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Cover Cropping Systems for the Central Corn Belt

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Research Question

Due to environmental and economic concerns, interest in winter cover crops is increasing in the central USA. The purpose of this study was to evaluate the feasibility and compare the profit potential of corn and grain sorghum in cover crop systems in Illinois.

Literature Summary

Many scientists and corn producers have concluded that cropping systems with corn and cover crops are less profitable than corn/fallow cropping systems in the central USA. Grain sorghum may be a better summer grain crop for such cover crop systems with hairy vetch or rye. Grain sorghum requires less N and water for an economically optimal yield and can tolerate a later planting date without suffering a yield loss. Grain sorghum and cover crop systems have been shown to work in Georgia, but farmers and scientists have little experience or research information to predict the outcome of such a system in the central Corn Belt.

Study Description

This field study was conducted during 1991 and 1992 on three farms in Illinois. Treatments consisted of hairy vetch (25 lb seed/acre) and rye (150 lb seed/acre) cover crops as well as winter fallow. The cover crops were killed 1 week prior to the appropriate corn planting date for each site or about 2 wk later. Corn and grain sorghum were planted no-till and conventionally 1 wk after the cover crops were killed. Four rates of N fertilizer (0, 80, 160, 240 lb N/acre) were applied as a sidedress. Plots were harvested at maturity.

Applied Questions

Did delayed planting of corn and grain sorghum result in increased cover crop production and N content?

Delayed planting did increase hairy vetch and rye production and N content, but decreased corn (128 vs. 106 bu/acre) and grain sorghum yield (94 vs. 89 bu/acre). Thus, planting of corn or grain sorghum should not be delayed in an effort to increase cover crop biomass or N content.

Are cover crops profitable?

Grain yield following rye was significantly less than either fallow or hairy vetch and thus less profitable (Fig. 1). At the economically optimal yield level, grain yield following hairy vetch was 3 bu/acre greater than when following fallow but not large enough to compensate for seed and planting costs of hairy vetch. At economically optimal yield levels, we calculated that hairy vetch contributed only 20 lb N/acre to the subsequent summer grain crops. Soil erosion was not measured in this study, but it is reasonable to assume that no-till or cover crop systems would decrease soil erosion substantially.

Full scientific article from which this summary was written begins on page 55 of this issue.

Is grain sorghum preferable to corn in a cover crop system?

Grain sorghum required less N than did corn for an economically optimal yield (180 vs. 108 lb N/acre) (Fig. 2), but grain sorghum yield was so much less than corn (132 vs. 98 bu/acre at the economically optimal yield) that it was not competitive with corn regardless of the N rate used. Thus, grain sorghum is not preferable to corn for profitable cover crop systems in the central Corn Belt.

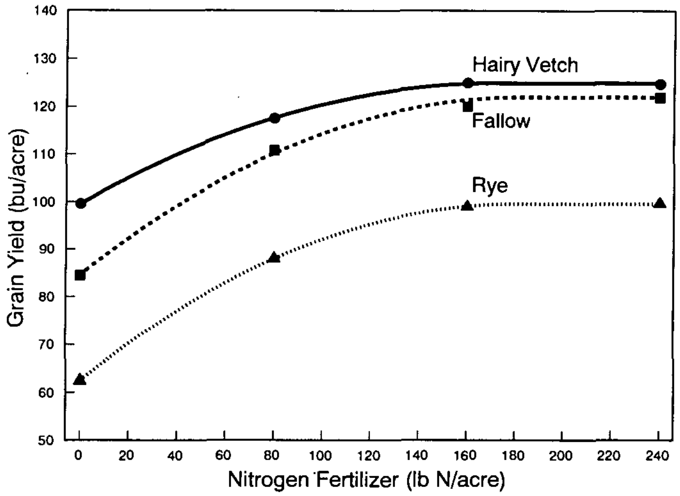

Fig. 1. The effect of N fertilizer on mean grain yield of a summer grain crop following either a hairy vetch or rye cover crop or fallow.

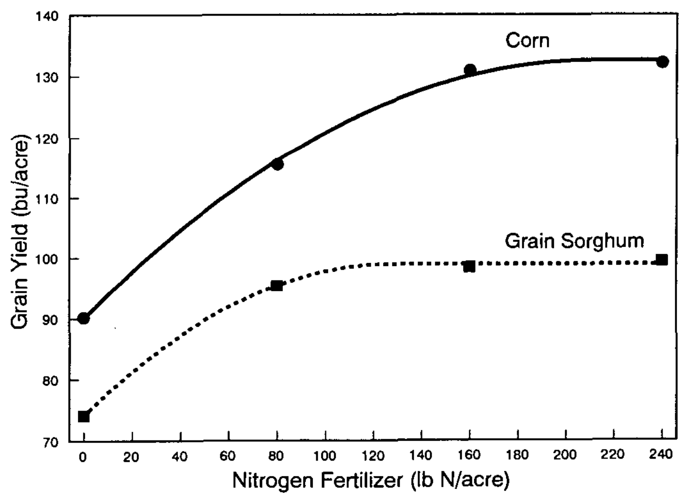

Fig. 2. The effect of N fertilizer on mean yield of corn and grain sorghum.

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Corn (*Zea mays* L.) predominates in the central USA but grain sorghum [*Sorghum bicolor* (L.) Moench] may be preferable for cover crop systems. Effects of tillage (no-till and disk), cover crops, grain crop, planting date, and N fertilizer rate were investigated to compare grain sorghum and corn in cover crop systems. This 2-yr field study was conducted at Fisher, IL, on an Ashkum silty clay loam (fine, mixed, mesic Typic Haplaquolls); Toledo, IL, on a Cisne silt loam (fine, montmorillonitic, mesic Mollic Albaqualf); and Albion, IL, on a Belknap silt loam (coarse silty, mixed, mesic Aeric Fluventic Haplaquepts). Grain yield was not affected by tillage. Delayed planting of the grain crop increased cover crop biomass and N content at the expense of corn (128 vs. 106 bu/acre) and grain sorghum (94 vs. 89 bu/acre) yield. Grain yield following rye (*Secale cereale* L.) was less than when following hairy vetch (*Vicia villosa* Roth) or fallow. Optimal N rate was higher and yield was higher following hairy vetch (133 lb N/acre and 124 bu/acre) than following fallow (153 lb/N acre and 121 bu/acre) or rye (152 lb N/acre and 100 bu/acre), but cover crop establishment cost exceeded the benefit. Grain sorghum required less N than corn (108 vs. 180 lb N/acre), but the associated optimum yield (98 vs. 132 bu/acre) resulted in an economic advantage for corn. Thus, grain-sorghum-and-cover-crop systems are not attractive alternatives to corn-cover-crop or conventional-corn systems in the central Corn Belt.

Environmental and economic concerns have fueled interest in soil erosion, N fertilizer efficiency, nitrate leaching and agriculture's economic competitiveness (Heichel and Barnes, 1984). Winter cover crops have been suggested as possible tools for addressing the environmental concerns. A cover crop can be a legume which contributes significant amounts of organic N via N_2 fixation, a nonlegume which scavenges residual soil nitrates and consequently reduces the amount of nitrates available for over-winter leaching, or a combination of legume(s) and nonlegume(s).

Many winter cover crops can be used to reduce soil erosion and provide organic N. In the central and lower U.S. Corn Belt, hairy vetch is the preferred legume while rye is the preferred nonlegume (Ebelhar et al., 1984; Frye et al., 1988; Mitchell and Teel, 1977). Most research indicates that hairy vetch contributes an equivalent of 65 to 90 lb N/acre, but resulting yields are not usually economically competitive with corn receiving the normal 150 to 225 lb N/acre as N fertilizer (Ebelhar et al., 1984; Moschler et al., 1967). The reason for the yield reduction is explained as a combination of the large N demand of corn, the necessity of early corn planting date, and the tendency of hairy vetch to deplete soil moisture (Ebelhar et al., 1984; Moschler et al., 1967).

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Corn is the major feed grain crop in the central USA. Virtually all of the winter cover crop and summer feed grain crop rotation work in this area has looked only at corn, but corn may not be the best feed grain for such a system. Grain sorghum has a shorter grain-fill period and thus can be planted later than corn without suffering a yield reduction (Olson et al., 1986). Grain sorghum also has a lower economically optimal N rate than does corn (Olson et al., 1986) and thus may be a potential alternative summer feed grain. This may be particularly true on drought-prone soils or where hairy vetch must be allowed to grow relatively late into the spring in order to fix more N. Wagger (1987) reported that killing hairy vetch the first week of May instead of the third week of April resulted in an additional production of 1.8 tons dry matter/acre and 52 lb N/acre. This is in agreement with Frye et al. (1988), who noted that most vegetative growth of hairy vetch occurred in the 3 wk prior to the onset of the reproductive stage. Grain sorghum is also more drought tolerant than corn (Olson et al., 1986). Hargrove (1986) has demonstrated in Georgia that a production system using winter legumes followed by grain sorghum is very competitive. Such a system has not been investigated in the central Corn Belt and farmers and scientists have little experience to predict the outcome of such a system.

The objective of this experiment was to evaluate the feasibility and compare the profit potential of cropping systems using corn and grain sorghum planted after hairy vetch or rye cover crops or fallow ground.

MATERIAL AND METHODS

This 2-yr field study was conducted on three privately owned farms: at Fisher, IL, on an Ashkum silty clay loam; at Toledo, IL, on a Cisne silt loam; and at Albion, IL, on a Belknap silt loam. At each location, the experimental design was a modified split-split-split plot with a split-block component in a randomized complete block with two replicates. Tillage (no-tillage and disk) was assigned to main plots, and cover crops (hairy vetch, fallow, and rye) were split-plots within tillage. Date of corn and grain sorghum planting was arranged as a split-plot treatment within tillage, but as a split-block across cover crops. Similarly, summer grain crops (corn and grain sorghum) were arranged within dates of planting as split-split plots, but ran across cover crops as a split-split-block. Nitrogen fertilizer rate (0, 80, 160, and 240 lb N/acre as 28% N solution [UAN]) was arranged as split-split-split plots within summer grain crop. Each plot was 15 ft (six 30 in. rows) by 62 ft long. In the second year, the experiment was conducted immediately adjacent to the first year plots. Thus, the plots did not exist in the exact place in the first and second year.

Cover crops were no-till planted immediately following soybean harvest in the autumn. Hairy vetch was planted at 25 lb/acre and was inoculated with *Rhizobium*

Table 1. Effect of kill date on hairy vetch and rye DM production and N content across five environments in Illinois.

Cover crop	Cover crop kill date	Dry weight	N content
		lb/acre	
Hairy vetch	First	1650	70
	Second	2325	110
Rye	First	2220	35
	Second	4035	45

leguminosarum var. *vicaea* (Urbana Labs, St. Joseph, MO)[1]. Rye was planted at 150 lb/acre.

The following spring, biomass samples from 12 sq ft (three 4 sq ft samples) were taken from each cover crop plot to calculate average biomass production. Samples were taken at the time of killing the cover crops. Cover crops were killed 1 wk before planting corn and grain sorghum. All plots were treated with 0.3 lb a.i./acre of 2,4-D and 1 lb a.i./acre glyphosate plus nonionic surfactant to kill all existing vegetation. For weed control, all plots also were treated with 2.5 lb a.i./acre of alachlor and 1.5 lb a.i./acre of atrazine mixed in 30 gal water/acre after killing the cover crops and before planting the corn and grain sorghum. In 1991 at Albion and Toledo, an additional 0.3 lb a.i./acre of 2,4-D was sprayed 20 d after planting corn and grain sorghum in order to further control broadleaf weeds. In both years and at all locations, all conventional tillage plots were also cultivated once.

At each location and in each year, 'Pioneer 3379' hybrid corn was planted at 27 000 seed/acre and 'Pioneer 8333' grain sorghum was planted at 110 000 seed/acre. First and second dates of planting at Fisher were 23 April and 19 May 1992; at Toledo, 9 May and 21 May 1991 and 9 May and 22 May 1992; at Albion, 9 May and 22 May 1991 and 9 May and 1 June 1992. The 28% UAN fertilizer solution was injected into the soil with a coulter applicator between 20 and 25 d after the second date for corn and grain sorghum. Grain yields were estimated by harvesting the entire length of the middle two rows of each plot and then adjusting for moisture.

Economically optimal N rates were calculated based upon a price of $2.50/bu for corn, $2/bu for grain sorghum, and $0.15/lb for N. This resulted in fertilizer-to-grain price ratios of 3.36 for corn and 4.20 for grian sorghum.

Each year-location was considered an environment as suggested by Carmer et al. (1989). Environments were considered random. The Fisher-1991 data were dropped because of inconsistent and incomplete kill on covers following improper herbicide application. This left five environments for analysis.

Statistical analysis was conducted with the GLM and NLIN procedures of SAS (SAS, 1992). Appropriate error terms for testing were calcualted based on the estimation of the variances of pairwise mean differences presented by Carmer et al. (1989). The corresponding degrees of freedom associated with the estimated variance were approximated using Satterthwaite's procedure (Satterthwaite, 1946).

[1]Mention of a company or brand name does not constitute an endorsement by authors, University of Illinois, or the granting agencies.

Table 2. Mean summer grain yield as affected by the interaction of planting date and cover crops over five environments in Illinois.

Cover crop	Cover crop kill date: First	Cover crop kill date: Second	Prob > F‡
	bu/acre		
Hairy vetch	125	109	†
Fallow	113	107	NS
Rye	97	78	*
LSD (0.05)§	17	17	
LSD (0.10)	13	13	

*,† Significant at α = 0.05 and 0.1, respectively; NS = not significant.
‡ The probability > F for the effect of planting date within each cover crop.
§ The LSDs for the difference between covers within each planting date.

RESULTS AND DISCUSSION

Neither tillage, nor any interaction involving tillage, significantly affected grain yield. Therefore, tillage treatments are not discussed further.

The mean total aboveground dry matter production and N content of hairy vetch and rye at the first and second dates of planting of the five environments are presented in Table 1. For both hairy vetch and rye, the second date of planting of the summer grain crop allowed a longer growth period and, thus, increased cover crop dry weight and cover crop N content. This is in agreement with the majority of the literature (Ebelhar et al., 1984; Hargrove, 1986; Utomo, 1986). The increased cover crop production came at the expense of corn and grain sorghum yield. Corn suffered a greater loss with delayed planting (128 vs. 106 bu/acre) than did grain sorghum (94 vs. 89 bu/acre).

There was a significant cover crop × planting date interaction for grain yield. Within each planting date, grain yield following rye was significantly less than when following either hairy vetch or fallow (Table 2). Thus, rye was inferior to either hairy vetch or fallow at either planting date. The lower yields on rye probably were due largely to 25 to 50% reductions in final stand caused by excessive mulch that hindered planting in general and the no-tillage treatments in particular. Rodent damage also contributed to reduced stands in no-tillage plots at Fisher. Rodent damage on corn planted on rye residues is also mentioned by Utomo et al. (1990).

When the effect of planting date on summer grain yield was compared within each cover crop, there was a significant decrease in grain yield with delayed planting only for hairy vetch and rye. Yield was not affected by planting date for the fallow treatments. The additional biomass obtained with delayed kill of both cover crops made it impossible to obtain an adequate plant stand, even in the disked plots. Thus, the effect of cover crop is confounded with summer grain plant population, however we believe the reduction in plant population is unavoidable and similar to what farmers would experience. A similar situation was reported by Eckert (1988). Furthermore, excessive cover growth may have reduced available soil moisture. The reduction of moisture content of the soil is an aspect mentioned as well by Ebelhar et al. (1984). These data indicate that planting date should not be delayed in order to allow a cover crop to grow longer. This agrees with Wagger (1987).

Analysis of variance indicated that summer grain yield was also affected significantly by the main effect of N fertilizer rate and the interactions of cover crop × N fertilizer rate (C × N) and summer grain species × N fertilizer rate (G × N). The summer grain species × cover crop × N fertilizer rate interaction was not significant.

The significant C × N interaction was due to a difference in the magnitude of response of summer grain yield to N fertilizer when planted after different cover crops. For each cover crop, summer grain yield increased with N fertilizer, but the magnitude of the response differed according to cover crop (Fig. 1). We calculated mean economically optimal fertilizer rates of 133 lb N/acre for the hairy vetch, 153 lb N/acre for the fallow, and 152 lb N/acre for the rye systems, respectively. Mean summer grain yield associated with these economically optimal N fertilizer rates was 124 bu/acre for the hairy vetch, 121 bu/acre for the fallow, and 100 bu/acre for the rye systems. At the economically optimal N fertilizer rates, hairy vetch allowed for an additional 3 bu/acre above that of the fallow system and 25 bu/acre above that of the rye system.

Note that summer grain yield following fallow or rye failed to equal the yield following hairy vetch even at the highest N fertilizer rates (Fig. 1). This is similar to the work of Utomo et al. (1990), who reported that at high N fertilizer rates hairy vetch added yield, but did not reduce the need for N fertilizer. In this experiment, hairy vetch apparently provided a small rotational effect separate from, and in addition to, the N contribution. Frye et al. (1985) reported that hairy vetch may benefit a following summer grain crop not only by contributing N but also by improving soil physical conditions and water relations via increased organic matter.

Using fertilizer replacement value methodology (Mitchell and Teel, 1977), we calculated that hairy vetch provides a mean of 42 lb N/acre to subsequent grain crops. This value was obtained by determining the amount of N fertilizer required in the fallow treatment to produce summer grain yield equal to hairy vetch with 0 lb N/acre. This amount is lower than reported by other researchers (Blevins et al., 1990; Ebelhar et al., 1984; Mitchell and Teel, 1977; and Touchton et al., 1984); however even our lower estimate may be inflated. We suggest the yield increase noted when a summer grain crop follows hairy vetch is due to both N contribution and rotational effect. The fertilizer replacement value methodology confounds the N contribution and rotational effects and credits the yield increase entirely to the legume N contribution (Harris and Hesterman, 1990). We believe that it is more realistic to estimate the N contribution from legumes as the difference in the economically optimal N fertilizer rate for each cropping system. We contend that is correct since the economically optimal N fertilizer rate is the level at which farmers should be operating rather than the 0 lb N/acre level which the fertilizer replacement value methodology assumes. Using this approach we calculate the difference, and thus the N contribution by hairy vetch, as only 20 lb N/acre (153 − 133 lb N/acre).

The large yield decrease associated with the rye cover crop clearly indicates that system was not profitable. Yield was not decreased by the hairy vetch cover crop, but that system also was not profitable. A brief economic analysis shows that the rotational benefit was not large enough to warrant the cost of the cover crop. We estimated a net loss of $28/acre due to the hairy vetch cover crop based on the following values: planting hairy vetch was $31.75/acre (seed [$18.75/acre = 0.75/lb × 25 lb/acre] + no-till drill [$13/acre]); the N contribution was worth $3 (20 lb N/acre × $0.15/lb N); and the additional yield was worth $6.75/acre (3 bu/acre × $2.25/bu grain). Clearly, the hairy vetch cover crop did not increase profit. The combination of the reduced N fertilizer requirement and increased yield due to the rotational effect were not large enough to compensate for the

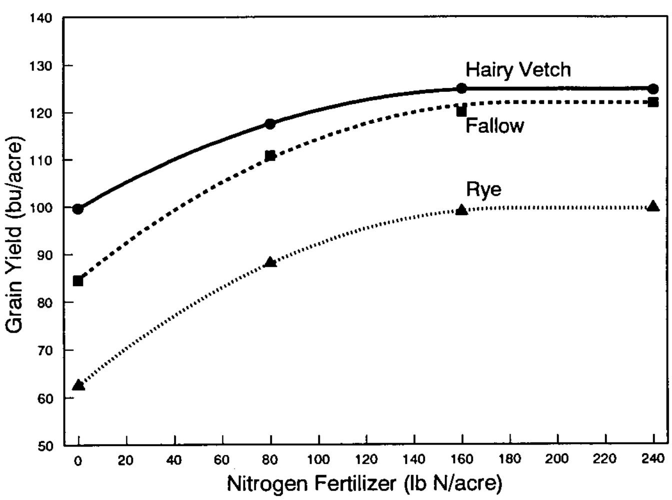

Fig. 1. The effect of N fertilizer on mean grain yield of a summer grain crop following either a hairy vetch or rye cover crop or fallow.

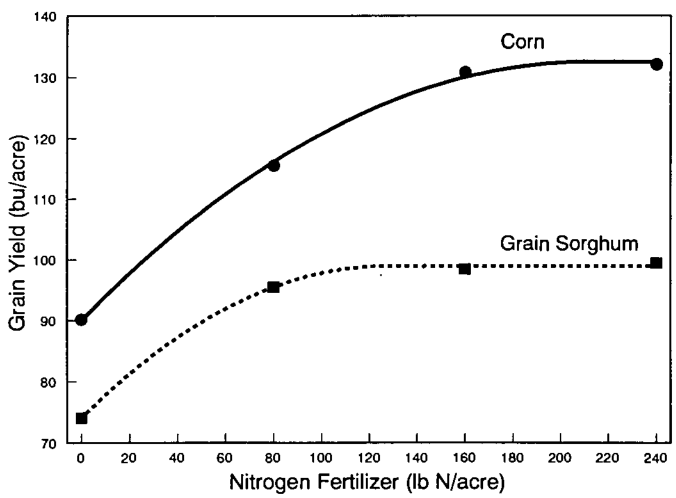

Fig. 2. The effect of N fertilizer on mean yield of corn and grain sorghum.

additional cost. It should be realized that soil erosion would presumably decrease with cover crop or no-till systems. Similarly it can be argued that some farmers may need a cover crop to reduce soil erosion and thus meet conservation compliance requirements. A decrease in the rate of soil erosion would often be desirable and beneficial, but we did not measure soil erosion in this study nor did we attempt to quantify the benefit for the economic analysis.

We also noted a significant interaction of summer grain species × N fertilizer rate (G × N) (Fig. 2). Both summer grain crops increased yield with increasing N rate, but the magnitude of the response differed. The economically optimal fertilizer rate for corn was 180 lb N/acre, giving an optimal yield of 132 bu/acre. The economically optimal fertilizer rate for grain sorghum was much less at 108 lb N/acre, but the economically optimal yield was also much less at only 98 bu/acre. Thus, grain sorghum reached a maximum grain yield at much lower N fertilizer rate than did corn, but total yield was so much less than of corn that the grain sorghum was simply not economically competitive with corn, despite its lower N requirement. These results and the lack of a significant interaction of cover crop × summer grain species × N fertilizer rates, or the interaction of cover crop × summer grain species, suggest that a cover crop system using grain sorghum is not an economically attractive alternative to either a corn/cover crop system or conventionally produced corn in the central Corn Belt regardless of tillage, date of planting, or N fertilizer rate used.

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REFERENCES

Blevins, R.L., J.H. Herbek, and W.W. Frye. 1990. Legume cover crops as a nitrogen source for no-till corn and grain sorghum rotation and fertilizer treatment. Agron. J. 82:769–772.

Carmer, S.G., W.E. Nyquist, W.M. Walker. 1989. Least significant difference for combined analyses of experiment with two- or three-factor treatment designs. Agron. J. 81:665–672.

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.

Eckert, D.J. 1988. Rye cover crops for no-tillage corn and soybean production. J. Prod. Agric. 1:207–210.

Frye, W.W., R.L. Blevins, M.S. Smith, S.J. Corak, and J.J. Varco. 1988. Role of annual legume cover crops in efficient use of water and nitrogen. p. 129–143. *In* W.L. Hargrove (ed.) Cropping strategies for efficient use of water and nitrogen. ASA Spec. Publ. 51. ASA, CSSA, and SSSA, Madison, WI.

Frye, W.W., W.G. Smith, and R.J. Williams. 1985. Economics of winter cover crops as a source of nitrogen for no-till corn. J. Soil Water Conserv. 40:246–249.

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

Harris, G.H., and O.B. Hesterman. 1990. Quantifying the nitrogen contribution from alfalfa to soil and two succeeding crops using nitrogen-15. Agron. J. 82:129–134.

Heichel, G.H., and D.K. Barnes. 1984. Opportunities for meeting crop nitrogen needs from symbiotic nitrogen fixation. p. 49–59. *In* D.F. Bezdicek (ed.) Organic farming: Current technology and its role in a sustainable agriculture. ASA Spec. Publ. 46. ASA, CSSA, and SSSA, Madison, WI.

Mitchell, W.H., and M.R. Teel. 1977. Winter-annual cover crops for no-tillage corn production. Agron. J. 69:569–573.

Moschler, W.W., G.M. Shear, D.L. Hallock, R.D. Sears, and G.D. Jones. 1967. Winter cover crops for sod-planted corn: Their selection and management. Agron. J. 59:547–551.

Olson, R.A., W.R. Raun, S.C. Yang, and J. Skopp. 1986. Nitrogen management and interseeding effects on irrigated corn and sorghum and on soil strength. Agron. J. 78:856–862.

SAS Institute. 1992. SAS user's guide. SAS Inst., Cary, NC.

Satterthwaite, F.E. 1946. An approximate distribution of estimates of variance components. Biom. Bull. 2:110–114.

Touchton, J.T., D.H. Rickerl, R.H. Walker, and C.E. Snipes. 1984. Winter legumes as a nitrogen source for no-tillage cotton. Soil Tillage Res. 4:391–401.

Utomo, M. 1986. Role of legume cover crops on no-tillage and conventional tillage corn production. Ph.D. diss. University of Kentucky, Lexington.

Utomo, M., W.W. Frye, and R.L. Blevins. 1990. Sustaining soil nitrogen for corn using hairy vetch cover crop. Agron. J. 82:979–983.

Wagger, M.G. 1987. Timing effects of cover crop desiccation on decomposition rates and subsequent nitrogen uptake by corn. p. 35–37. *In* J.F. Power (ed.) The role of legumes in conservation tillage systems. Soil and Water Conserv. Soc., Ankeny, IA.