

As with corn yields per plant, tillage treatments did not affect ear lengths or circumferences (Table 3). Tillage and cover crop treatments did not affect ear numbers exhibiting corn earworm (*Helicoverpa zea*) damage, but earworm damage was significantly greater in 1995 and 1996 if inorganic N was not supplied (data not presented).

It was concluded that no-tillage decreased projected sweet corn yields by reducing plant population densities with rye or biculture winter cover crops, in contrast to vetch. Vetch supplied sufficient N to sweet corn when vetch N content was 150 kg·ha^{-1}, but not when N content was 120 kg·ha^{-1}. The vetch/rye biculture could not supply adequate N to corn on a sustained basis.

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