CONSERVATION OF ENERGY IN NO-TILLAGE SYSTEMS BY MANAGEMENT OF NITROGEN

R. L. BLEVINS, W. W. FRYE AND M. J. BITZER

Energy conservation is a major concern and priority in agriculture today. The inputs of fertilizers, pesticides, and fuels in crop production have increased rapidly in recent years and farming is now a very energy dependent industry. About 80 percent of the energy used by agriculture is from liquid petroleum fuels and natural gas, which makes efficient use of energy in agricultural production even more important. No-tillage systems of crop production are one alternative for conserving energy. Conventional tillage of corn and soybeans requires large amounts of fuel in plowing and disking operations. Part of the fuel saved in no-tillage due to fewer trips across the field is offset by slightly higher amounts of herbicides and, in some cases, higher rates of N fertilizer used for no-tillage corn production.

The greatest single energy input into corn production is nitrogen fertilizer, representing almost one-half of the total energy input for no-tillage corn. Conclusions from earlier work in Kentucky (Thomas et al., 1973; Blevins et al., 1977; M. S. Smith, Univ. of Ky., personal communication) which are pertinent to the N status under no-tillage compared to conventional tillage include the following associated with no-tillage:

- ---Higher soil water content at the beginning of any particular rainfall event
- ---Greater preservation of large soil pores by lack of tillage
- ---Slower rate of organic matter decomposition
- ---Less mineralization of N
- ---Higher immobilization of N.

These factors resulted in lower plant available N under no-tillage during the growing season due to higher leaching loss of NO_3^-, slower N release from organic matter and greater immobilization. These results led to recommendation of higher rates of N fertilizer for no-tillage corn production than for conventional tillage. But, more recent comparisons of yields of no-tillage and conventional tillage corn (Frye et al., 1978) showed a greater response to N fertilizer, higher yields at higher N rates, more efficient use of N fertilizer, and a lower input:output ratio of energy with no-tillage.

R. L. Blevins and W. W. Frye are Associate Professors of Agronomy and M. J. Bitzer is Associate Extension Professor of Agronomy, Department of Agronomy, University of Kentucky, Lexington, Kentucky 40546.

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In this paper, we discuss the response of no-tillage corn to N fertilizer, compare the N efficiency in no-tillage and conventional tillage systems, and suggest better ways to manage nitrogen in no-tillage corn production. By improved management of nitrogen, energy is conserved or used more efficiently.

Response to Nitrogen Fertilizer

A summary of corn yields from a long-term no-tillage and conventional tillage experiment is presented in Table 1. On plots where no nitrogen was applied the 10-year average corn yield was 76 bu/acre for no-tillage and 95 bu/acre for the conventional tillage treatments. We conclude that a combination of greater leaching losses, a slower rate of mineralization and more immobilization of N resulted in lower yields and plants showing more severe N stress during the growing season in no-tillage. Nitrogen rates above 75 lb/acre resulted in slightly higher grain yield for no-tillage compared with conventional tillage. The lower yields with no-tillage at low levels of N fertilizer and higher yields at higher rates of N fertilizer are similar to results reported by Bandel et al., 1975 in Maryland and Moschler et al., 1974 in Virginia.

In our experiments (Table 1), highest yields were obtained during the second and third years (1971 and 1972). Both of these years had a very favorable distribution of rainfall for corn, whereas the first year (1970) had low rainfall during the growing season. The high yield with no nitrogen fertilizer is evidence that the soil initially had a high potential for soil nitrogen mineralization. Yields produced in the tenth year (1979) were comparable to the 10-year average, except for the observed yield decrease in the zero nitrogen treatment of conventional tillage. This suggests that corn yields can be maintained over a long period of time in no-tillage as well as conventional tillage.

A comparison of yields on the Maury soil *to* yields on other well-drained soils in Kentucky is shown in Table 2. Yields from no-tillage and conventional tillage receiving 150 lb N/acre showed the highest yield increase for no-tillage on the Crider silt loam soil. The Crider is a deep, well-drained soil developed in residuum of limestone with a thin layer of loess at the surface. The well-drained to moderately well-drained sloping soils with moderate porosity seem best suited for no-tillage systems in Kentucky. No-tillage on soils with high water table or slow internal drainage often results in lower yields of corn than conventional tillage. This is related to increased wetness due to the surface mulch and cooler temperatures at planting time, which contribute to lower plant stands, the development of stress conditions during early stages of growth and, perhaps, denitrification loss of N.

Table 1. Summary of corn yields from limed plots on a Maury silt loam soil at Lexington, Ky. with different levels of nitrogen and no-tillage and conventional tillage systems. (Yields from unlimed plots omitted for brevity.)

Year	Tillage system	Nitrogen applied as NH_4NO_3 (lb/acre) 0	75	150	300
		---bu/acre---			
1970	NT[†]	90	99	99	105
	CT[†]	91	90	90	90
1971	NT	99	166	170	173
	CT	151	180	159	162
1972	NT	118	153	149	155
	CT	130	161	159	165
1973	NT	66	119	126	121
	CT	66	123	129	135
1974	NT	89	154	165	167
	CT	129	162	163	162
1975	NT	60	97	100	106
	CT	78	80	82	96
1976	NT	69	144	156	170
	CT	85	129	141	141
1977	NT	58	106	109	115
	CT	88	123	127	132
1978	NT	33	78	85	99
	CT	67	100	97	100
1979	NT	73	118	123	121
	CT	68	130	124	123
10-year	NT	76	123	128	133
Ave.	CT	95	128	125	131

[†]NT = No-Tillage; CT = Conventional Tillage.

Table 2. Average corn grain yields produced on well-drained soils in Kentucky by no-tillage and conventional tillage systems with 150 lb/acre N.

	Number of year tested	Grain yields No-tillage	Conventional tillage
		---bu/acre---	
Maury silt loam	10	128	125
Crider silt loam	5	158	133
Allegheny loam	3	175	174

Nitrogen Efficiency

Table 3 shows the N fertilizer efficiency[1/] values for the yield responses to each 75-lb increment of the 75- and 150-lb rates of N fertiliz'er for no-tillage and conventional tillage corn on the Maury soil at Lexington which was shown in Table 1. Grain yields from each pound of N fertilizer of both increments were greater for no-tillage than conventional tillage, This may be somewhat misleading with regard to the first increment, since the average yields with both the 0 and 75 lb/acre N treatments were lower for no-tillage plots than for conventional tillage (Table 1). But the efficiency values in Table 3 are based on increases in yield resulting from the added nitrogen fertilizer. If one looks at the yield response in Table 1 together with the N fertilizer efficiency values in Table 3, the results suggest the need for slightly more N fertilizer to obtain maximum yields in no-tillage; however, the nitrogen fertilizer is used more efficiently. The more efficient use of nitrogen in no-tillage corn is probably due to the soil moisture conserved by no-tillage.

Table 3. Efficiency of nitrogen fertilizer in no-tillage and conventional tillage corn grown on Maury soil at Lexington, Ky. (Based on 10-year average yields.)

N fertilizer applied	lb grain/lb N†		BTU in grain/BTU in N‡	
	No-till	Conventional	No-till	Conventional
1st 75 lb/acre	35.1	24.6	9.5:1	6.7:1
2nd 75 lb/acre	3.7	-3.7	1.0:1	-1.0:1

†Calculated by subtracting yield without N fertilizer from yield with N fertilizer and dividing by incremental amount of N fertilizer applied, in this case, 75.

‡6,800 BTU/lb corn grain; 25,000 BTU/lb N.

Using a value of 25,000 BTU/lb of N, each lb is equivalent to less than one quart of gasoline (145,000 BTU/gal) or about one pint of diesel fuel (207,000 BTU/gal). Therefore, to realize the full effects of no-tillage on energy conservation, it must be viewed in terms of improved energy input:output ratio associated with higher crop yield or greater N efficiency. Table 3 shows the N fertilizer efficiency values converted to energy input:output ratios. They do not represent direct energy savings but represent more efficient use of energy in no-tillage crop production. No-tillage itself results in direct energy conservation through less fuel consumption than conventional tillage. These data point out that the energy saved with reducing tillage operations is not lost in additional N fertilizer that may be recommended for no-tillage corn.

1/ N fertilizer efficiency as used in this paper is grain yield with N fertilizer minus grain yield without N fertilizer.

Effect of N Fertilizer Management Practices

Certain N fertilizer management practices may result in direct energy savings or more efficient use of energy in no-tillage systems. These practices may provide the N efficiency necessary to allow the farmer to use no-tillage and obtain the energy conservation benefits associated with it without requiring more N fertilizer to maintain yields equal to or greater than conventional tillage.

As pointed out previously, loss of NO_3^- by leaching during the growing season was greater under no-tillage than under conventional tillage (Thomas et al., 1973). N may be lost also by denitrification when soil moisture remains above field capacity for periods of several days where easily oxidized organic matter is present. These conditions often occur under no-tillage on soils with sticky clay subsoils or on soils with fragipans that retard internal water movement. To avoid these losses, a split application or delayed application of N fertilizer 4 to 6 weeks after planting has become an accepted and useful management practice in Kentucky. Table 4 shows the results from a study of the optimum application of N fertilizer for corn on a well- to moderately well-drained, slowly permeable Hampshire silt loam soil. The delayed application of 150 lb/acre N as ammonium nitrate gave significantly higher yields. Yields, N fertilizer efficiency, and energy efficiency are favored by delaying the N fertilizer on soils with slow permeability.

Table 4. Effect of time of nitrogen application as ammonium nitrate on no-tillage corn production on a Hampshire silt loam soil in Franklin County, Ky.

		Efficiency of N fertilizer	
N applied (lb/acre)	Yield (bu/acre)	lb grain/ lb N added†	BTU in grain/ BTU in N‡
0	75	-	-
150 at planting	104	10.4	2.8:1
150 delayed 5 weeks	131	20.5	5.6:1
75 at planting + 75 delayed	135	22.0	6.0:1

†Calculated by subtracting yield without N fertilizer from yield with N fertilizer and dividing by the amount of N fertilizer applied (150).

‡6,800 BTU/lb corn grain; 25,000 BTU/lb N.

Losses of N by leaching and denitrification are likely to be greater early in the cropping season in Kentucky, accounting for the beneficial effects of delaying application of N fertilizer. Fertilizer recommendations in Kentucky state that rates of N fertilizer can be decreased by 35 lb/acre N, if as much as two-thirds of the N is delayed 4 to 6 weeks for no-tillage corn on moderately well-drained soils and for conventional tillage corn on moderately well and poorly drained soils. The N saved by this practice represents about 875,000 BTU of energy or about 6 gal of gasoline per acre. It should be pointed out, however, that the N recommendation on soils with impaired drainage is 50 lb/acre more than on well-drained soils if the N fertilizer is all applied at planting. Thus, even with delayed application, at least 15 lb/acre more N is recommended for soils with impaired drainage as a safe-guard against the greater potential N loss.

An additional management practice recommended for no-tillage corn production on wet soils is delaying planting for 2 to 3 weeks later than the recommended planting date for conventional tillage corn. This practice usually results in a better stand of plants and allows application of N fertilizer after the soil has dried out but before N demand is high in the crop.

A nitrification inhibitor, nitrapyrin,[2/] sprayed onto granules of ammonium nitrate fertilizer which was broadcast on the soil surface substantially increased yields of no-tillage corn in experiments over several years at several locations in Kentucky (manuscript in review). Yield increases ranged up to 46%, depending on soil and weather conditions. The increased N fertilizer efficiency achieved by inhibiting nitrification also would represent considerable energy efficiency.

Another approach to energy conservation through N fertilization is to provide N to the no-tillage corn crop by growing winter-annual legumes as cover crops. Winter cover crops included in this research in Kentucky are hairy vetch, bigflower vetch, crimson clover and rye. Preliminary results show that the legumes can provide substantial amounts of nitrogen for no-tillage corn, with hairy vetch being more effective than the others. In 1979, grain yields on plots with hairy vetch but with no N fertilizer were statistically equal to yields on other plots with 88 lb/acre N fertilizer added, N fertilizer conservation of such a magnitude would represent considerable conservation of energy.

Summary

No-tillage production of corn requires considerably less tractor fuel than conventional tillage, but N management is more critical due to slower mineralization, higher immobilization and potentially greater losses by leaching and denitrification of NO_3^-. More N fertilizer may be recommended for no-tillage corn, but the N is usually more efficient, producing more grain/lb of N than under conventional tillage. Several N management practices have been shown to improve N efficiency in no-tillage experiments in Kentucky, thus contributing to energy conservation. These practices include delaying N fertilizer application for 4 to 6 weeks after planting corn, growing winter-annual legumes as cover crops for no-tillage corn, spraying a nitrification inhibitor (nitrapyrin) onto N fertilizer granules, and delaying planting on wet soil until it has dried out and the potential for denitrification has diminished.

1/ Nitrapyrin, 2-chloro-6(trichloromethyl) pyridine, is manufactured by Dow Chemical U.S.A., Midland, Mich.

These management practices along with the generally more efficient use of N fertilizer in no-tillage allow farmers to obtain the energy conservation associated with fuel savings in no-tillage due to fewer trips across the field without having this advantage negated by application of higher rates of N fertilizer. Through efficient N management no-tillage can be both a direct and indirect energy conserving practice, and yields equal to or greater than conventional tillage can be maintained.

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