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Final Report

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Role of Cereal Grain (Rye) Cover Crops in Nitrogen Management for the Chesapeake Bay Region.

Cooperating Institutions

University of Delaware
University of Maryland
Pennsylvania State University
Rodale Institute

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Overview

Recently, there has been increasing concern about the impact of agricultural chemicals on groundwater resources. This is particularly true in the Chesapeake and Delaware Bay watersheds. One of the most prevalent issues is that of groundwater contamination with nitrate originating from soil fertility management practices. Nitrate in groundwater results from leaching of applied nitrogen, either directly or indirectly, and thus represents the loss of a resource required for crop production. For grain production of corn, recommended fertilizer rates are based on utilization efficiencies of approximately 60 percent, however, suboptimum growing conditions can reduce the percentage of applied nitrogen which is utilized by the crop to much lower levels. These inefficiencies have been recognized for some time but until the recent development of environmental issues, the unused portion of applied nitrogen was considered only as an economic loss. The development of agricultural management systems which focus on strategies for reducing the loss of nitrogen from the root zone must be considered.

Historically, cover crops were used to reduce soil erosion, fix nitrogen, and as a source of forage in integrated agricultural systems. Since 1945, the development of relatively inexpensive inorganic fertilizers, and the concurrent spatial separation of livestock and grain production, has caused a dramatic reduction in the use of winter cover crops. Although much of the recent research on cover crops has focused on the use of legumes to supply nitrogen for future grain crops, long before nitrogen was recognized as a problem in the environment, scientists had documented the ability of cereal grain cover crops to reduce the leaching of nitrate from the root zone. However, the successful integration of cereal grain cover crops into current cropping systems will require an understanding of the dynamics of cover crop nitrogen uptake and mineralization in order to minimize nitrogen losses to the environment while providing maximum benefit to following grain crops.

The project brought together research, extension, private agencies and farmers in coordinated effort to accomplish the following objectives.

1. Evaluate the management of cereal grain (rye, Secale cereale L.) cover crops to reduce the leaching of nitrate to groundwater and to optimize nitrogen recycling on the farm.

2. Evaluate the economic impact of cereal grain (rye) cover crops on the farming system.

3. Develop on-farm research to promote the use of cereal grain (rye) cover crops as a tool for nitrogen management.

The project was a cooperative effort between the University of Delaware, University of Maryland, Pennsylvania State University, and the Rodale Institute. Nitrate leaching under different cover crop management systems including dairy manure and forage production, poultry manure and irrigation, and continuous corn was considered. Selected management practices were also evaluated on farms in Maryland, Delaware, and Pennsylvania to promote the use of cereal grain (rye) cover crops in nitrogen management. Although results from the on-farm research and intensive plot research were to be used to assess the economic impact of the different cover crop management practices on the farming system, this objective was not addressed because funding for the project was terminated after the first year. Results for objectives one and three are included in this final report.

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Executive Summary

The University of Delaware results indicate that a rye cover crop will not reduce irrigated corn yields on sandy soils and will reduce nitrate leaching. To maximize nitrogen uptake by the cover crop, they should be planted as soon as possible in the fall following corn harvest. Research results also indicate that regular poultry manure or composted poultry manure may be used as a nitrogen source in conjunction with cover crops and corn yields will be similar to yields obtained with commercial fertilizers.

Results from the University of Maryland study indicate that rye cover crops can immobilize residual rootzone nitrogen left in the soil profile following corn harvest and make it unavailable for leaching during late fall and early winter groundwater recharge. When compared to the no cover areas, residual soil nitrate levels were consistently lower in the cover crop areas to a depth of five feet for all sample dates. Results also indicate that early fall cover crop planting coupled with early spring kill results in maximum nitrogen immobilization and maximum corn yield the following year.

The application of dairy manure in the fall in the Pennsylvania study increased soil nitrate content by approximately 30% above background levels. However, by the following spring soil nitrate levels in the first foot of soil under the cover crop area was only about 50% of those levels in the no-cover areas. Although the Piper sudangrass yields were less than the corn silage yields, the advantages of flexibility in timing field operations may outweigh the yield penalty of this crop in some farm situations.

On-farm trials conducted by the Rodale Institute indicate corn yields in the rye cover crop areas were not significantly different than yields in the no cover areas. Nitrogen uptake and commensurate reductions in soil nitrate levels for the on-farm trials were similar to those obtained in the research trials.

During the winter of 1989, approximately 260 people attended educational workshops in Maryland and Pennsylvania. Results of this study were presented. In addition, a table-top display for creating awareness of the project and of the potential benefit of rye cover crops was constructed. The display was set up at several educations events in Delaware, Maryland and Pennsylvania.

University of Delaware

Biomass and Soil Sampling:

A rye cover crop was planted on four of eight small watersheds in October and November 1988. Four of the watersheds which had full season soybeans planted in 1988 were planted to non-irrigated corn in 1989. Four of the watersheds which had irrigated corn in 1989, had irrigated corn grown in 1988. In addition to the eight watersheds a rye cover crop was also planted on four small watersheds that were planted to double-cropped soybeans in 1988. The four watersheds that had double-cropped soybeans were planted to irrigated corn in 1989. Rye was also planted on 24 of 48 plots that are 30 x 50 ft in size. Non-irrigate corn was grown on these plots in 1988.

A rye cover crop was planted again during the week of October 22, 1989 on four watersheds and the small plots. Soil samples were broken at depths of 0-6 and 6-12 in. when the rye cover crop was planted in 1989. Biomass samples were to have been taken on the watersheds and small plots in late December, 1989, but because of the extremely cold weather and snow cover, no samples were taken. Samples were taken in late March, 1990 before the rye was killed in early April. Soil samples were also taken from 0-6 and 6-12 in. when biomass samples were collected. Rye yields and N uptake rates for the 1988 fall sampling are presented in Table 1. Biomass yields and nitrogen uptake rates were low for all locations. All of the cover crops were planted late for optimum growth and very little fertilizer was applied to the small plots in 1988.

Table 1. Biomass Yields And Nitrogen Uptake Rates For December, 1988

Location	Biomass (lb/a)	N Concentration (%)	N Uptake (lb/a)
Small Plots	940	2.07	19.4
Watershed 9-2	331	3.02	10.0
Watershed 9-3	173	3.02	5.2

Biomass yields and nitrogen uptake rates for the March 1989 sampling are presented in Table 2. There was considerable biomass production and N uptake for the March samples. The four watersheds where the cover crops were planted in November had N uptake rates that ranged from 24.2 to 31.2 lb/a. There was very little growth in these watersheds in the fall of 1988. Average N uptake for the small plots was 42.7 lb/a.

The nitrate content ranged from 9 to 19.4 lb/a in the top 12 in. in December of 1988 for the watersheds and small plots. No differences were detected in soil nitrate concentrations between the rye cover crop and no cover crop treatments. This would be expected because there was very little nitrate uptake by the cover crop in December.

The nitrate content of the top 12 in. collected in March of 1989 for the watersheds and small plots was low with concentrations ranging from 10 to 15 lb/a. Soil sampling below the 12 in. depth indicated some nitrate leaching occurred below the root zone. For the October 1989 sampling, there was less than 12 lb/a of nitrate in the top 12 inches of the soil profile on both the watersheds and small plots. There was very little difference in nitrate concentration for the different treatments. Nitrate concentrations ranged from 1.5 to 3.0 ppm. This would be expected because of the excessive rainfall that occurred in September and early October.

Table 2. Biomass Yields And Nitrogen Uptake Rates For March, 1989

Location	Biomass (lb/a)	N Concentration (%)	N Uptake (lb/a)
Small Plots	3772	1.13	42.7
Watershed 9-2	3520	0.81	28.5
Watershed 9-3	2249	1.01	22.7
Watershed 7-2	1877	1.37	25.7
Watershed 7-4	1576	1.98	31.2
Watershed 27-1	2426	1.14	25.7
Watershed 27-2	2264	1.15	24.2

Biomass production and nitrogen uptake for the fall and winter of 1989 and 1990 were low (Table 3). The rye was planted late because of wet conditions and very little growth occurred in the fall because of an extremely cold December.

Table 3. Biomass Yields And Nitrogen Uptake Rates For March, 1990

Location	Biomass (lb/a)	N Concentration (%)	N Uptake (lb/a)
Small Plots-NT	1500	1.55	23.3
Small Plots-CT	1398	1.58	22.1
Watershed 9-2-NT	683	1.41	9.6
Watershed 9-3-CT	765	0.83	6.3
Watershed 7-2-NT	712	1.60	11.4
Watershed 7-4-CT	1118	1.69	18.9

Corn Yields

Corn yields for 1989 and 1990 are presented in Tables 4 to 7. In 1989 and 1990, all of the plots were irrigated along with the #9 watershed and the #27 watershed in 1989. The #27 watershed was not used in 1990. The #7 watershed was non-irrigated. Because of adequate rainfall in 1989, very little irrigation water was applied. The small plots received 26.2 inches of rainfall from planting to maturity and the watersheds received 28.6 inches of rainfall. In 1990, 18.5 inches of rainfall occurred during the growing seasons. The small plots received 12.8 inches of irrigation and the watersheds received 13.5 inches.

Corn yields on the small plots ranged from 120.2 to 142.9 bu/a. An analysis of variance indicated there was no significant difference in yield for the treatments at the 5% level. For the no-till plots, corn yields were higher on the rye cover crop treatments than the no cover treatments, while for the conventional tillage plots, corn yields were higher on the no cover treatments. In general, there was very little difference in the nitrogen source yields. A total of 210 lb/a of nitrogen fertilizer was applied and a total of 250 lb/a of total nitrogen was applied in the poultry manure and composted poultry manure.

Corn yields on the watersheds varied from 98.2 to 140.9 bu/a with the irrigated corn yields higher than the non-irrigated yields. There was very little difference in the yields between the rye cover crop and no cover crop treatment.

Table 4. Corn Yields on Small Plots for 1989

Tillage	N[a] Source	Yield[b] (bu/a) Cover	No Cover
No-till	F	133.8	123.8
	PM	135.3	136.6
	CPM	139.6	135.8
Conventional	F	133.6	142.8
	PM	120.2	130.9
	CPM	129.3	142.9

[a] F - fertilizer, PM - poultry manure, CPM - composted poultry manure.
[b] LSD at 5% level was 7.7 bu/a.

Table 5. Corn Yields on Watersheds for 1989

Watershed No.[a]	Tillage	Cover	Yield (bu/a)
9-4	NT	None	131.9
9-3	CT	Cover	134.8
9-3	CT	None	124.5
9-1	NT	Cover	140.9
7-1	NT	None	107.1
7-3	CT	None	110.3
7-2	NT	Cover	99.2
7-4	CT	Cover	101.7
27-1	NT	None	101.9
27-2	CT	None	124.2
27-3	NT	Cover	113.3
27-4	CT	Cover	124.5

[a] Watersheds 9 and 27 were irrigated and watershed 7 was not irrigated.

Table 6. Corn Yields on Small Plots for 1990

Tillage	N Source	Yield[a] (bu/a) Cover	No Cover
No-till	F	114.2	110.7
	PM	116.7	108.3
	CPM	109.7	103.3
Conventional	F	124.7	130.3
	PM	129.7	140.3
	CPM	118.3	118.3

[a] LSD at 5% level was 4.5 bu/a.

Table 7. Corn Yields on Watersheds for 1990

Watershed No.[a]	Tillage	Cover	Yield (bu/a)
9-1	CT	None	120.7
9-2	NT	Cover	122.7
9-3	CT	Cover	128.0
9-4	NT	None	104.7
7-1	NT	None	44.7
7-2	NT	Cover	37.3
7-3	CT	None	69.0
7-4	CT	Cover	75.0

[a] Watersheds 9 were irrigated and 7 non-irrigated

In 1990, corn yields were lower in the non-irrigated then the irrigated watersheds. Also, yields were higher for conventional till then no-till. There was very little difference in yield between no cover and cover. For the same plots, there was a significant difference in tillage treatments at the 5 percent level with conventional tillage having higher yields then no-till. There was no significant difference between poultry manure and commercial fertilizer and composted poultry manure.

Groundwater Quality: Groundwater quality was monitored during the winter of 1989 on the 12 watersheds. The watersheds 9-1 to 9-4 have three wells installed at the 10 ft depth and three wells at the 15 ft depth in each watershed. Watersheds 7-1 to 7-4 have three wells in each watershed at a depth of 15 ft and watersheds 27-1 to 27-4 have six wells in each watershed at a depth of 15 ft. There are also a number of wells located outside the watersheds that are sampled for background purposes.

Average nitrate concentrations in the groundwater for winter, spring and summer for all 12 watersheds in 1989 are presented in Table 5. During the winter months, all monitoring wells had nitrate concentrations above 10 mg/l N. Nitrate concentrations were the lowest during the summer months on most of the watersheds when the least amount of recharge occurs. In 1990, nitrate concentrations with groundwater were similar to 1989.

Table 8. Nitrate Concentrations In Groundwater

Watershed	Well Depth (ft)	Tillage	Cover	Nitrate Concentrations Winter	Spring (mg/l N)	Summer
9-1	10	NT	None	27.5	18.2	3.72
9-2	10	CT	Cover	27.5	16.9	3.47
9-3	10	CT	None	Dry	17.1	1.17
9-4	10	NT	Cover	12.6	12.9	4.69
9-1	15	NT	None	16.0	12.9	3.08
9-2	15	CT	Cover	23.3	14.2	4.04
9-3	15	CT	None	17.3	10.6	2.74
9-4	15	NT	Cover	18.3	10.7	1.11
7-A	15	NT	None	10.8	14.1	2.14
7-B	15	CT	None	11.4	13.1	1.51
7-C	15	NT	Cover	14.9	15.9	2.47
7-D	15	CT	Cover	12.6	14.1	2.23
27-1	15	NT	None	12.7	2.26	11.7
27-2	15	CT	None	18.2	2.45	15.2
27-3	15	NT	Cover	14.7	2.32	12.7
27-4	15	CT	Cover	21.6	2.80	14.3

Summary:

Nitrogen uptake by the cover crops during the two year study were relatively low. In 1988 and 1989, the cover crops were not planted at the optimum time because of weather conditions. There was very little difference in yield between cover and no cover. Conventional tillage yields were greater than no-till yields. Nitrate concentrations in the groundwater in the groundwater changed very little over the two year study period.

The use of cover crops has increased in the Inland Bay's watershed in Sussex County over the past several years. The use of poultry manure as a fertilizer has also increased and SCS is promoting cover crops as a BMP in the Inland Bay's watershed.

University of Maryland

In late September 1988 a grid of 15 x 40 ft plots was established in continuous no-till and conventional till corn fields. Each grid contained 54 plots in a 9 x 6 configuration, thus allowing 18 treatments replicated 3 times. On September 30, 1988 rye was no-till drilled into 36 plots within each grid (3 spring kill dates x 4 1989 N treatment rates x 3 replications). Three additional plots in each grid were planted on October 15 and 29, 1988 to address the effect of fall planting date on N uptake. Spring management practices focused only on the early fall planting date treatments.

Soil samples were taken in both tillage systems using a push probe at 0-6 and 6-12 in depths prior to rye emergence, and on October 31, November 23, December 21, 1988 and February 13, March 29, and April 4, 1989. Samples were dried to determine moisture content and extracted for determination of nitrate concentrations. Rye above-ground biomass was sampled on the last two soil sampling dates in 1988 and all three soil sampling dates in 1989, with one additional sampling on May 23, 1989. Samples were dried to determine biomass production and total N content.

Two field scale watersheds which had been planted continuously in corn since 1984, one no-till and one conventional till, were planted with rye using a no-till drill during the last week of September 1988. Nitrogen movement from these systems via surface runoff and groundwater had been monitored since 1984. Sampling continued through the 1988-89 recharge cycle. Shallow groundwater samples are taken monthly and all surface runoff was quantified both in terms of volume, N, P content and sediment loads. Leachate from gravity-fed lysimeters were monitored as well as atmospheric N inputs to these systems. Deep soil cores (0-60 in) were taken in 6 in. increments in both watersheds on November 1 and December 1, 1988 and March 22 and April 20, 1989. Another set was taken in late November within the watersheds as well as in adjacent areas where no cover crop was planted.

Results for biomass production and nitrogen assimilation by the rye cover crop for the three planting dates is shown in Table 1 and Figures 1a, 1b, 2a and 2b. For the conventional tillage system total dry matter production of approximately 9008, 7048 and 3187 lbs/a and total nitrogen assimilation of 162.6, 135.8 and 71.1 lbs N/a were observed approximately 180, 165 and 150 days after planting, respectively. Nitrogen content of the rye tissue was above four percent for the November sampling date and declined steadily as biomass production increased. Nitrogen content of the rye tissue increased with the later planting dates for all sample dates considered. Conversely, biomass production decreased with planting date, resulting in decreased nitrogen uptake.

For the no-tillage system total dry matter production of approximately 3059, 2834 and 1615 lbs/a and total nitrogen assimilation of 49.7, 53.1, and 33.7 lbs N/a were observed approximately 180, 165 and 150 days after planting respectively. Nitrogen content of the rye tissue although consistently lower than for the conventional tillage system, followed the same trends.

Average nitrate-N concentrations in the top 12 inches of the soil profile for the three rye planting dates for the conventional till and no till plots shown in Table 2 and Figures 3a and 3b. For the conventional till cover plots for almost all sample dates, nitrate-N concentrations were greater in the 0-6 inch depth than the 6-12 inch depth. Although the same trend was observed in the no-till cover plots, the average nitrate-N concentrations were approximately threefold lower. Similar trends were observed for the no cover plots except the differences were approximately twofold lower for the no-till cover plots.

Generally, the trend for the three planting dates for both tillage systems mirror the nitrogen assimilation results given in Table 1. It is interesting to note the nitrate-N concentrations for the March 29, 1989 sample date were similar for all treatments in both tillage systems including the no cover controls. These results clearly show that the nitrogen not immobilized using cover crops was leached out of the root zone. This is particularly evident in the conventional till no cover plot where a tenfold reduction in average nitrate-N concentrations were observed between the February 13 and March 29, 1989 sampling.

This trend is further substantiated when deep cores are considered. Table 3 shows the average nitrate-N concentrations in deep cores with and without a rye cover crop for the conventional till watershed where the rye was planted on October 1, 1988. Average nitrate-N concentrations across all depths were consistently lower in cover crop area compared to the no cover area for all four sample dates. It is also interesting to note that average nitrate-N concentrations decrease for both treatments with time. However, in the no cover area, the decrease in nitrate-N concentration is the result of leaching where as in the cover area, the decrease in nitrate-N concentration resulted from plant (rye) uptake.

Corn yield for 1989 as a function of the three rye planting dates, three rye spring kill dates, and four nitrogen rates for both the conventional till and no-till plots are given in Table 4. Generally, as nitrogen application rates decrease, grain yields decrease for both tillage systems for all rye kill dates. Overall yields also decrease with delayed rye kill dates for both tillage systems. Later rye planting dates coupled with early spring rye kill date resulted in higher yields at comparable N application rates. Overall, yields were somewhat higher for the no cover plots compared to the cover plots for both tillage systems.

Table 1. Average biomass yields and nitrogen assimilation for rye cover crop.

Sample date	Tillage practice	Planting date	Biomass (lb/a)	N Conc (%)	N uptake (lb/a)
11/22/88	CT	10/01/88	1504	4.24	63.7
	CT	10/15/88	591	5.16	30.5
	CT	10/30/88	74	5.20	3.9
	NT	10/01/88	1046	3.38	35.4
	NT	10/15/88	407	4.14	16.8
	NT	10/30/88	68	4.48	3.1
12/22/88	CT	10/01/88	2894	3.83	110.8
	CT	10/15/88	1249	4.33	54.1
	CT	10/30/88	269	4.90	13.2
	NT	10/01/88	1294	2.61	33.8
	NT	10/15/88	650	3.43	22.3
	NT	10/30/88	176	4.67	8.2
02/20/89	CT	10/01/88	4709	2.90	136.5
	CT	10/15/88	2642	3.13	82.7
	CT	10/30/88	951	4.69	42.2
	NT	10/01/88	2196	1.88	41.2
	NT	10/15/88	1837	2.47	45.5
	NT	10/30/88	849	3.53	30.1
03/29/89	CT	10/01/88	9088	1.74	162.6
	CT	10/15/88	7048	1.93	135.8
	CT	10/30/88	3187	2.23	71.1
	NT	10/01/88	3059	1.46	49.7
	NT	10/15/88	2834	1.68	53.1
	NT	10/30/88	1615	1.88	33.7
04/24/89	CT	10/01/88	14630	1.17	170.3
	NT	10/01/88	6086	0.87	52.7
05/23/89	CT	10/01/88	18764	0.63	118.2
	NT	10/01/88	11210	0.47	52.2

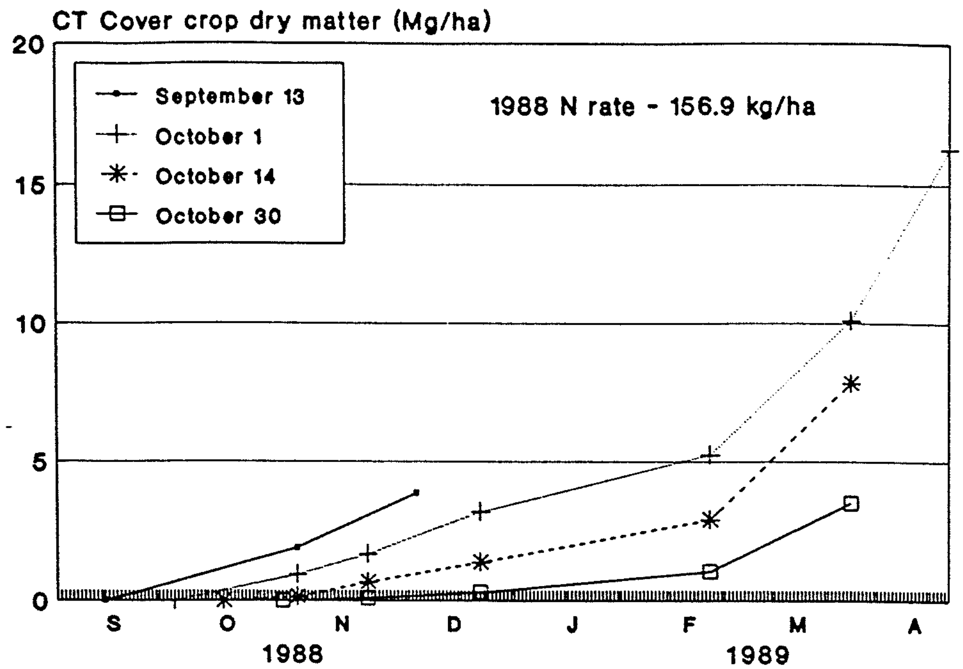

Fig 1a. Cover crop dry matter production as a function of planting date following the 1988 corn harvest in the CT treatment.

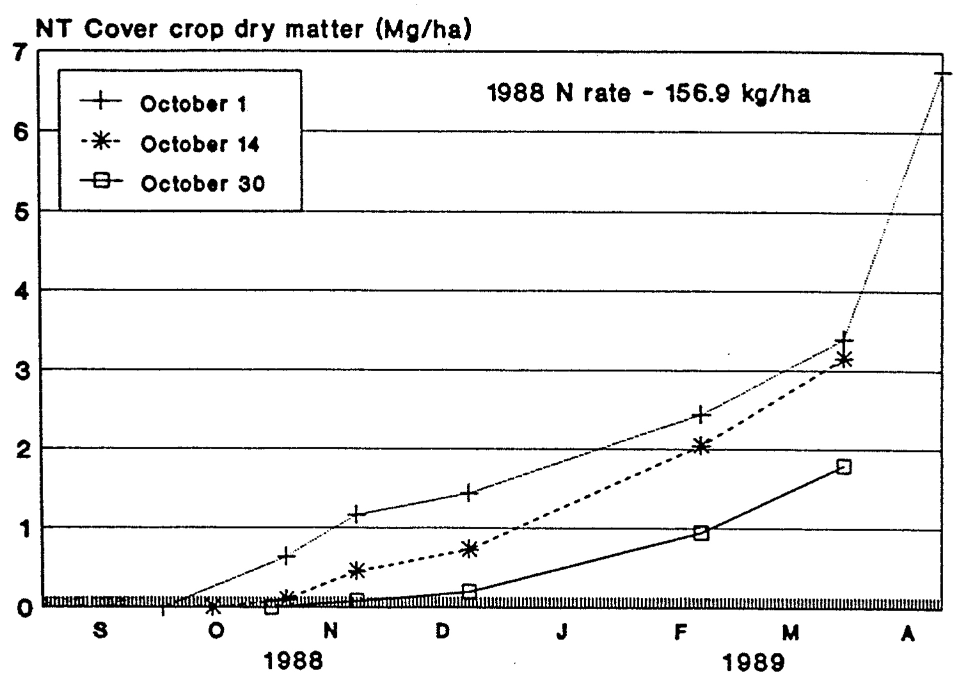

Fig 1b. Cover crop dry matter production as a function of planting date following the 1988 corn harvest in the NT treatment.

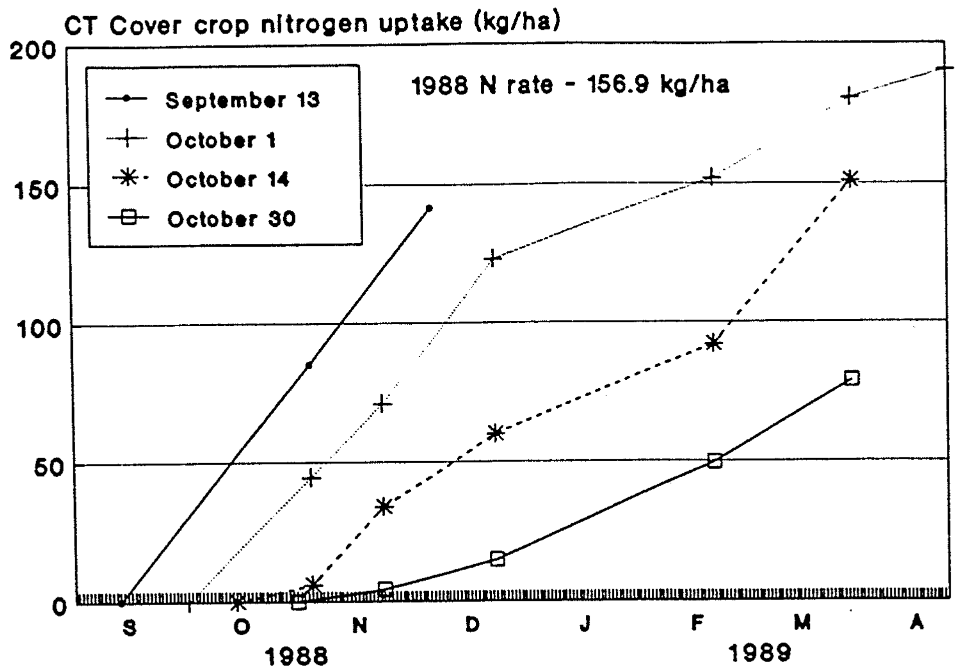

Fig 2a. Above ground cover crop nitrogen assimilation in the CT treatment area as a function of planting date following the 1988 corn harvest.

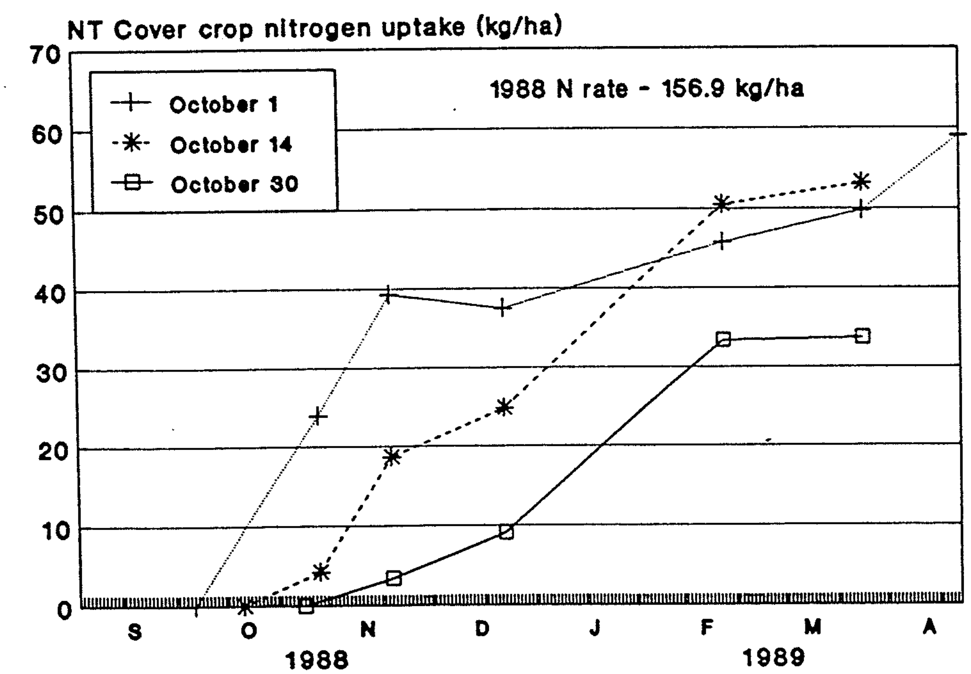

Fig 2b. Above ground cover crop nitrogen assimilation in the NT treatment area as a function of planting date following the 1988 corn harvest.

Table 2. Average nitrate-N concentrations in the top 12 inches of the soil profile for three rye planting dates for conventional (CT) and no-till (NT) plots.

Rye Planting Dates	Soil Sample Date											
	10/05/88		10/31/88		11/23/88		12/21/88		02/13/89		03/29/89	
	Avg	SE	Avg	SE	Avg	SE	Avg	SE	Avg	SE	Avg	SE
	CT Concentrations (ppm)											
10/01/88												
0- 6	23.97	5.13	8.70	1.17	2.00	0.59	2.90	1.14	1.20	0.07	0.90	0.16
6-12	31.80	6.27	22.80	6.61	9.90	5.38	5.00	1.89	1.60	0.51	0.90	0.28
10/15/88												
0- 6			26.30	18.95	12.50	8.04	3.50	1.06	1.10	----	0.08	0.16
6-12			24.70	7.01	21.40	4.33	7.90	2.21	1.40	0.52	1.00	0.32
10/30/88												
0- 6					17.10	8.40	9.70	6.93	2.00	0.29	0.70	0.07
6-12					25.50	0.36	16.60	6.27	5.50	0.95	0.90	0.29
No Cover												
0- 6	20.10	3.94	14.90	5.46	10.50	4.15	10.80	3.25	10.80	3.25	1.30	0.22
6-12	35.60	5.78	20.70	2.66	18.30	2.98	17.60	3.63	17.60	3.63	1.70	0.69
	NT Concentrations (ppm)											
10/01/88												
0- 6	8.32	0.94	3.25	0.85	1.30	0.15	2.10	0.43	0.90	0.09	1.10	0.19
6-12	6.01	1.06	4.45	2.05	0.80	0.16	0.80	0.04	0.80	0.07	0.90	0.11
10/15/88												
0- 6			5.30	0.87	2.80	0.37	2.40	0.65	1.30	0.14	1.40	----
6-12			3.44	0.77	2.40	1.01	0.70	0.08	0.90	0.08	0.70	0.04
10/30/88												
0- 6					2.60	0.38	7.90	3.77	2.30	0.17	1.60	0.11
6-12					5.50	2.38	11.90	6.58	1.70	0.28	0.80	0.07
No Cover												
0- 6			9.83	4.96	3.70	0.83	6.60	1.20	6.00	0.93	3.70	1.29
6-12			4.89	2.00	5.00	2.40	3.40	0.93	4.20	0.53	2.10	0.89

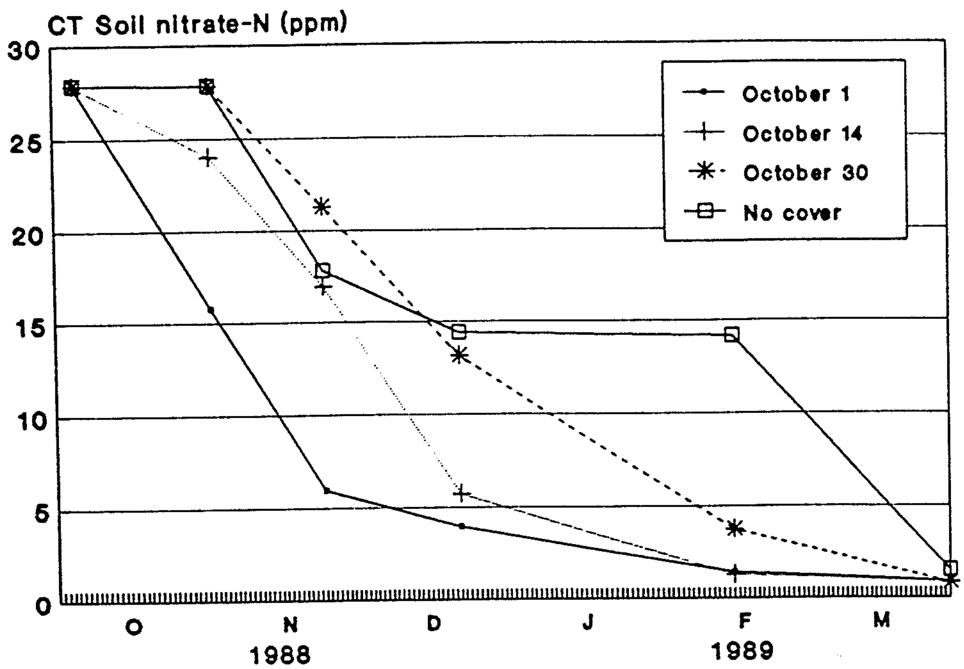

Fig 3a. Average soil nitrate-N concentration (0-30 cm) in the CT treatment area following the 1988 corn harvest as affected by cover crop planting dates.

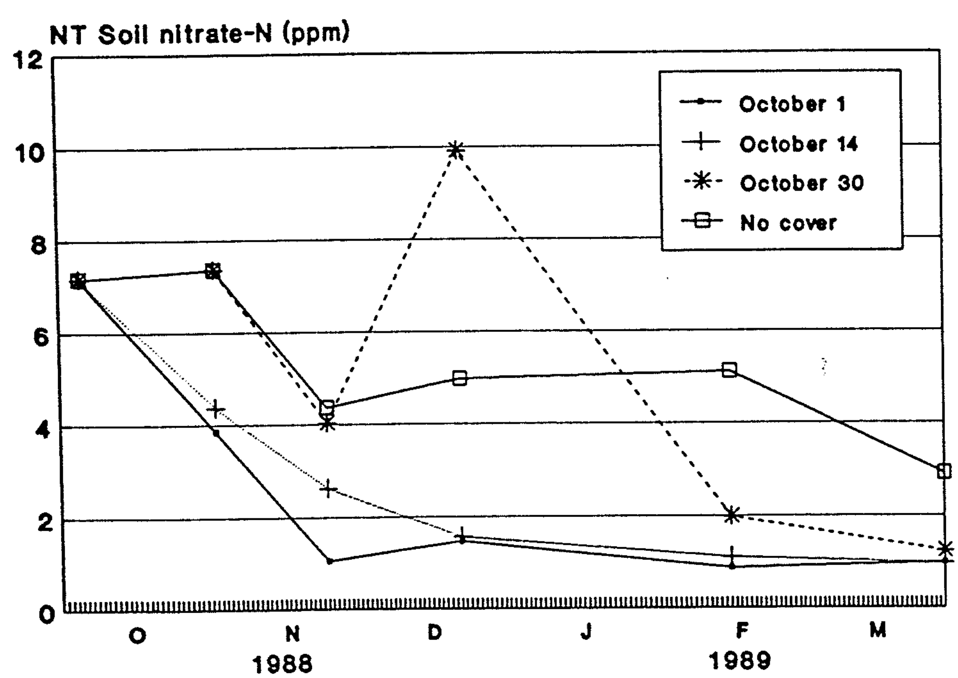

Fig 3b. Average soil nitrate-N concentration (0-30 cm) in the NT treatment area following the 1988 corn harvest as affected by cover crop planting dates.

able 3. Average nitrate-N concentrations in deep soil cores with and without a rye cover crop for the conventional (CT) watershed.

oil epth in)	Soil Sample Dates															
	11/01/88				12/01/88				03/22/89				04/20/89			
	Concentrations (ppm)															
	Cover		No Cover		Cover		No Cover		Cover		No Cover		Cover		No Cover	
	Avg	SE	Avg	SE	Avg	SE	Avg	SE	Avg	SE	Avg	SE	Avg	SE	Avg	SE
0- 6	7.40	2.17	43.50	20.20	1.50	0.48	14.80	5.07	0.70	0.16	1.00	0.08	0.70	0.10	2.10	1.09
6-12	23.40	4.12	40.50	10.50	4.50	1.91	29.00	9.63	0.60	0.11	5.90	2.22	0.50	0.11	1.10	0.31
2-18	10.60	2.12	13.40	4.25	11.10	5.00	24.90	5.39	0.90	0.23	20.50	5.38	0.90	0.47	8.80	3.68
8-24	7.60	0.92	6.60	0.96	7.60	2.72	12.50	3.77	0.80	0.19	19.00	3.60	1.00	0.39	13.80	5.19
4-30	5.50	1.17	3.80	0.60	6.00	2.47	8.80	3.05	1.30	0.89	12.40	1.78	1.10	0.48	12.00	3.93
0-36	4.50	0.91	4.40	0.75	4.60	1.56	6.00	0.89	2.20	1.25	10.70	1.87	2.40	1.15	9.80	3.03
6-42	3.90	0.87	2.60	0.40	4.80	1.19	5.80	1.80	2.90	0.72	7.50	1.18	3.30	1.84	7.50	1.82
2-48	4.60	0.30	2.60	0.45	4.30	1.22	4.60	1.34	3.30	0.44	6.40	0.80	2.60	0.75	6.70	1.58
8-54	3.90	0.50	2.80	0.26	4.80	1.02	5.20	1.45	3.80	0.69	7.10	0.91	4.20	1.83	5.50	0.75
4-60	4.50	1.02	2.80	0.30	5.50	1.27	4.70	1.40	5.00	1.41	5.90	0.87	5.50	2.89	6.30	0.78

Table 4. Corn yield as a function of three rye planting, three spring kill dates, and four nitrogen rates for conventional (CT) and no till (NT) plots.

Rye Planting Date	Rye[1] Kill Date	$N^{(2)}$ Rate	Grain Yield (bushels/acre) CT Avg	CT SE	NT Avg	NT SE
10/01/88	1	1	42.30	6.49	38.40	4.06
		2	71.00	15.22	59.10	2.98
		3	83.20	11.39	108.10	11.77
		4	80.00	8.18	102.70	0.66
	2	1	39.20	1.66	37.90	2.68
		2	72.20	12.43	92.20	2.63
		3	92.10	22.05	73.20	13.37
		4	100.40	15.57	103.30	4.70
	3	1	32.30	7.23	42.40	3.05
		2	35.40	9.91	46.40	6.52
		3	45.40	13.45	87.80	8.50
		4	54.70	18.45	96.20	11.71
No cover	-	1	69.20	12.30	50.80	8.82
	-	2	114.20	8.11	88.20	10.30
	-	3	98.10	16.20	107.10	15.43
	-	4	112.10	8.28	115.70	9.11
10/15/88	1	3	96.80	6.99	118.40	9.11
10/30/88	1	3	107.10	14.34	98.50	6.88

(1)Spring 1989 rye kill dates: 1 = March 29; 2 = April 25; 3 = May 23.
(2)Nitrogen rates: N_1 = 0.0 lbs/ac; N_2 = 84.0 lbs/ac; N_3 = 112.0 lbs/ac; N_4 = 140.0 lbs/ac

Pennsylvania State University

Experimental Layout

Two field experiments were established on two soils on a cooperating farm (Milton Hershey School Farm, Hershey, PA) in southeastern Pennsylvania. The experiments were: rye cover crop followed by corn for silage and rye cover crop followed by annual warm-season grass. Each of these experiments was established on each of the two soils. Mainplot treatments (Table 1) were applied in the early autumn 1988.

Rye/Corn Silage Experiment

Table 1. List of treatments for the rye/corn silage experiments.

Main Plot Treatment	Rye Cover	Manure Time	Manure Amount T/A
A	No	0	0
B	No	Spring	15
C	Yes	0	0
D	Yes	Spring	15
E	Yes	Spring	30
F	Yes	Fall	15
G	Yes	Fall	30

The statistical design is a split plot with cover and manure application (rate and time) as the main plots. Nitrogen fertilizer rates at five levels from 0 to 200 lbs N/A were the split plots applied to the corn as ammonium nitrate at sidedressing. Pioneer 3737 corn hybrid was planted at approximately 28,000 seeds/A. A low residue herbicide application was made. Soil samples were collected from the O N corn plots in each manure treatment for presidedressing nitrate determinations. Corn rootworm beetles were counted in the experimental area during August to determine potential risk of infestation in the following crop year. The two soils are a fine-textured limestone-derived soil (H: Hagerstown) and a medium-textured shale-derived soil (B: Berks). There were three replications on each soil.

Additional spring treatments in the rye/corn experiment were attempted to evaluate a "burn down" rye treatment as a linkage with the treatments of the experiments in Maryland and Delaware where the rye was not harvested (Table 2).

Table 2. Additional spring treatments in the rye/corn silage experiment.

Rye Treatment	Cover	Manure Time	Manure Amount	N/Rye	Kill Time
				lbs/A	
38	Yes	0	0	150	Early
39	Yes	0	0	150	Late

Due to difficulties in the experimental layout in the field, these treatments were not implemented.

Liquid dairy manure (approx. 5% solids) was applied to the fall main plot treatments in mid-September. The plots were disked to incorporate the manure and rye planted on the appropriate main plots of each experiment. In 1989, small plots were harvested from the main plots of the rye/corn experiment in mid-November and soil samples collected concurrently in two increments, 0 to 6" and 6 to 12", for nitrate analysis. Due to weather delays in 1989, the rye was not planted until about two weeks later than in 1988 (early October). Consequently, there was little rye growth by mid-November when the fall sampling was made (approximately 250 lbs/A). Soil and plant sampling of selected treatments was repeated in early April, 1989. Harvest strips were measured from each of the rye and manure treatment combinations in the corn and warm-season annual experiments on each soil. Spring manure applications were made after rye harvest. The plots were disked before and soon after manure application, except when significant rainfall occurred in the interim.

Manure treatments were revised at the time of the fall application (Table 3) based on operational problems associated with the high rates of application to the plots and the limited amount of manure available for spreading at any one time.

Table 3. List of treatments for the rye/corn silage experiments (Fall 1989 revision).

Main Plot Treatment	Rye Cover	Manure Time	Manure Amount
			T/A
A	No	0	0
B	No	Spring	10
C	Yes	0	0
D	Yes	Spring	10
E	Yes	Spring	20
F	Yes	Fall	10
G	Yes	Fall	20

Manure was applied following corn harvest and rye planted in the appropriate main plots. Soil samples of the surface root of soil were collected in November from each of the split plots.

Rye/Annual Warm-season Forage Grass Experiment

Table 4. Treatments for the rye/warm-season forage grass experiment.

Main Plot Treatment	Rye Cover	Manure Time	Manure Amount
			T/A
A	Yes	0	0
B	Yes	Spr/Sum	15
C	Yes	Spr/Sum	30

The statistical design is a split plot with manure application (rate and time) as the main plot and nitrogen rate from 0 to 200 lbs N/A as the sub-plots. Manure was applied in the spring after rye harvest (two-thirds total rate) before grass planting, and after the first harvest of the grass (one-third total rate) using Piper sudan grass. This experiment was also conducted on the two soils described for the rye/corn experiment. There were 15 treatments on each soil in this experiment with three replications.

Results

Fall 1988

Rye yields and plant N uptake were significantly different between the two locations. Yields from the Hagerstown (H) site were greater than those of the Berks (B) site (Table 5).

Table 5. Rye yields and plant N parameters when harvested in mid-November, 1988 from two locations of the rye/corn experiment.

	Location	
	H	B
Yield (lbs/A)*	870	603
Plant N		
Concentration (%)	5.03	5.21
Uptake (lbs N/A)*	40.1	30.2

* Significant at P=0.05.

Manure rate did not affect any of the plant growth or plant N parameters (Table 6).

Table 6. Rye yields and plant N parameters when harvested in mid-November, 1988 at three manure rates on the rye/corn experiment.

	Manure Rate		
	0	1	2
Yield (lbs/A)	641	811	757
Plant N			
Concentration (%)	5.37	5.00	4.98
Uptake (lbs N/A)	33.9	39.7	33.9

Soil nitrate in the first increment sampled was not different between the locations, but the concentration in the second increment was greater at location H. The total was also greater at H (Table 7). This differential N concentration probably reflects the previous management histories of the fields. Field H had been fertilized and manured more intensively than field B.

Table 7. Concentrations of nitrate N in the soils at the two research locations in mid-November, 1988.

	Location	
	H	B
Soil nitrate	---- lbs/A ----	
increment 1	40.4	33.9
increment 2*	31.2	22.2
total*	71.6	56.0

* Significant at P=0.05.

Soil nitrate concentrations were generally greater in areas where the cover crop was planted than in the non-cover crop areas because manure had been applied to only the cover-cropped treatments in the fall (Table 8).

Table 8. Concentrations of soil nitrate N in the rye/corn experiment with and without cover crops when sampled in mid-November, 1988.

	Cover Crop	
	Rye	No Cover
Soil nitrate	----- lbs/A -----	
increment 1*	41.7	23.7
increment 2*	28.4	21.6
total*	70.0	45.3

* Significant at P=0.05.

Soil nitrate was closely related to rates of manure application in the autumn, 1988. However, growth of rye in the fall with no manure application decreased the concentration of nitrogen in the soil compared to the concentration when no cover crop was grown (Table 9).

Table 9. Concentrations of soil nitrate N in the rye/corn experiment with and without cover crops at several rates of manure application when sampled in mid-November, 1988.

	Cover Crop			
	Rye			No Cover
	Manure rate			
	0	1	2	
Soil nitrate	----------- lbs/A -----------			
increment 1*	11.6c	44.7b	68.7a	23.7c
increment 2*	12.1d	28.6b	44.4a	21.6c
total*	23.6d	73.4b	113.1a	45.2c

* Significant at P=0.05. Means followed by the same letter in a row are not different.

Spring 1989

Rye yields and plant N uptake were significantly different between the two locations although plant N concentrations were similar (Table 10).

Table 10. Rye yields and plant N parameters when harvested in early April, 1989 from two locations of the rye/corn experiment.

	Location	
	H	B
Yield (lbs/A)*	2935	1316
Plant N		
Concentration (%)	4.05	3.97
Uptake (lbs N/A)*	120	53

* Significant at P=0.05.

Manure rate did affect the plant growth parameters (Table 11) with yields greater following manure application (but no difference due to rate of application). Plant N was greatest at the heaviest manure application as was the plant uptake of N. Nitrogen concentration in the plants was not different between the light manure application and the no manure application.

Table 11. Rye yields and plant N parameters when harvested in early April, 1989 at three manure rates on the rye/corn experiment.

	Manure rate		
	0	1	2
Yield (lbs/A)*	1393b	2182a	2802a
Plant N			
Concentration*	3.69b	3.99ab	4.35a
Uptake (lbs N/A)*	52c	87b	120a

* Significant at P=0.05. Means followed by the same letter in a row are not different.

Total soil nitrate or nitrate in the first or second increments sampled were not different between the locations (Table 12). This contrasts with the fall sampling when the nitrate in the surface increment only was similar between locations. All parameters measured were approximately 75% less than the comparable fall measurements.

Table 12. Concentrations of nitrate N in the soils at the two research locations in early April, 1989.

	Location	
	H	B
Soil nitrate (lbs/A)		
increment 1	10.9	10.5
increment 2	8.1	8.1
total	18.6	19.0

Soil nitrate concentrations were about 50% less for the cover crop than the non-cover crop area due to nitrate utilization by the growing rye crop (Table 13). This reversal of relative nitrate concentrations from the fall sampling, when the concentrations were 30% greater for the cover crop, reflects the potential contribution of the rye to the decrease in environmental contamination from residual or fall-applied nitrogen.

Table 13. Concentrations of soil nitrate N in the rye/corn experiment with and without cover crops when sampled in early April, 1989.

	Cover Crop	
	Rye	No Cover
Soil nitrate (lbs/A)		
increment 1*	8.9	16.1
increment 2*	5.9	14.7
total*	14.8	30.8

* Significant at P=0.05.

Soil nitrate was related to fall manure applications (Table 14). As the manure applications increased, soil nitrate concentrations in the first increment and the total for the two increments increased. However, soil nitrate following manure applications with a rye cover crop was less than two-thirds the concentration when no manure was applied and no cover crop grown. Thus, even with fall manure applications, the rye cover crop reduced the soil nitrate concentrations below those of the soil with no manure applied. The total soil nitrate decreased by approximately 30% since the fall sampling when no rye cover crop was grown. When the rye cover crop was grown at the heaviest manure application the decrease was greater than 80% from the fall to the spring sampling.

Table 14. Concentrations of soil nitrate N in the rye/corn experiment with and without cover crops at several rates of manure application when sampled in early April, 1989.

	Cover Crop			
	Rye			No Cover
	Manure rate			
	0	1	2	
Soil nitrate (lbs/A)				
increment 1*	5.4d	8.6c	12.6b	16.1a
increment 2*	3.0c	6.4b	8.3b	14.7a
total*	8.4d	15.0c	20.9b	30.8a

* Significant at P=0.05. Means followed by the same letter in a row are not different.

Spring Harvest

The location effect was significant for the rye/corn experiment (Table 15). The rye grown on the H site yielded 40% more than the B site.

Table 15. Rye yields when harvested in late April, 1989 from two locations of the rye/corn experiment.

	Location	
	H	B
Rye yield (lbs/A)*	4633	3289

* Significant at P=0.05.

Manure applications increased yields of rye by almost 30% when compared to no manure applications, but there was no difference in yields among the manure rates (Table 16).

Table 16. Rye yields and plant N parameters when harvested in late April, 1989 at three manure rates on the rye/corn experiment.

	Manure rate		
	0	1	2
Rye yield (lbs/A)*	3622b	5142a	5028a

* Significant at P=0.05. Means followed by the same letter in a row are not different.

There was a significant interaction between soil (site) and time of manure application. For this first year of the experiments time of application was confounded since manure has only been applied in the fall. The increases in yield ranged from 48 to 63% with the B site (lowest residual nitrate) responding the most to the manure applications (Table 17).

Table 17. Rye yields with different times on manure application when harvested in late April, 1989 from two locations of the rye/corn experiment.

	Location	
	H	B
Manure	Yield (lbs/A)*	
Fall applied*	5830	4340
Spring applied*	3931	2659

* Significant at P=0.05.

Manure and N treatments were not applied to these areas in the Fall of 1988. However, a winter cover crop of rye was grown. The yield results (Table 18) support the differences measured in the rye/corn experiments. The rye yielded less from the B site than the H site.

Table 18. Rye yields when harvested in late April, 1989 from two locations of the rye/warm-season annual experiment.

	Location	
	H	B
Rye yield (lbs/A)*	4390	3104

* Significant at P=0.05.

In 1989, corn silage yields were not significantly different among the mainplots at location H, but they were at location B (Table 19). Location B was the site with the originally lower nitrogen availability.

Table 19. Mainplot corn silage yields for September 1989 harvest for two locations of the rye/corn experiment.

Main Plot Treatment	Rye Cover	Manure Time	Manure Amount T/A	Corn Silage Yield Location H lbs/A (dry)	Corn Silage Yield Location B lbs/A (dry)
A	No	0	0	13552	10763c*
B	No	Spring	15	13454	10894bc
C	Yes	0	0	12814	11907abc
D	Yes	Spring	15	13405	11439abc
E	Yes	Spring	30	13638	10730c
F	Yes	Fall	15	13179	12192a
G	Yes	Fall	30	12902	11988ab
				ns	

* Means followed by the same letter are not significantly different (DMR, p=0.05).

The splitplot nitrogen rates were significant sources of variation in yield at location B, but not H (Table 20).

Table 20. Splitplot corn silage yields for September 1989 harvest for two locations of the rye/corn experiment.

Splitplot N rate lbs/A	Corn Silage Yield Location H lbs/A (dry)	Corn Silage Yield Location B lbs/A (dry)
0	13200	10486c*
50	13195	10749bc
100	13582	11637ab
150	13182	11916a
200	13230	12292a
	ns	

* Means followed by the same letter are not significantly different (DMR, p=0.05).

The significant main plot effects at location B suggest that additional components of the main effects can be considered for that location. Although there was not a significant effect of manure rate on yield, the timing of manure application was significant (Table 21). This effect appeared to be due primarily to difficult field operations following the application of the manure and the planting of corn soon after. This type of timing problem is an real feature of multiple cropping schemes that must be considered in their development and promotion among farmers.

Table 21. Relationship of timing of manure application to corn silage yields in the rye/corn experiment.

Time of Manure Application	Corn Silage Yield Location B
	lbs/A (dry)
Fall	12090a*
Spring	11084b
None	11188b

*Means followed by the same letter are not significantly different (DMR, p=0.05).

The mean corn silage yields were greater on the main plots with the rye cover crop (Table 22). The reason for this difference is not clear, although it may be due to the only manure application to the no cover plots occurred in the spring when the impact of the manure on stand establishment complicated the effect of the nutrient contributions.

Table 22. Relationship of rye cover to corn silage yields in the rye/corn experiment.

Rye Cover	Corn Silage Yield Location B
	lbs/A (dry)
Yes	11651*
No	10828

*Means are significantly different (p=0.05).

The response of the corn silage to nitrogen application in the plots with cover as compared to those without (Table 23) suggests that the winter cover may have reduced the nitrogen available for corn growth or that other factors complicating the corn production affected the plots without cover.

Table 23. Splitplot corn silage yields for September 1989 harvest at location B of the rye/corn experiment.

Splitplot N rate	Corn Silage Yield Cover	
	with	without
lbs/A	lbs/A (dry)	
0	10746b*	9836
50	10832b	10544
100	11699ab	11484
150	12144a	11348
200	12836a	10932

*Means followed by the same letter are not significantly different (DMR, p=0.05).

All 1990 corn yields reported are fresh weights normalized for plant population differences. Therefore, the relationships among the treatments are subject to change when additional analyses are performed.

Corn silage yields following rye cover appeared to be greater than for the no cover situations (Table 24). Manure applications, especially in the spring, seemed to contribute to corn production. Additional increments of manure beyond the first addition did increase corn silage production.

Table 24. Mainplot silage corn silage yields (fresh weight, normalized for average plant populations) for September 1990 harvest for one location of the rye/corn experiment.

Main Plot Treatment	Rye Cover	Manure Time	Manure Amount	Corn Silage Yield Location H
			T/A	lbs/A (fresh)
A	No	0	0	15154c*
B	No	Spring	15	18437bc
C	Yes	0	15	21385ab
D	Yes	Spring	15	22379a
E	Yes	Spring	30	22005ab
F	Yes	Fall	15	21463ab
G	Yes	Fall	30	21754ab

*Means followed by the same letter are not significantly different (DMR, p=0.05).

There was no difference among the N fertilizer rates as split plots (Table 25) or within the cover treatments.

Table 25. Splitplot corn silage yields (fresh weight, normalized for average plant populations) for September 1990 harvest for one location of the rye/corn experiment.

Splitplot N rate	Corn Silage Yield Location H
lbs/A	lbs/A (fresh)
0	18675
50	19764
100	21777
150	20619
200	21005
	ns

Spring and fall applications of manure did not significantly affect corn silage yields (Table 26), but the yields were greater than with no manure applied.

Table 26. Relationship of time of manure application to corn yields (fresh weight, normalized for average plant populations) for September 1990 harvest for one location of the rye/corn experiment.

Time of Manure Application	Corn Silage Yield Location H
	lbs/A (fresh)
Fall	21609a*
Spring	20940a
None	18269b

*Mean followed by the same letter are not significantly different (DMR, p=0.05).

The corn silage yields were greater with the rye cover crop than without the cover (Table 27).

Table 27. Relationship of rye cover to corn silage yields (fresh weight, normalized for average plant populations) for September 1990 harvest for one location of the rye/corn experiment.

Rye Cover	Corn Silage Yield Location H
	lbs/A (fresh)
Yes	21797*
No	16797

*Means are significantly different (p=0.05).

Rye/Annual Warm-season Forage Grass Experiment

Manure and N treatments were not applied to these areas in the Fall of 1988. However, a winter cover crop of rye was grown. The yield results (Table 28) support the differences measured in the rye/corn experiments. The rye yielded less from the B site than the H site.

Table 28. Rye yields when harvested in late April, 1989 from two locations of the rye/warm-season annual experiment.

	Location H	Location B
Rye yield (lbs/A)*	4390	3104

*Significant at P=0.05.

The main plot treatments affected the mean Piper sudangrass yields only at site B, the low historic nitrogen site (Table 29). A significant nested effect of the splitplot nitrogen rate did exist.

Table 29. Mean Piper sudangrass yields for the mainplot treatments of the rye/warm-season forage grass experiment in 1989.

Main Plot Treatment	Rye Cover	Manure Time	Manure Amount	Sudangrass Yield Location H Harvest 1	Harvest 2	total	Location B Harvest 1	Harvest 2	total
			T/A	lbs/A (dry)					
A	Yes	0	0	4435	3090	7526	4205	3602b*	7807b
B	Yes	Spr/Sum	15	4676	3442	8118	4737	4512a	9250a
C	Yes	Spr/Sum	30	4447	3160	7607	4201	4551a	8753ab
				ns	ns	ns	ns		

*Means followed by the same letter are not significantly different (DMR, p=0.05).

A significant nested effect for the rate of nitrogen application within the manure treatments (main plots) at location B indicated that the effects of the nitrogen applications were different for the treatments. When no manure was applied, the sudangrass responded favorable to nitrogen application. This response was decreased with the first increment of manure application. The high rate of manure application eliminated the nitrogen fertilizer response.

Sundangrass appears to be an effective crop for nitrogen management in soils in combination with rye cover crops (Table 30). Although the actual yield of sudangrass is less than the corn silage yields, the cultural practices for the sudangrass and rye are less sensitive to time constraints than for the corn and rye combination. Further, sudangrass is typically a low input crop requiring neither chemical weed control or insect control in a conservation or conventional tillage situation.

Table 30. Mean Piper sudangrass yields for the split plot treatments of the rye/warm-season forage grass experiment at location B.

Main Plot Treatment	Harvest	Sudangrass Yield Split Plot Rate (lbs/A N) 0	50	100	150	200
		lbs/A (dry)				
A	1	2697b*	3898ab	4530a	4981a	4918a
	2	2003d	2687cd	3584bc	4729ab	5006a
	total	4701d	6586c	8114b	9710a	9924a
B	1	4023	5180	4535	5256	4692 ns
	2	3067b	4650ab	4397ab	4884ab	5563a
	total	7091b	9830a	8931ab	10140a	10255a
C	1	3574	4737	3821	3850	5028 ns
	2	3824	4072	5204	5159	4498 ns
	total	7397	8809	9024	9009	9526 ns

*Means followed by the same letter are not significantly different (DMR, p=0.05).

Manure contributed significantly to sudangrass production (Table 31) in 1990.

Table 31. Mean Piper sudangrass yields for the mainplot treatments of the first harvest of the rye/warm-season forage grass treatment.

Treatment	Cover	Manure Time	Manure Amount T/A	Sudangrass Yield Location H Harvest lbs/A (dry)
A	Yes	0	0	3259b*
B	Yes	Spr/Sum	15	3508b
C	Yes	Spr/Sum	30	4160a

*Means followed by the same letter are not significantly different (DMR, p=0.05).

Across all manure rates, the N applications up to 100 or 150 lbs/A did significantly increase total sudangrass production (Table 32).

Table 32. Mean Piper sudangrass yields for the split plot treatments of the rye/warm-season forage grass experiment in 1990.

Location	Sudangrass Yield Split Plot Rate (lbs/A N) 0	50	100	150	200
	lbs/A (dry)				
H	6713d*	8695c	8899bc	9556ab	10015a
B	6010c	7674b	8392ab	8429ab	8650a

*Means followed by the same letter are not significantly different (DMR, p=0.05).

The total forage yields of both rye and sudangrass were increased by fertilizer applications more at location II where the yield potential of the site was greater than location B (Table 33).

Table 33. Mean total forage yields for the split plot treatments of the rye/warm-season forage grass experiment in 1990.

Location	Sundangrass Yield Split Plot Rate (lbs/A N) 0	50	100	150	200
	lbs/A (dry)				
H	10171c*	12540b	12438b	13263ab	15105a
B	8513c	10232b	11434a	11147a	11290a

*Means followed by the same letter are not significantly different (DMR, p=0.05).

The main effect of manure on sudangrass was significant only at location B (Table 34).

Main Plot Treatment	Rye Cover	Manure Time	Manure Amount	Sudangrass Yield Location H Harvest 1	H Harvest 2	H total	B Harvest 1	B Harvest 2	B total
			T/A	lbs/A (dry)					
A	Yes	0	0	3920	3983	7903	1964	4962	6926b
B	Yes	Spr/Sum	15	4157	4296	8425	2622	5405	8027ab
C	Yes	Spr/Sum	30	4385	4256	8641	3007	5533	8540a
				ns	ns	ns	ns		

*Means followed by the same letter are not significantly different (DMR, p=0.05).

The main effect of manure on rye and total forage production likewise was only significant at location B (Table 35).

Table 35. Mean rye yields and the total forage for the mainplot treatments of the rye/warm-season forage grass experiment in 1990.

Treatment	Cover	Time	Amount	Sudangrass Yield Location H Harvest Rye	H Harvest Total	H B Harvest Rye	H B Harvest Total
			T/A	lbs/A (dry)			
A	Yes	0	0	3514	11653	2346c	9273b
B	Yes	Spr/Sum	15	3649	12461	2653b	10682a
C	Yes	Spr/Sum	30	3802	13181	3076a	11617a
				ns	ns		

*Means followed by the same letter are not significantly different (DMR, p=0.05).

The Piper sudangrass and rye combination could be a competitive cropping sequence with corn silage under some conditions. It has advantages over summer crops and rye and corn silage combinations.

Conclusion:

Because of Pennsylvania weather conditions, several normal growing season options in combination with a rye cover crop are most likely to achieve adoption of the cover crop practice. Attempting to only follow corn can lead to management problems that are not out weighed by the cover crop advantages. However, in combination with other crops such summer annuals, not only is the nitrogen retained well within the cropping system, there is little introduction of pesticides for insect or weed control.

Rodale Institute: On-farm trials

Maryland

Two on-farm research and demonstration trials were established in Queen Anne's County. Rye was no-till drilled into no-till corn fields on October 7, 1988. Three strips of rye were planted the entire length of each field, separated by three strips without rye. Each strip was 30 feet wide. Corn yields (Table 1) were similar for both treatments.

Table 1. 1989 corn yields with and without a rye cover crop on two Maryland farms.

	Corn Yields* (bu/ac)	
	Location	
	S	B
No Rye Cover	133.8	151.3
Rye Cover	136.9	156.2

*Yield values are the average of three replications.

Delaware

In the fall 1988, corn was harvested from one on-farm research and demonstration trial in Sussex County. Corn yield was 145.4 bu/ac following a rye cover crop and 151.6 bu/ac without a rye cover crop. Corn yields are an average of three machine-harvest sub-plots within each treatment.

Pennsylvania

Research results were presented at a farmer meeting in cooperation with Rodale Research Center and at a series of six county-level extension meetings as part of Penn State Cooperative Extension Service Programs. The themes stressed were the use of rye cover crops to reduce the impacts of nitrogen and manure management on water quality and the role of annual warm season grasses as components of a pesticide and fertilizer use reduction program for mixed crop and livestock farms. Additional work was initiated in another research project as a result of the experiences in this project. Another presentation on warm-season annual grasses is scheduled for the 1991 Pennsylvania Forage and Grassland annual conference.

Other Activities

A one-page fact sheet was prepared to use as a hand out to help create awareness of the project and of the potential benefits of rye cover crops. A table-top display was constructed for use at various field days to promote cover crop use. Educational workshops were held throughout the region.

A survey questionnaire was returned by 182 farmers in the Mid-Atlantic region. The survey included questions on the use of cereal grain cover crops. The information was used to (1) help determine the extent of cover crop use (2) to contact certain farmers using cover corps to learn more about cover crop management, uses of cover crops and problems encountered with cover crops and (3) to identify farms willing to share their experiences with cover crops with other farmers.