Demonstration Report No. 5

Implementation, Demonstration, and Evaluation of BMPs for Water Quality: Application Methods ("Manure Injections") for Improved Management of Manure Nutrients

Lake Champlain Basin Program

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Lake Champlain Basin Program Demonstration Reports

1. *Case Study of the Town of Champlain.* Yellow Wood Associates. October 1993.

2. *(A) Demonstration of Local Economic/Other Community Impacts.* Community Case Studies for Economic Plan Elements. The City of Vergennes, Vermont. Economic and Financial Consulting Associates, Inc. October 1993.

   (B) Demonstration of Local Economic/Other Community Impacts. Community Case Studies for Economic Plan Elements. Appendix. The City of Vergennes, Vermont. Economic and Financial Consulting Associates, Inc. October 1993.

3. *The Archeology on the Farm Project.* Improving Cultural Resource Protection on Agricultural Lands: A Vermont Example. Jack Rossen. May 1994.

4. (A) *The 1992 Fort Ticonderoga-Mount Independence Submerged Cultural Resource Survey. Executive Summary.* Arthur Cohn. May 1995.

   (B) *The 1992 Fort Ticonderoga-Mount Independence Submerged Cultural Resource Survey.* Arthur Cohn. May 1995.

5. *Implementation, Demonstration, and Evaluation of BMPs for Water Quality: Application Methods ("Manure Injections") for Improved Management of Manure Nutrients.* Bill Jokela, Sid Bosworth and Don Meals. September 1995.

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Implementation, Demonstration, and Evaluation of BMPs for Water Quality: Application Methods ("Manure Injection") for Improved Management of Manure Nutrients

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Final Report
Presented to the Technical Advisory Committee
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I. Introduction

Situation

Field application of fertilizer and manure on dairy farms is considered an important source of nutrients, especially phosphorus, entering Lake Champlain and contributing to water quality problems (NY-VT Strategic Core Group, 1992). Because of the major role of dairy farming in the Lake Champlain Basin, management of manure plays a critical role in determining the amount of phosphorus available for delivery to surface waters in agricultural runoff. In a sampling of nine farms in the St. Albans Bay RCWP during 1987-1989, 71% of the phosphorus and 80% of the nitrogen applied to fields was from manure with the remainder applied as fertilizer (Jokela, 1991). Almost two-thirds of the manure phosphorus and nitrogen was applied to cornland.

At the present time, Extension and the Natural Resource Conservation Service (NRCS) recommend spring application of manure on corn with same-day incorporation to provide most efficient utilization of manure nutrients and to minimize surface and ground water quality impacts. However, because of limited manure storage and other practical circumstances on many farms, significant amounts of manure are applied in the fall and much is not incorporated the same day. Application of slurry manure with equipment that injects below the surface would result in immediate incorporation without tillage, thus largely preventing loss of manure phosphorus and nitrogen in surface runoff and loss of N by volatilization of ammonia. It would also allow application of manure as a sidedressed application into the growing crop, giving farmers another window of application on cornland before the post-harvest period in the fall. Sidedressing supplies nitrogen at the optimum time for efficient N uptake by the crop and would minimize nitrate leaching. It would also make possible the use of the Pre-sidedress Nitrate Test (PSNT) as a tool to adjust manure N rates to crop need. Nutrient loss in runoff would likely be very low because of immediate incorporation and because of the low probability of runoff events at that time of year compared to fall and early spring.

Objectives

The overall purpose of this project was to demonstrate alternative manure application techniques to improve management of phosphorus and nitrogen from manure and commercial sources on silage corn, and to evaluate the effects of these techniques on corn yields and nutrient losses via surface runoff and leaching.

More specifically, the objectives were to:

1) Stimulate farmer recognition of the importance of nutrient management planning and improved manure management for their farming operations from both an economic and water quality perspective.

2) Demonstrate alternative methods, in terms of both timing and technique, for application of dairy slurry, to include sidedress and fall injection.

3) Monitor and evaluate these alternative methods to compare their effects on corn yields and loss of P and N via runoff and leaching.

In order to meet both the demonstration and the evaluation and monitoring objectives, we conducted two different types of field comparisons of manure application equipment. Demonstration were conducted on field scale units on dairy farms in both New York and Vermont. Quantitative evaluation and monitoring was conducted on one site on replicated field strips on a dairy farm in Vermont. While the field scale farm demonstrations were important for evaluation of the practical aspects of these methodologies and for demonstration purposes, reliable quantitative comparisons of yields and water quality impacts required the more intensive replicated field trial.

Throughout much of this report we have used English units because they are more commonly used for measurement of crop yields, nutrient uptake, and manure application rates. However, we used metric units for the surface runoff section because metric units have come into fairly common usage for measurement of water quality parameters.

II. Field Scale Farm Demonstrations

We demonstrated and evaluated sidedress incorporation and/or fall injection of liquid manure on six farms in the Champlain Valley. This included four demonstrations open to the public or viewed by invited groups, as well as the replicated strip trial set up to monitor runoff. Farms and fields within those farms were selected to represent a range of soil types typical of the Champlain Basin, as well as a geographic range that included one New York and three Vermont counties (Table 1).

All manure applications were done with a commercial 1500 gallon slurry tank spreader purchased from Nuhn Industries of Sebringville, Ontario. This is smaller than the 3000 gallon spreaders commonly used on many dairy farms to provide easier and safer transport over the road, better maneuverability on field strip comparisons, and suitability for a range of tractor sizes including smaller ones sometimes used for corn planting (which would be set at the correct wheel spacing for sidedressing). The spreader has tandem axles adjustable to straddle either two or three corn rows (approximately 60 to 90 in.). It is equipped with three options for direct incorporation of manure -- a sweep injector (10-inches wide), concave covering disks, and s-tine cultivator shanks (Fig. 1), as well as the standard splash plate to broadcast manure. The injection option consists of heavy shanks with sweep shovels to place the manure a few inches below the surface. The covering disk and s-tine cultivator options apply the manure in a band on the surface and two concave disks or a gang of s-tines immediately cover it and mix it with two to three inches of soil (Fig. 2). While these methods do not actually inject the manure, they do provide immediate incorporation. And they have some advantages over injection (especially deep injection with chisel shanks), including lower power requirement, faster tractor speed, lower cost, more uniform manure distribution, and improved N availability (Jokela and Côté, 1994).

While the spreader we used is smaller than many in use on dairy farms, it was built with the same design and features as larger ones. Spreaders with similar equipment for injection or other direct incorporation techniques are available for tankers with much larger capacity (3000 to 6000 gallons). Most manufacturers of liquid manure spreaders provide sweep injectors as an option. At least three companies in addition to Nuhn Industries, two in Canada and one in the U.S., make s-tine and/or concave covering disk attachments for their spreaders, typically in sets of four, five, or six units. The practice of sidedressing liquid manure on corn, especially with s-tine cultivators attachments, has become fairly common in Quebec where an estimated 15% of hog producers use the practice (D. Côté, Quebec Ministry of Agriculture, personal communication, 1994).

Table 1. Cooperators and other information about field demonstrations.

Cooperator	Date	Town	Soil	Methods[1]	Tractor size	Audience (no.)
Dan Pillsbury	June 28	Shelburne, VT	Vergennes clay	SD: s-tine, disk	100 hp	Ag Adv. Council (17)
Dave Russell	June 29	Starksboro, VT	Adams l f sand &	SD: s-tine	65hp 4WD	E. Europ. visitors (15)
	June 30		Stetson g f s loam	SD: s-tine		Public (8)
Dave Manning	July 6	Swanton, VT	Messena s loam	SD: s-tine, disk	85 hp	Coop. farmers (3)
Don Tetreault	July 8	Champlain, NY	Adjidaumo clay	SD: s-tine	100 hp	Public (12) + TV
Dave Conant	July 15	Williston, VT	Whately silt loam	SD: s-tine, other	100 hp 4WD	None
Don Tetreault	Oct 10	Champlain, NY	Grenville loam	P-H: sweep, disk	100 hp	None
Eric Clifford	Oct 12	Starksboro, VT	Canadaigua si loam	P-H: sweep	135 hp	Coop. farmer, others (5)

[1]Methods: SD = sidedress, P-H = post-harvest

Table 2. Nutrient analyses of manure from field demonstrations.[1]

Name	Date	DM	N	Org-N	NH_4-N	P_2O_5	K_2O	Ca	Mg	Zn
		%	lb/1000 gal							
Clifford	10/12	13.7	35.7	20.9	14.8	16.4	27.5	23.4	6.6	0.33
Conant	5/23	12.3	28.9	15.4	13.6	14.9	25.5	25.0	4.7	0.18
Conant[2]	6/6	7.1	24.2	9.3	15.0	10.4	21.2	16.6	3.4	0.11
Conant[2]	7/15	7.9	25.8	12.9	13.0	11.3	22.2	16.0	3.7	0.13
Manning	7/6	7.1	24.1	11.4	12.6	10.1	21.4	9.6	3.9	0.11
Pillsbury	6/23	5.2	22.7	8.9	13.9	11.1	20.9	33.2	3.9	0.11
Russell[2]	7/15	7.1	23.2	13.0	10.2	10.6	18.0	9.4	3.9	0.10
Tetrealt	10/10	19.3	35.3	19.7	15.6	18.9	29.1	18.0	9.8	0.37

[1]Analyses conducted by UVM Agricultural and Environmental Laboratory.
[2]Average of two samples.

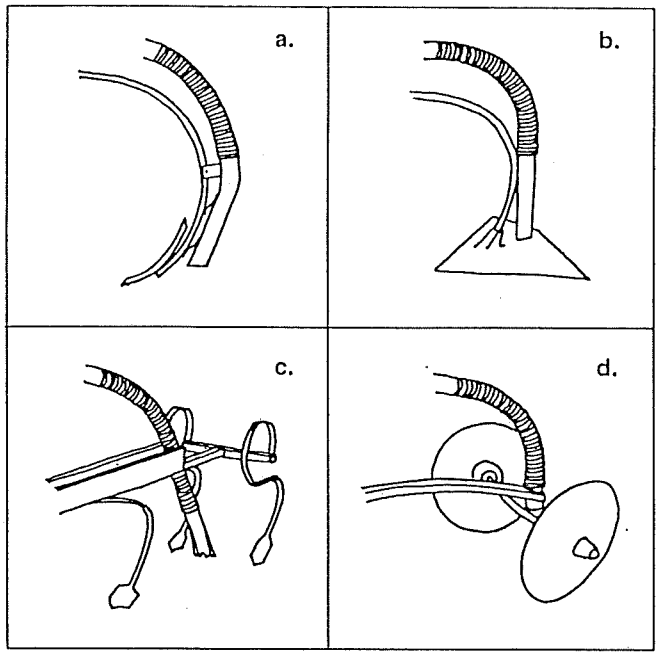


Fig. 1. Attachments for direct incorporation of liquid manure: a) chisel or knife injector, b) horizontal sweep injector, c) s-tine cultivator, d) concave covering disks

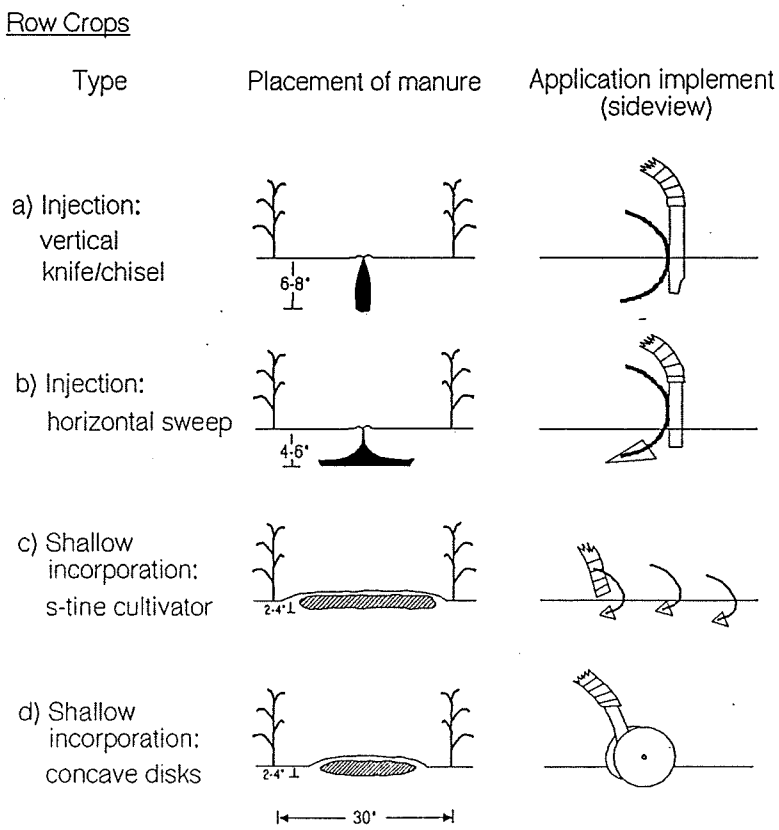


Fig. 2. Equipment options for direct incorporation in row crops or on bare ground.

We also purchased, evaluated, and used a Manure Nitrogen Meter, an instrument developed by Agros in Sweden, which can give an analysis of the ammonium-N content of manure in the field at the time of application (Kjellerup, 1985). Normally farmers are not able to sample until the storage facility is agitated just before spreading begins, and they do not obtain the results of manure analysis from the laboratory until after the manure has been applied. Use of the Nitrogen Meter could potentially be quite useful because they would be able to obtain an NH_4-N analysis before they begin spreading to help determine an optimum manure application rate.

Each field scale farm demonstration included two or more of the following manure or fertilizer application methods:

a) Sidedress direct incorporation of manure with s-tine cultivators
b) Sidedress direct incorporation of manure with paired concave covering disks
c) Sidedress nitrogen fertilizer
d) Post-harvest manure injection with sweep shovels
e) Post-harvest manure injection with paired concave covering disks
f) Fall surface-applied manure

All treatments were applied at rates estimated to supply adequate N for the crop based on the Pre-sidedress Nitrate Test, or PSNT, (for sidedress demonstrations), manure analysis, and estimates of the availability of manure N (Table 2). In addition to the laboratory analysis obtained on manure sampled in advance, we used the Manure Nitrogen Meter to determine the ammonium-N content of manure in the field just before application. Each demonstration field was also soil sampled for standard nutrient analysis in advance of manure application as part of a nutrient management package (Table 3).

Table 3. Soil test results for seven demonstration farm sites[1]. May 1994.

Treatment	pH	Avail.P	Res. P	K	Mg	Al	Zn	CEC
		ppm						
Pillsbury	7.5	18.4	83	89	227	15	0.3	--
Russell	7.0	12.1	100	71	52	25	0.5	7.1
Manning	6.4	8.7	52	80	186	17	1.0	10.4
Tetreault								
East (SD)	7.0	6.4	41	115	412	25	0.8	18.4
West (P-H)	6.7	8.5	--	70	195	12	0.8	--
Clifford	7.2	50.7	142	131	220	11	1.07	
Conant	7.0	2.1	71	36	25	25	0.2	5.3

[1]Analysis by UVM Agricultural and Environmental Testing Laboratory, except Tetreault West sample which was analyzed by the Cornell Nutrient Analysis Laboratory.

Sidedress Demonstrations

- We did equipment set-up and field testing and calibration work on land on the Dan Pillsbury farm in Shelburne, VT (Table 1). Dan contributed a tractor, a manure tank truck, and many hours of his time for this effort. We demonstrated direct incorporation of sidedressed manure (s-tine and covering disks) at this site and had a discussion with members of the Agricultural Advisory Council of the LCBP at this site in late June. The same group also visited the replicated strip trial at the Conant site on the same day to view the field design and runoff collectors.

- A field demonstration/meeting at the Dave Russell farm in Starksboro, VT, on June 30 was attended by farmers, NRCS and Extension personnel, and others (Table 1). A group of 15 agricultural students from the former USSR, participants in a St. Michael's College program, made a field visit at the Russell site to see the equipment and learn about nutrient management and agriculture in Vermont. We demonstrated direct incorporation with s-tine cultivators, as well as use of the Manure N Meter. At this site, we coordinated with Sue Hawkins of the Champlain Valley Crop Management Association, who developed a nutrient management plan for the field and the entire farm.

  We also established a field strip trial at the Russell site, comparing sidedressed manure (incorporated with s-tine cultivator), sidedressed nitrogen fertilizer, and a no-nitrogen control. (See Fig. 3 for plot plan.) Visual observations in July and September suggested that the control plots were slightly N deficient, showing lighter color and less robust growth. Nitrogen concentration in the leaf opposite the earleaf at 50% silk (Aug. 11) confirmed this, with those treatments receiving manure or N fertilizer having higher N content (Table 4). Only the sidedressed manure treatment had %N values approximately equal to levels commonly considered sufficient (2.76%). Silage yields in late September ranged from 20 to 22 tons per acre with no significant treatment effect (Table 5). However, N uptake was higher from the manure and N fertilizer treatments, a result of the combination of slightly higher (though not significantly so) yields and N concentration (Table 4). Uptake of other nutrients was not affected by treatment, indicating adequate amounts available from the soil previously applied fertilizer.

- David Manning, a cooperator in the Lower Missisquoi HUA Project who farms in Swanton, sidedressed manure on corn using both the s-tine cultivator and the concave covering disks on July 6 (Table 1). Follow-up observations in August showed similar growth of corn sidedressed with manure and adjacent corn in the same field sidedressed with urea fertilizer. We videotaped the manure sidedressing operation and have shown it at several farmer and LCBP meetings.

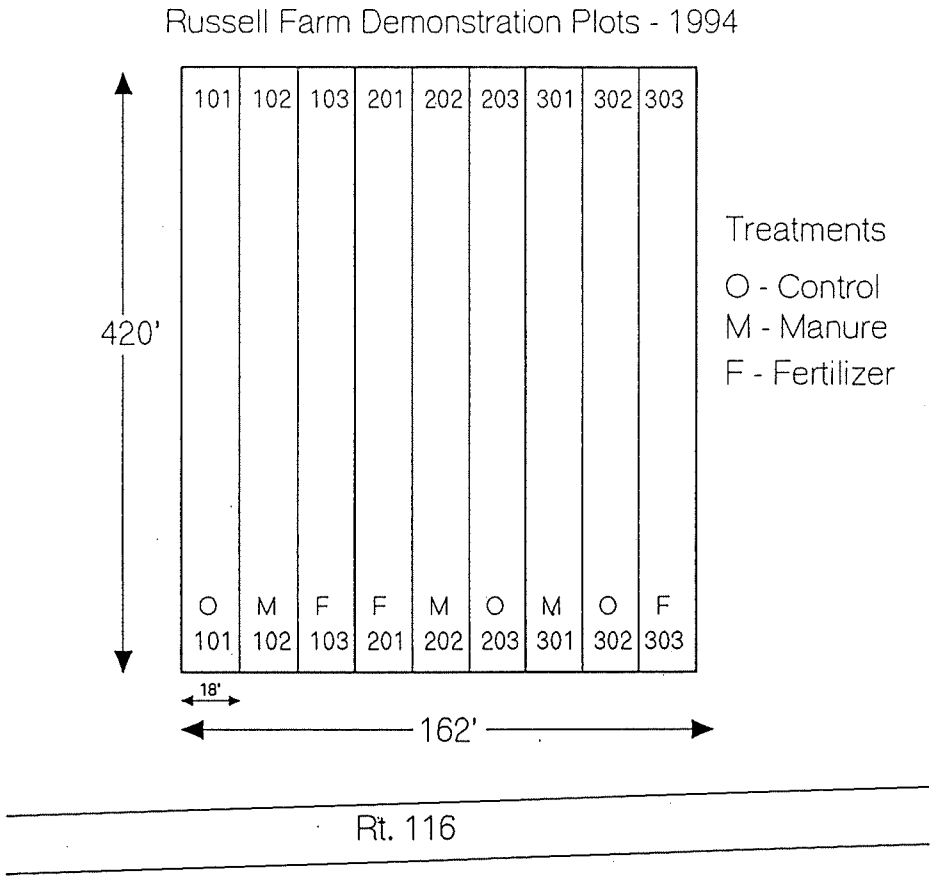


Fig. 3. Field strip plan of Russell site.

- We held a public field day at the Tetreault farm in Champlain, NY, on July 8 in cooperation with Beth Spaugh of Cornell Cooperative Extension (Table 1). The event was attended by approximately 12 people, including area farmers and Extension and Conservation District staff. Unfortunately, difficulties with the Tetreault's manure pump and storage pit necessitated using manure pit drainage liquid rather than true manure. However, the demonstration was quite successful and participants engaged in considerable discussion (despite the heat of the day). We also presented information on soil testing and nutrient management in general and demonstrated use of the Nitrogen Meter to measure NH_4-N in manure in the field. A reporter from Channel 3 TV attended the event, and videotaped footage of the event was shown on the evening news. Unfortunately, because the "manure" we used was not true dairy manure, we were not able to follow-up in terms of crop growth and yield response.

Table 4. Nitrogen concentrations of earleaf at 50% silk and nutrient concentrations of silage at harvest. Russell site. 1994.

Treatment	Earleaf N	Silage N	P	K	Mg	Zn
	%					ppm
1 SD-INCORP	2.73	1.17	0.24	1.21	0.11	15
2 SD-NFERT	2.57	1.15	0.22	1.21	0.12	15
3 CONTROL	2.47	1.12	0.24	1.24	0.11	13
Signf.[1]	+	NS	+	NS	NS	NS
C.V. (%)	5	9	5	8	6	12
Statistical Contrasts[1]						
Treatments Compared						
1, 2 vs 3	*	NS	NS	NS	NS	NS
1 vs. 2	NS	NS	*	NS	NS	NS

[1]**, *, and + indicate significant differences at probability levels of 0.01, 0.05, and 0.10, respectively. NS = nonsignificant

Our demonstrations of direct incorporation of manure as a sidedress in corn showed, for the most part, that this technology could be used successfully on a range of soils in the Champlain Valley. We applied manure rates of 3000 to 5000 gal/acre at different sites, depending on the N need of the crop. The s-tine cultivator attachment applied manure across the entire inter-row area, and did an effective job of incorporating manure, although in some cases a small amount of manure remained uncovered immediately along the plant row. This method also provided supplemental weed control via cultivation. We found a ground speed of about 4.5 mph to be optimum with our equipment. At this speed, using four-row equipment in 30-inch rows, an operator could cover about 3.3 acres per hour, or 10,000 to 17,000 gal/hour, assuming a field efficiency of 60% and not including loading time. (See Section V for more detail, including economics.) The paired covering disks were another option we evaluated. They did an effective job in some cases, but we had some concerns about root pruning by the disks. Since the disks were spaced about 15 inches apart, the zone of tillage and manure incorporation for this method was narrower than with the s-tines. We also encountered design and mechanical problems, most notably, loss of disks because of faulty bearings. Because of these problems, we were not able to adequately evaluate the covering disk concept. Nuhn Industries has redesigned the disk system and is providing a new product for the next season.

Table 5. Yield and nutrient uptake of silage at harvest. Russell site. September 1994.

Treatment	Yield	N	P	K	Mg	Zn
	T/A, 30% DM	---------- lb/A ----------				
1 SD-INCORP	21.6	152	31.4	155	14.7	0.19
2 SD-NFERT	21.7	150	28.9	158	15.1	0.19
3 CONTROL	20.5	138	29.5	153	14.1	0.16
Signf.[1]	NS	NS	NS	NS	NS	NS
C.V. (%)	12	9	7	5	13	
Statistical Contrasts[1]						
Treatments Compared						
1, 2 vs. 3	NS	*	NS	NS	NS	NS
1 vs. 2	NS	NS	NS	NS	NS	NS

[1]**, *, and + indicate significant differences at probability levels of 0.01, 0.05, and 0.10, respectively. NS = nonsignificant

Post-harvest/Fall Demonstrations

- Field demonstrations of post-harvest application of manure using direct incorporation methods were conducted in October at the Tetreault farm, Champlain, NY, and at the Eric Clifford farm in Starksboro, VT (Table 1). At the Tetreault site we used both the concave disk and the sweep injection techniques on a field of Grenville loam that had been in no-till corn for several years. Although the soil was more compacted than most annually tilled fields, the sweep injector penetrated well and did an effective job. The covering disks were not able to penetrate the soil enough to do adequate tillage. This equipment relied on the weight of the tool bar and attachments, whereas some other designs provide active downpressure via a hydraulic reservoir system. The penetration problem has now been corrected by the company by providing hydraulic downpressure.

- We used only the sweep injector method at the Clifford site (because of disk equipment breakdown at the NY location). The sweep injectors -- four units, 30 inches apart -- worked very well and we were able to inject manure in bands four to six inches deep at an application rate of 10,000 gal/acre travelling about four mph. This application rate is equivalent to 3.4 acres per hour, or 34,000 gal/hour, assuming a field efficiency of 70% (excluding travel and loading time). The soil disturbance from the injectors was equivalent to a shallow tillage operation and manure coverage was excellent. Excavation with a shovel showed a layer of

manure 15-inches wide four to six inches deep, resulting in manure coverage of 50% of the field surface area. Since the sweep shovels were only ten inches wide, this indicates that manure was forced laterally along cracks created by the action of the sweeps.

Survey Results: Feasibility of Direct Incorporation Methods

Farmers and other agricultural professionals who participated in or observed one of the field demonstrations were sent a questionnaire to evaluate their opinions on methods of direct incorporation of liquid manure. Some of the potential benefits observed included improved manure nitrogen utilization, odor control, and another window of time to apply manure. One participant felt that the cultivation sidedress method could also be combined with weed management.

Some of the major limitations that participants observed included increased equipment cost, slower manure application and time and labor conflicts. It was also pointed out that with the sidedress method, there is the additional risk of emptying the spreader tank before coming to the end of the pass. This could result in either a part of the row not receiving any manure or an additional pass would have to be made.

When asked of their opinion of what percentage of corn growing farmers in the Champlain Valley would consider adopting this technology, the general response was 6-25% for sidedress and less than 5% for post-harvest application.

III. Educational Program and Other Public Activities

In addition to the field demonstrations described above, a number of other educational activities were carried out:

- The project provided direct, hands-on experience for the cooperating farmers in use of the alternative techniques with the expectation of sharing of these experiences with neighbors and other farmers.

- Slides and videotape material were prepared. Results of this project have already been presented in several extension programs in Vermont and New York.

- Our study was featured in an article in a recent edition of *Impact*, a quarterly publication of the UVM Extension System and Agricultural Experiment Station. The article, *Manure injection part of pollution solution puzzle*, was based on interviews with investigators Meals and Jokela, project cooperator Eric Clifford, and College Dean Larry Forcier. See Appendix.

- The project P.I. (Jokela) made a presentation at the Liquid Manure Application Systems Conference, sponsored by NRAES, Cornell University, December 1-2 in Rochester, NY (Jokela and Côté, 1994). The talk and proceedings paper, *Options for Direct Incorporation of Liquid Manure*, discussed various methods for injection and incorporation of manure on cropland, including some preliminary results from this study. Approximately 300 farmers, ag business, and university/ government personnel attended the conference.

- Project P.I. Jokela presented results and practical experience gained from this project in a presentation at the Mechanical Weed Control session of the New York State Vegetable Conference in Syracuse, NY, on February 16. The title of the talk was *Cultivation for Direct Incorporation of Manure* (Jokela, 1995).

- A poster presentation on the field strip trial is scheduled as part of the Animal Waste and the Land-Water Interface conference in Fayetteville, Arkansas, in July (Jokela et al., 1995).

- Projects results will be presented at the annual meetings of the American Society of Agronomy in St. Louis, MO, in November.

IV. Replicated Field Strip Trial

Methods

The replicated field strip study was conducted to obtain reliable comparisons of the treatments in terms of silage yields, phosphorus and nitrogen runoff losses, nitrate leaching potential, nutrient budgets, and economic returns. The site selected for this trial was a field in Williston, VT, on the farm of Dave and Deb Conant. An on-site survey of the field by NRCS Assistant State Soil Scientist Stephen Gourley determined that the soil was primarily a Whately variant (Mollic Haplaquent), a poorly drained silt loam underlain by clay at a depth of 18 to 30 inches. It is classified in Hydrologic Group D, indicating low infiltration and high runoff potential, despite having a slope of only 2 to 4%. The field had been in silage corn production without manure application for several years before initiation of the experiment.

Manure and fertilizer treatments were applied to field strips arranged in a randomized block design with four replicates. Each strip was 100 ft long and 21.3 ft wide (eight 32-inch rows). See Fig. 4 for field plot design.

We compared the following treatments:

1. Pre-plant broadcast manure, incorporated by tillage within 1 hour (PP-BRDCST)
2. Sidedressed manure incorporated with s-tine cultivators (SD-INCORP)
3. Sidedressed manure, surface applied (nonincorporated) (SD-SURF)
4. Sidedressed fertilizer N (SD-NFERT)
5. No N fertilizer or manure (CONTROL)

While the primary objective of this study was to evaluate direct incorporated ("injected") sidedressed manure in comparison with sidedressed fertilizer N, we included a pre-plant incorporated manure treatment because that is currently considered the optimum method, from both an environmental and nutrient efficiency perspective. The surface sidedressed manure treatment was included to evaluate the importance of incorporation for N conservation and nutrient runoff control. The CONTROL was intended to provide a measure of crop yield response to N and to give a background level for water quality parameters.

Application rates were based on meeting the N needs of the silage corn crop according to UVM Extension recommendations (Jokela et al., 1993). The availability of N in manure was based on analysis from a sample taken earlier and analyzed at the UVM Agricultural and Environmental Testing Laboratory (Table 2) and modified based on NH_4-N analysis with the Manure N Meter at the time of application. The PP-BRDCST application rate was higher (7800 gal/acre) than the SD rates (5200 gal/acre) for two reasons (Table 6). First, the PP N rate is an estimate (100 lb/acre plus starter N) based on crop yield goal and soil information, while the SD rates were based on

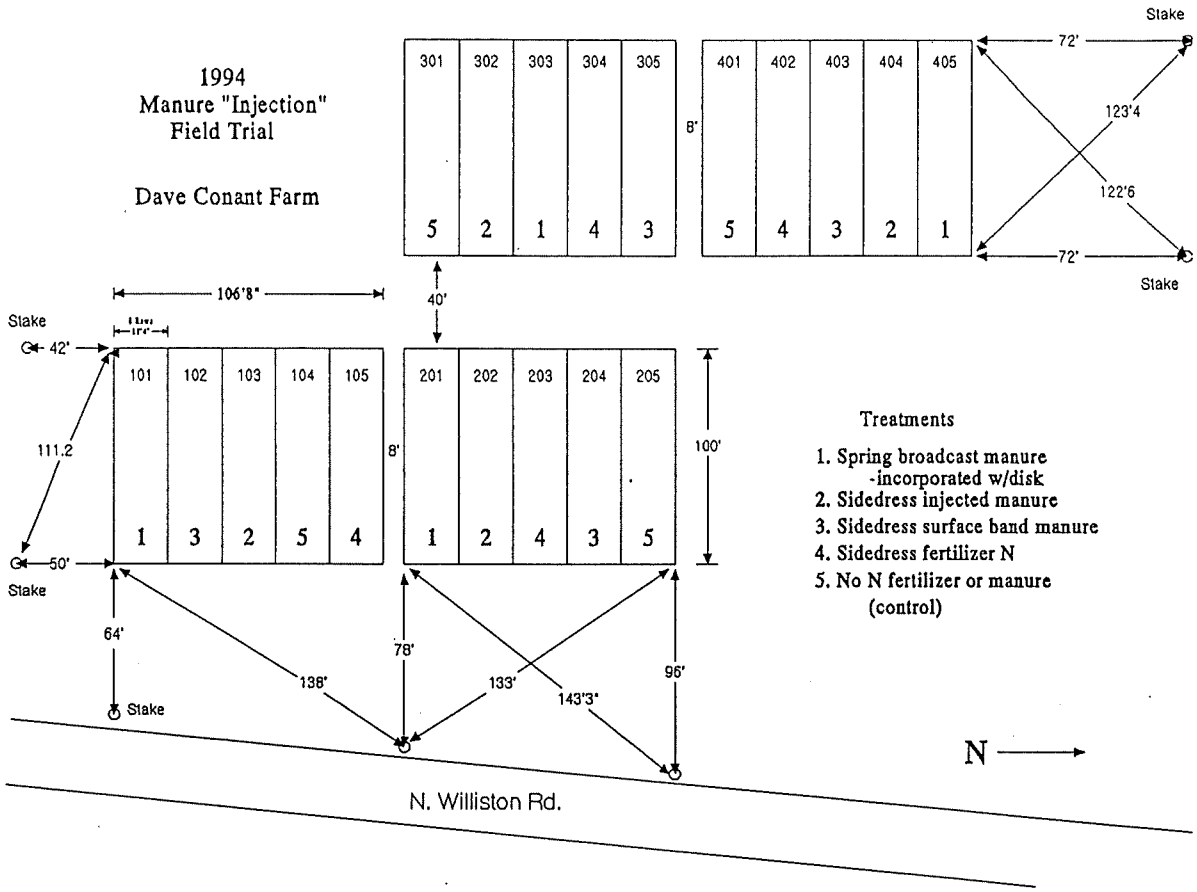


Fig. 4. Field plot plan for Conant site.

results of the Pre-sidedress Nitrate Soil Test (PSNT), which gave a lower N requirement (65 lb/acre). Secondly, the availability of N in manure incorporated at SD time is estimated to be greater because it is applied with immediate incorporation and closer to the time of maximum crop N uptake, leaving less time for loss of N. Liquid dairy manure for the study was obtained from the earthen storage facility on the Conant Farm in Richmond, VT. Broadcast potassium fertilizer (180 lb K_2O/acre) and banded starter fertilizer (200 lbs/acre of 10-34-0) were applied to all plots.

Table 6. Nutrient amounts applied with manure in pre-plant (PP) and sidedress (SD) applications. Conant site. 1994.

Appl. Time	Manure Rate	N Total	N NH_4-N	N Avail	P_2O_5 Total	P_2O_5 Avail	K_2O Total
	gal/A	lb/A					
PP	7800	189	117	111	81	65	165
SD	5200	134	67	74	61	49	115

Standard production practices were carried out on the study area by farmer-cooperator Dave Conant (Table 7). The study area was not planted until June 11, a result of a combination of the timing of spring rains and the poorly drained nature of the field. Pre-plant manure was applied by Conant under supervision of project staff using the 1500 gallon Nuhn spreader equipped with a single rear-mounted splash plate. Sidedress manure and fertilizer treatments, as well as all research measurements, were carried out by project personnel.

The following measurements were made to accomplish the evaluation and monitoring objectives of the study (Table 7):

- Routine soil sampling of the plow layer for pH, P, K, and other nutrients. Sampling of the overall study area was done in the spring to determine the nutrient status of the site and again in the fall by individual plot to assess the effect of manure treatments on soil test levels. Samples were analyzed for pH (Eckert and Sims, 1991), available P, K, Mg, and Zn (Modified Morgan's solution (NH_4 Acetate, pH 4.8); Wolf and Beegle, 1991), and reserve P (McIntosh, 1969).

- Deep soil sampling for nitrate. Field strips were sampled in one-foot (30-cm) increments to a depth of four feet (1.2 m) before planting in the spring and again after harvest. Samples were extracted with 1 *M* KCl and analyzed by Cd reduction (Lachat autoanalyzer; APHA, 1985).

- Soil sampling for Pre-sidedress Nitrate Test in all plots was done on July 7 (12-inch depth, plants 12 inches tall) to determine rate of sidedressed manure or fertilizer needed.

- Soil solution sampling. This was done to assess the concentration of nitrate at a point well into the root zone as an indicator of nitrate leaching. Ceramic cup suction samplers (1.5 inch diameter) were placed (two per plot) in three replicates of four treatments (1, 2, 4, and 5) at a depth of approximately 18 inches. That depth was the maximum that would keep the samplers within the upper silt loam

layer and avoid them penetrating the silty clay layer below. Analysis was by Cd reduction (Lachat autoanalyzer; APHA, 1985).

- Surface runoff collection. Runoff collectors consisted of sheet metal barriers 64 by 96 inches (two by three row spaces), an area of about 43 ft^2 (4 m^2), draining to an outlet at the tip of a "V" at the lower end. Runoff passed from the outlet through a black flexible PVC pipe into 13-liter polyethylene containers (two in series). Samples were analyzed for total phosphorus (perchloric acid digestion; APHA, 1985), soluble reactive phosphorus (automated ascorbic acid; APHA, 1985), total Kjeldahl nitrogen (semi-micro Kjeldahl; APHA, 1985), nitrate-N (Cd reduction by Lachat autoanalyzer; APHA, 1985), and ammonium-N (Lachat autoanalyzer; APHA, 1985) at the UVM Agricultural and Environmental Testing Laboratory. EPA-accepted methods were followed for analysis and collection container cleaning.

Table 7. Field activities at Conant site. 1994.

Date		Activity	Specifics
May	24	Routine soil sampling	0-8 in.; one sample/plot area
	24	Soil sample for NO_3	0-4 ft in 1-ft increments; 3 -1.5 in. cores/plot
	25	Broadcast fertilizer	300 lbs of 0-0-60; whole field
June	6	Pre-plant manure	Spreader with single splash plate
	6	Disk-harrow	Within 1 hour of manure application
	11	Plant corn	NK 1500 @ 26,000 ppa; 200 lb/A (10-34-0)
as			starter fertilizer
	24	Install runoff collectors	1 per plot, all plots
July	7	Soil nitrate (PSNT)	1-ft depth; all plots
	15	Apply sidedress manure	s-tine cultivator; 5200 gal/acre
	15	Apply sidedress N fert.	65 lb/acre as NH_4NO_3; surface broadcast
Aug.	12	Sample ear leaves	50% silk, 20 leaves per plot, Treatment 1
	16	Sample ear leaves	50% silk, 20 leaves per plot, Trt. 2, 3, 4, 5
	19	Install suction samplers	18 in. depth; 2 per plot, Trts. 1, 2, 4, and 5
Sept.	28	Silage yield checks	20 ft/plot (2 rows x 10 ft)
	28	Remove runoff collectors	
	28	Remove suction samplers	
Oct.	11	Harvest field for silage	Machine harvest
	26	Reinstall runoff collectors	
Nov.	17	Reinstall suction samplers	
	11	Soil sample for NO_3	0-4 ft in 1-ft increments; 3 - 1.5 in. cores/plot
	17	Routine soil sampling	0-8 in.; one sample/plot area

- Earleaf sampling. Samples of the leaf opposite and below the earleaf were taken from 20 plants per plot at 50% silk stage and analyzed for total N (semi-micro Kjeldahl; APHA, 1985), P, K, Mg, and Zn (nitric-perchloric digestion with analysis by ICP-AES; APHA, 1985) to assess the nutrient status of the crop as affected by treatment.

- Silage yields. Yields were measured by harvesting and weighing measured lengths (10 ft) from each of two center rows of each field strip. Subsamples were dried, ground, and analyzed for total N, P, K, Mg, and Zn (same analysis as for earleaf) to determine nutrient uptake for each treatment.

- Stalk nitrate. Samples consisting of an 8-inch section of the base (6 to 8 inches from the ground) of ten stalks were collected at harvest from each plot. The samples were dried, ground, and extracted with 1 *M* KCl, and analyzed for NO_3-N (Cd reduction by Lachat autoanalyzer; APHA, 1985). It has been shown that the stalk NO_3-N concentration can identify whether the N rate applied was a deficient, excessive, or optimum rate (Binford et al., 1992).

- Precipitation. A standard rain gage was set up at the study field to record weekly precipitation during the study period.

Data Analysis

All data analysis, except that for soil solution samples, was based on the means from four replicate plots for each treatment. Results were analyzed using analysis of variance statistical procedures to compare the alternative manure and N fertilizer application methods.

Plant and soil data were analyzed using the Statistix program, Version 4.1 (Analytical Software, 1994). In addition to standard ANOVA procedures to determine the probability of a significant difference among treatment means based on the F statistic (labeled as "Signif." in data tables), single degree of freedom contrasts were carried out to test pre-determined treatment comparisons as follows:

a: Mean of nutrient treatments (manure or fertilizer) vs. Control (1, 2, 3, 4 vs. 5)
b) Pre-plant manure vs. sidedress, incorporated manure (1 vs. 2)
c) Sidedress manure: Incorporated vs. Surface-applied (2 vs. 3)
d) Sidedress, incorporated manure vs. fertilizer N (2 vs. 4)

The data for all runoff variables were log-normally distributed; all analyses were performed on log-transformed data and reported means are anti-logs of log means. Statistical analysis, including basic data description, Analysis of Variance, and linear regression, was done using the BMDP statistical analysis package (Dixon, et al., 1990).

Crop Growth, Yields, and Plant Nutrients

Crop growth and development was somewhat delayed because of the relatively late planting date of June 11 (Table 7). Early growth was also affected by problems we assessed as a combination of zinc deficiency and root disease. The effect on growth was variable across the plot area, contributing to high overall variability (reflected in high Coefficients of Variation, or CVs) and making it difficult to measure statistically significant treatment effects. All nutrient concentrations of earleaf samples taken at 50% silk were above levels considered sufficient except those for zinc, confirming our earlier diagnosis (Table 8). Only nitrogen concentrations were affected by treatment, those receiving manure or N fertilizer being higher than the control. An exception was SD-SURF which had a level almost identical the control, illustrating the poor N utilization from surface-applied manure and emphasizing the importance of timely incorporation. While even the lowest treatments tested above the sufficiency guidelines, visual appearance and growth suggested that CONTROL and SD-SURF were N deficient.

Table 8. Nutrient concentrations of earleaf at 50% silk. Conant site. August 1994.

Treatment	N	P	K	Mg	Zn
	%				ppm
1 PP-BRDCST	3.10	0.37	2.03	0.22	13
2 SD-INCORP	2.94	0.41	2.15	0.22	13
3 SD-SURF	2.85	0.40	2.15	0.23	11
4 SD-NFERT	2.98	0.42	2.34	0.21	14
5 CONTROL	2.86	0.37	2.27	0.21	13
Signf.[1]	*	NS	NS	NS	NS
C.V. (%)	6	11	12	13	16
Statistical Contrasts[1]					
Treatments Compared					
1, 2, 3, 4 vs. 5	+	NS	NS	NS	NS
1 vs. 2	+	NS	NS	NS	NS
2 vs. 3	NS	NS	NS	NS	NS
2 vs. 4	NS	NS	NS	NS	NS
Sufficient	2.75	0.25	1.75	0.16	16

[1]**, *, and + indicate significant differences at probability levels of 0.01, 0.05, and 0.10, respectively. NS = nonsignificant

Silage yields ranged from 12 to 17 tons per acre (Table 9). Although differences were not statistically significant, strong trends were as follows: PP-BRDCST > SD-INCORP = SD-NFERT > SD-SURF = CONTROL. The pre-plant manure treatment did show visually better growth than the other treatments throughout the season. Apparently, the pre-plant manure application was early enough to at least partially remedy the early growth problems, particularly zinc deficiency, whereas the sidedressed manure was applied after the damage had occurred. The low yield from the surface-applied manure shows the importance of incorporating manure to prevent ammonia volatilization and improve nutrient availability.

Differences in N uptake supported these yield trends. Manure/N fertilizer treatments surpassed the CONTROL, and incorporation of sidedressed manure (SD-INCORP) increased N uptake compared to surface applied manure (SD-SURF), again reflecting the reduction of volatile NH_3 loss by incorporation (Table 9 & Fig. 5). The PP-BRDCST and SD-INCORP manure treatments gave equal N uptake, as did SD-NFERT and SD-INCORP. Higher silage N concentrations in the sidedressed treatments than in the pre-plant manure (Table 10), despite higher N application with the pre-plant treatment, reflects the increased N efficiency from delayed application. The higher N concentrations compensated for slightly lower yield numbers (though not statistically so) to give equal N uptake. Differences in P and K uptake (Table 9) were driven by yield and, in the case of K, concentration differences.

Table 9. Yield and nutrient uptake of silage at harvest. Conant site. Sept., 1994.

Treatment	Yield	N	P	K	Mg	Zn
	T/A, 30% DM	lb/A				
1 PP-BRDCST	17.0	123	24.7	112	13.3	0.12
2 SD-INCORP	14.8	120	23.7	102	14.0	0.11
3 SD-SURF	12.8	96	20.2	87	10.9	0.10
4 SD-NFERT	14.0	108	21.0	93	11.9	0.10
5 CONTROL	12.3	83	17.9	70	11.5	0.09
Signf.[1]	NS	+	*	*	NS	NS
C.V. (%)	19	21	17	21	18	26
Statistical Contrasts[1]						
Treatments Compared						
1, 2, 3, 4 vs. 5	NS	*	*	**	NS	NS
1 vs. 2	NS	NS	NS	NS	NS	NS
2 vs. 3	NS	+	NS	NS	+	NS
2 vs. 4	NS	NS	NS	NS	NS	NS

[1] **, *, and + indicate significant differences at probability levels of 0.01, 0.05, and 0.10, respectively. NS = nonsignificant

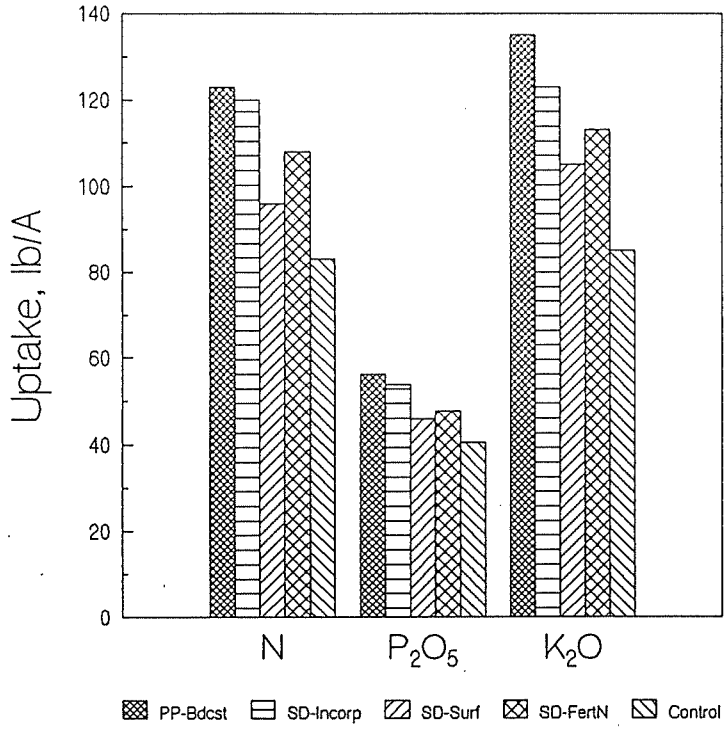


Fig. 5. Nutrient uptake by silage. Conant site.

Available Soil Nutrients

Results of the PSNT (Table 11) were used to determine N rates for the sidedress treatments, but also measured the effect of the only previously applied treatment (PP-BRDCST) on N availability. The PSNT value for the pre-plant manure treatment (21 ppm) gave a recommendation of little to no nitrogen (0 for 15 ton/acre yield and 30 lb/acre for a 20 ton/acre yield) (Jokela, 1993), which suggests that our estimated rate of pre-plant N was adequate to meet crop needs. The remaining four treatments, which at that point were all equivalent to controls, had quite similar PSNT levels, averaging 10 ppm. Recommendations were 50 and 80 lb N/acre for 15 and 20 ton/acre silage yield goals. Considering the late planting date, we estimated a 17 to 18 ton/acre yield and applied the sidedress treatments at 65 lb/acre (estimated N availability for the manure treatments).

Table 10. Nutrient concentrations of silage at harvest. Conant site. September 1994.

Treatment	N	P	K	Mg	Zn
	%				ppm
1 PP-BRDCST	1.21	0.24	1.11	0.13	12
2 SD-INCORP	1.36	0.27	1.17	0.16	13
3 SD-SURF	1.24	0.26	1.13	0.14	13
4 SD-NFERT	1.29	0.25	1.13	0.14	12
5 CONTROL	1.12	0.24	0.96	0.16	13
Signf.[1]	+	NS	NS	NS	NS
C.V. (%)	11	10	14	12	20
Statistical Contrasts[1]					
Treatments Compared					
1, 2, 3, 4 vs. 5	*	NS	+	NS	NS
1 vs. 2	+	NS	NS	*	NS
2 vs. 3	NS	NS	NS	NS	NS
2 vs. 4	NS	NS	NS	NS	NS

[1]**, *, and + indicate significant differences at probability levels of 0.01, 0.05, and 0.10, respectively. NS = nonsignificant

Routine soil analyses were performed on samples taken from the 8-inch plow layer in November to assess the effect of fertilizer and manure treatments on pH and available nutrients (Table 12). The only pH effect measured was a lower pH in the N fertilized treatment compared to sidedressed manure (which had a pH similar to the other manure treatments). This reflects the acidifying effect of NH_4 in the ammonium nitrate as it nitrifies compared to the neutral or increasing pH effect of manure. Phosphorus and potassium tests were increased by manure and fertilizer application relative to the control. This would be expected from the manure treatments because of the added P and K from manure, but reasons for higher P and K tests in the N fertilizer treatment, in some cases, are not readily apparent.

Preliminary results from the late-season stalk nitrate test (Binford, 1992) showed a good general relationship between treatment means for stalk NO_3 concentration and crop N uptake (Table 5), and the SD-SURF and CONTROL treatments appear deficient. However, results were highly variable within treatments, and we are reanalyzing samples using a different technique. Consequently, no data is presented at this time.

Table 11. Pre-sidedress nitrate soil test (PSNT), 0-12 in. depth. Conant site. July 1994.

Treatment	NO_3-N
	ppm
1 PP-BRDCST	20.8
2 SD-incorp	12.3
3 SD-SURF	9.5
4 SD-NFERT	8.8
5 CONTROL	10.0
Signf.[1]	**
C.V. (%)	52
Statistical Contrasts[1]	
Treatments Compared	
1, 2, 3, 4 vs. 5	NS
1 vs. 2	**
2 vs. 3	NS
2 vs. 4	NS

[1]**, *, and + indicate significant differences at probability levels of 0.01, 0.05, and 0.10, respectively. NS = nonsignificant

Nitrate Leaching Potential

Nitrate leaching was not directly measured in this study, but the potential for nitrate leaching was assessed by two approaches -- sampling of soil nitrate in the 4-foot profile and sampling soil solution within the root zone with ceramic suction samplers. Nitrate-N concentrations in the 0 to 4-foot soil profile in May were similar among all five treatment areas, as would be expected before any treatments were applied (Table 13). Nitrate-N concentrations in the top 1-foot were two to three times those in the remainder of the profile (Table 13; Fig. 6). Results from the sampling in November -- after manure and fertilizer additions, plant uptake, and losses or other changes -- showed significant differences in total nitrate and distribution within the profile among the various treatments (Table 14; Fig. 6). Most notably, the SD-NFERT treatment had the highest levels of NO_3-N, due to greater concentrations in the upper two feet, despite the fact that the N application rate was considerably less (65 lb/acre) than the rates added in the manure treatments (134 and 189 lb/acre for SD and PP applications). Nitrate for PP-BRDCST was higher than SD-INCORP only in the 2 to 3 foot layer. Nitrate levels were consistently higher in the manure/fertilizer treatments than in the control, except for the surface-applied manure, which was almost identical to CONTROL throughout the profile (Fig. 6; Table 14). The fact that concentrations

Table 12. Soil test results for 0-8 in. depth . Conant site. November, 1994.

Treatment	pH	Avail.P	Res. P	K	Mg	Al	CEC	Zn
		ppm						
1 PP-BRDCST	7.2	5.2	51	73	32	39	8.0	0.4
2 SD-INCORP	7.2	4.3	48	55	27	42	7.5	0.3
3 SD-SURF	7.1	3.3	43	57	28	43	7.0	0.3
4 SD-NFERT	6.9	5.5	54	60	27	37	6.8	0.3
5 CONTROL	7.0	2.7	39	44	24	38	7.0	0.3
Signf.[1]	NS	*	+	NS	NS	NS	NS	NS
C.V. (%)	4	41	19	32	21	34	13	50
Statistical Contrasts[1]								
Treatments Compared								
1, 2, 3, 4 vs. 5	NS	*	*	+	NS	NS	NS	NS
1 vs. 2	NS	NS	NS	NS	NS	NS	NS	NS
2 vs. 3	NS	NS	NS	NS	NS	NS	NS	NS
2 vs. 4	*	NS	NS	NS	NS	NS	NS	NS

[1]**, *, and + indicate significant differences at probability levels of 0.01, 0.05, and 0.10, respectively. NS = nonsignificant

Table 13. Soil NO_3-N concentration in 1-ft increments and amount in 4 ft profile. Conant site. May, 1994.

Treatment	Depth, ft				
	0-1	1-2	2-3	3-4	0-4
	ppm				lb/acre
1 PP-BRDCST	8.0	3.3	2.6	2.3	69
2 SD-INCORP	6.6	3.0	2.3	2.4	61
3 SD-SURF	7.2	3.0	2.6	2.1	63
4 SD-NFERT	7.1	3.1	2.3	2.2	63
5 CONTROL	6.9	2.8	2.4	2.2	61
Signf.[1]	NS	NS	NS	NS	NS
C.V. (%)	30	20	14	15	18

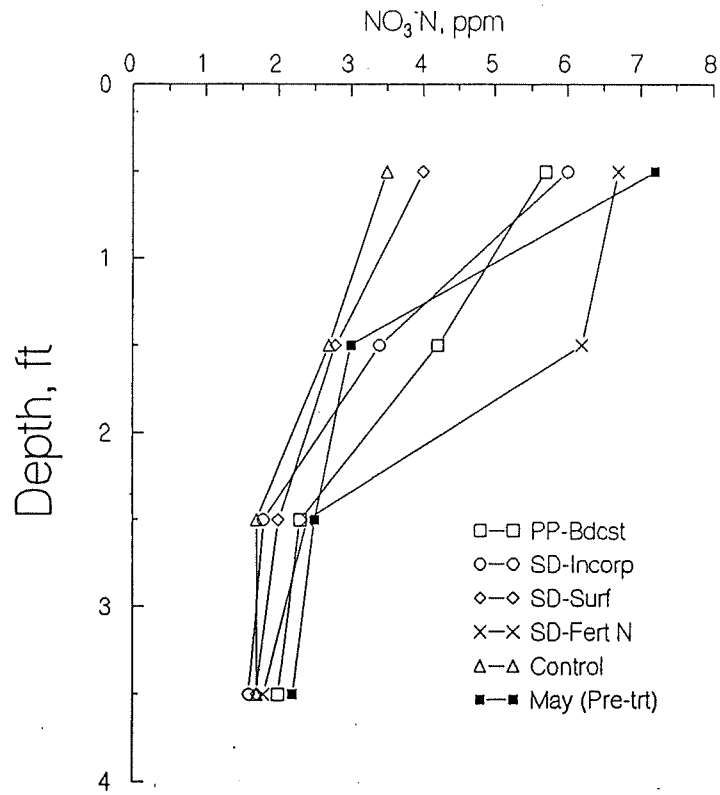


Fig. 1. Nitrate-N concentrations in 4-ft soil profile in November compared to average in May (pre-treatment). Conant site. 1994.

in the 3 to 4-foot depth were not significantly different among treatments and essentially unchanged from the May levels suggests that little or no leaching occurred beyond that depth by the November sampling time.

Suction samplers were installed in mid-August and, although a limited number of solution samples were obtained in late August, low soil moisture prevented our collecting replicate samples from most treatments. The first samples with adequate replication (though only two replicates in some cases) were collected on September 16 (Table 15). Although samples from PP-BRDCST averaged 50 to 100% higher than other treatments, results were not significant because of high variability (CV = 51%). Results from the Sept. 28 sampling showed higher NO_3-N concentrations from the PP and SD-INCORP manure than from SD fertilizer N, but data for the SD-INCORP treatment was from only one plot, so the value may not be reliable and no statistics could be carried out. Nitrate concentrations for the last two dates in late Nov. and early Dec. showed levels of 7 to 9 ppm with no significant differences. These concentrations represent a decrease of about 50% for the PP and SD manure treatments, probably due to conversion of NO_3 to other forms of N during the

Table 14. Soil NO_3-N concentration in 1-ft increments and amount in 4 ft profile. Conant site. November, 1994.

Treatment	Depth, ft 0-1	1-2	2-3	3-4	0-4
	ppm				lb/acre
1 PP-BRDCST	5.7	4.2	2.3	2.0	60
2 SD-INCORP	6.0	3.4	1.8	1.6	54
3 SD-SURF	4.0	2.8	2.0	1.7	45
4 SD-NFERT	6.7	6.2	2.4	1.8	72
5 CONTROL	3.5	2.7	1.7	1.7	41
Signf.[1]	*	*	+	NS	**
C.V. (%)	41	57	22	31	19
Statistical Contrasts[1]					
Treatments Compared					
1, 2, 3, 4 vs. 5	*	NS	+	NS	**
1 vs. 2	NS	NS	+	NS	NS
2 vs. 3	+	NS	NS	NS	NS
2 vs. 4	NS	*	*	NS	*

[1]**, *, and + indicate significant differences at probability levels of 0.01, 0.05, and 0.10, respectively. NS = nonsignificant

Table 15. Concentration of NO_3-N and NH_4-N in soil solution from suction samplers. Conant site.

	NO_3-N Date 9/16	9/28	11/29	12/6	NH_4-N 9/28
	ppm				
1 PP-BRDCST	16.0	17.0	9.3	9.3	1.7
2 SD-INCORP	10.8	16.5	7.1	9.5	4.3
4 SD-NFERT	8.8	10.1	7.3	8.2	1.0
5 CONTROL	8.3	9.7	8.0	8.3	2.4
Signf.[1]	NS	--	NS	NS	--
C.V. (%)	51	--	31	26	--

[1] NS = nonsignificant. Data for 9/28 had inadequate replication for statistical analysis.

intervening two months and perhaps some plant uptake (crop was harvested from the field on Oct. 11 (Table 7)). These are in contrast to the soil NO_3 results from November which showed higher concentrations in the 1-2 ft depth in the fertilizer N treatment than in the manure treatments (Table 14; Fig. 6). Ammonium-N concentrations are reported only for one date, Sept. 28 (Table 15), because levels for other dates were very low (less than 0.5 ppm), but lack of replication makes the data questionable, as discussed above with NO_3.

Surface Runoff and Water Quality

Raw data are tabulated in Appendix A. A summary of water quality data, including basic univariate statistics is given in Table 16.

Precipitation and Runoff

Precipitation measured at the study site over the study period was 45.2 cm (17.8 in); total rainfall recorded at the Burlington airport weather station for June through December was 43.0 cm (16.9 in), 6.4 cm (2.5 in) or 13% below the long-term normal (NOAA, 1994). Thirteen storms which generated runoff on the study site were monitored over this period; three of these occurred before the side-dress treatments were applied on July 15 and ten storms followed side-dress treatment. Precipitation and runoff data associated with these storms are summarized in Table 17. Monitored storms ranged from a low of 0.53 cm (0.2 in) of rainfall to a high of 4.88 cm (1.92 in). The total volume of precipitation received during the monitored storms was 29.71 cm (11.7 in), representing 66% of the total precipitation input recorded at the study site over the six-month study period.

Other than total rainfall amount, the relative magnitude of these storms (e.g. intensity, duration) is impossible to assess because only total event precipitation data were collected. However the 4.88 cm (1.92 in) of rain recorded for the largest storm (August 22) was somewhat less than the 1-year 24-hour storm of 5.33 cm (2.1 in) (USWB, 1961), suggesting that the monitored storms were within the range of what could be expected during a normal year.

Runoff quantities measured from collectors for each of the monitored storms are also summarized in Table 17, along with runoff coefficients, Cr, representing the percent of precipitation input exported as runoff from the collectors. Runoff from the collectors was highly variable both between storms and between treatments, from a high of up to 20% of input for the August 1 and December 2 storms, to a low of zero from some treatments in the smallest storms. Such variation was probably due to a variety of factors which cannot be sorted out in this study, including storm intensity, antecedent moisture conditions, and crop canopy development.

Event precipitation and mean event runoff for all treatments combined are plotted in Figure 7. The relationship between precipitation and runoff was not an obvious function of rainfall quantity alone. The largest runoff event (average 0.34 cm (0.13 in)), for example, occurred in the December 2 storm, which received only a moderate 2.16 cm (0.85 in) of rainfall. In contrast, mean runoff from the 4.88 cm (1.92 in) August 22 storm, the largest storm monitored, was considerably less: 0.25 cm (0.1 in). As summarized in Table 17, for all storms combined, runoff from the plots ranged from a low of 2.7% of input from the SD-INCORP plots to a high of 7% from the control plots. These values are consistent with values for runoff percentages for field-

size areas reported elsewhere (Meinzer, 1942; Chow, 1964).

It is interesting to note the pattern of runoff production during the study period in Figure 8, which shows the values of Cr in each storm for each treatment. For the most part, runoff percentages were similar among all plots prior to sidedress treatment. During the treatment period, however, the SD-INCORP treatment plots showed extremely low values of Cr, while other treatments seemed to track more or less together. Following harvest, differences between treatments decreased until the last monitored event when little difference between treatment was apparent.

Overall Treatment Effects

Mean values for runoff, nutrient concentration, and nutrient export by treatment are shown in Tables 18 and 19 for pre-sidedress and post-sidedress storms, respectively. For each variable, differences between treatments were tested by one-way Analysis of Variance (ANOVA) and Duncan's Multiple Range Test, at a probability level of 0.10. Range tests were applied only if a significant F-value was obtained in ANOVA.

As shown in Table 18, with one exception, no significant differences were observed between treatment groups of plots over the three pre-sidedress storms. The only significant difference between treatment groups prior to application of the main side-dress treatments was an elevated NO_3-N concentration in the runoff from the BRDCAST plots. This makes sense, because these plots received manure on June 6, before any of the monitored events, while other treatment plots received no manure or fertilizer until July 15.

Significant differences between treatments were observed for the post-sidedress storms (Table 19). Mean runoff volume differed significantly between treatments during the post-sidedress period. As shown in Figure 9, no significant differences between treatments were observed for pre-treatment storms, but after treatment, runoff from the SD-INCORP treatment was significantly lower than runoff from the other treatments and from the control (Figure 10). Runoff from the SD-SURFACE treatment plots was significantly higher than from the SD-INCORP plots, but still significantly lower than from the control plots. There were no statistically significant differences in mean runoff volume between the other treatments or the control.

Few significant differences in phosphorus or nitrogen concentrations in runoff were observed between treatments. As shown in Figure 11, mean Total Phosphorus runoff concentrations during post-sidedress storms did not differ significantly among treatments; mean SRP runoff concentration from the SD-SURFACE treatment was significantly higher than from the other treatments. A similar pattern was observed for nitrogen, as shown in Figure 12. Average Total Nitrogen concentration in runoff did not differ significantly between treatments. However, NO_3-N concentrations from all the sidedress treatments were significantly higher than the control. Nitrate

TABLE 16

Water Quality Data Summary - Pre-treatment Storms

	BRDCAST	SD-INCORP	SD-SURFACE	SD-NFERT	CONTROL
Runoff (cm)					
Mean	0.006	0.011	0.023	0.002	0.018
Median	0.004	0.007	0.018	0.009	0.010
Range	0 - 0.264	0 - 0.240	0.002 - 0.227	0 - 0.246	0.001 - 0.309
C.V.	0.51	0.48	0.26	0.84	0.32
n	12	9	12	12	12
[TP] (mg/l)					
Mean	4.3	6.3	7.5	8.5	7.2
Median	3.3	4.4	5.8	5.5	6.0
Range	0.2 - 30.1	0.7 - 44.8	1.8 - 33.1	1.0 - 73.4	1.3 - 35.1
C.V.	1.04	0.59	0.35	0.55	0.36
n	11	8	12	8	12
[TN] (mg/l)					
Mean	32	34	34	47	34
Median	21	34	32	27	26
Range	8 - 150	8 - 138	14 - 98	12 - 333	20 - 89
C.V.	0.09	0.07	0.06	0.07	0.05
n	7	8	11	7	11
[NO3-N] (mg/l)					
Mean	7.9	3.2	3.6	1.8	2.9
Median	11.4	4.2	3.0	1.5	3.0
Range	1.7 - 16.3	1.2 - 6.3	1.0 - 10.0	0.1 - 7.7	1.2 - 5.3
C.V.	0.28	0.60	0.54	2.56	0.59
n	7	8	11	7	10
[NH4-N] (mg/l)					
Mean	0.4	0.6	0.5	0.7	0.4
Median	0.5	0.5	0.6	0.9	0.5
Range	<0.1 - 0.8	0.4 - 1.1	<0.1 - 1.5	0.2 - 2.8	0.2 - 1.2
C.V.	6.51	2.38	0.52	3.42	3.66
n	7	8	11	7	10
[SRP] (mg/l)					
Mean	0.05	0.03	0.07	0.04	0.06
Median	0.04	0.03	0.05	0.04	0.06
Range	<0.01 - 0.14	<0.01 - 0.14	<0.01 - 0.52	0.02 - 0.10	<0.1 - 0.62
C.V.	49.80	77.98	7.75	45.36	43.18
n	8	8	12	7	11
TP (g/ha)					
Mean	1.6	5.2	17.5	0.6	13.2
Median	0.9	2.6	5.6	3.5	4.9
Range	0 - 607	0 - 988	0.7 - 752	0 - 1807	0.1 - 774
C.V.	0.62	0.50	0.27	0.94	0.31
n	12	9	12	12	12
TN (g/ha)					
Mean	25	23	102	2	84
Median	56	26	42	20	40
Range	0 - 2931	0 - 3048	11 - 2223	0 - 8185	5 - 2244
C.V.	0.48	0.45	0.20	0.83	0.22
n	8	9	11	11	11
NO3-N (g/ha)					
Mean	7.5	2.9	10.5	0.3	8.8
Median	24.0	4.1	9.4	1.9	7.0
Range	0 - 329	0 - 143	0.7 - 221	0 - 163	0.5 - 120
C.V.	0.49	0.47	0.23	0.84	0.24
n	8	9	11	11	10
NH4-N (g/ha)					
Mean	0.4	0.6	1.6	0.2	1.4
Median	1.1	0.6	0.8	0.3	0.6
Range	0 - 16.1	0 - 13.6	<0.1 - 32.2	0 - 68.9	<0.1 - 21.6
C.V.	0.68	0.47	0.28	0.87	0.33
n	8	9	11	11	10
SRP (g/ha)					
Mean	0.02	0.01	0.09	0.1	0.08
Median	0.0	0.0	0.1	0.0	0.1
Range	0 - 2.7	0 - 0.9	0 - 9.1	0 - 2.4	0 - 2.5
C.V.	1.20	1.21	0.69	1.43	0.70
n	9	9	12	11	11

TABLE 16

Water Quality Data Summary - Post-treatment Storms

	BRDCAST	SD-INCORP	SD-SURFACE	SD-NFERT	CONTROL
Runoff (cm)					
Mean	0.030	0.002	0.018	0.040	0.077
Median	0.081	0.001	0.088	0.107	0.163
Range	0 - 0.599	0 - 0.448	0 - 0.586	0 - 0.473	<0.001 - 0.574
C.V.	0.42	1.00	0.56	0.38	0.23
n	40	32	40	40	40
[TP] (mg/l)					
Mean	1.3	1.2	1.4	1.4	1.1
Median	1.4	1.4	1.5	1.3	1.1
Range	0.2 - 8.2	0.3 - 5.0	0.2 - 5.9	0.2 - 8.5	<0.1 - 7.4
C.V.	2.15	2.39	1.65	1.94	2.91
n	35	16	32	36	39
[TN] (mg/l)					
Mean	6	6	6	8	7
Median	6	7	7	8	7
Range	1 - 33	1 - 13	1 - 16	1 - 38	2 - 31
C.V.	0.36	0.34	0.34	0.28	0.35
n	35	15	31	34	39
[NO3-N] (mg/l)					
Mean	0.5	1.0	0.9	1.3	0.4
Median	0.5	0.6	0.9	1.1	0.4
Range	<0.1 - 2.3	0.2 - 11.5	<0.1 - 8.9	<0.1 - 27.5	<0.1 - 2.8
C.V.	5.47	3.31	3.71	2.94	7.49
n	26	12	24	27	31
[NH4-N] (mg/l)					
Mean	0.4	0.2	0.4	0.6	0.4
Median	0.3	0.2	0.4	0.6	0.4
Range	0.1 - 5.0	<0.1 - 0.9	0.1 - 2.1	0.1 - 5.7	0.1 - 1.8
C.V.	5.95	11.88	6.71	4.81	5.93
n	26	12	23	27	31
[SRP] (mg/l)					
Mean	0.07	0.09	0.55	0.08	0.05
Median	0.11	0.12	0.55	0.18	0.07
Range	0.01 - 0.66	0.01 - 0.40	0.34 - 1.06	0.01 - 3.4	0.01 - 1.0
C.V.	63.14	32.43	2.47	67.45	88.67
n	16	7	16	19	20
TP (g/ha)					
Mean	3.8	0.1	2.0	5.7	10.2
Median	7.6	0.1	9.3	14.2	12.4
Range	0 - 253	0 - 88	0 - 28.6	0 - 403	0.1 - 238
C.V.	0.43	1.02	0.55	0.38	0.24
n	39	31	40	39	39
TN (g/ha)					
Mean	16	0.2	6.5	33.5	61.1
Median	31	0.03	41.3	94.6	580
Range	0 - 1175	0 - 229	0 - 776	0 - 1509	1 - 895
C.V.	0.39	1.03	0.54	0.34	0.18
n	39	30	39	37	39
NO3-N (g/ha)					
Mean	1.0	0.04	0.8	4.3	2.6
Median	4.2	0	9.5	9.8	5.2
Range	0 - 100	0 - 60	0 - 134	0 - 596	0.1 - 63
C.V.	0.56	1.16	0.68	0.40	0.24
n	30	27	32	30	31
NH4-N (g/ha)					
Mean	1.0	0.02	0.5	1.9	2.4
Median	1.9	0	1.8	7.3	3.6
Range	0 - 39.5	0 - 9.6	0 - 29	0 - 53.5	0 - 25.5
C.V.	0.46	1.26	0.63	0.44	0.27
n	30	27	31	30	31
SRP (g/ha)					
Mean	0.15	<0.01	0.37	0.17	0.24
Median	0.28	0	2.80	0.45	0.40
Range	0 - 9.6	0 - 1.7	0 - 31.7	0 - 28.7	0 - 11.7
C.V.	0.73	1.52	0.76	0.75	0.56
n	20	22	24	22	20

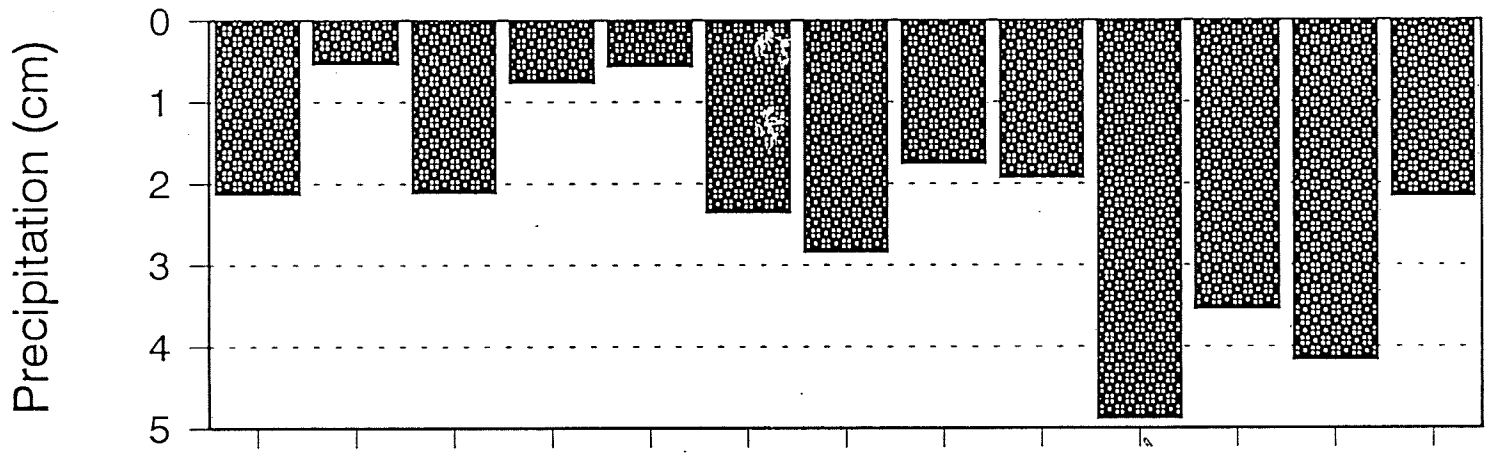
TABLE 17

Monitored Storm Event Precipitation, Runoff, and Runoff Coefficients

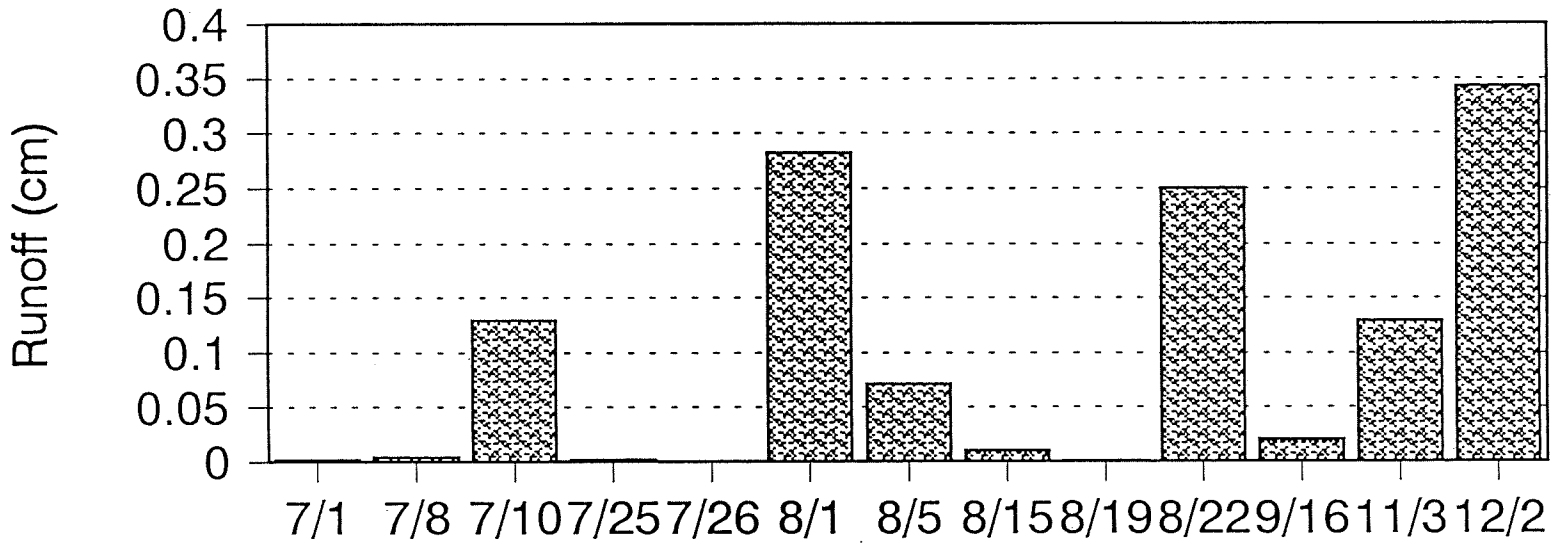
		BRDCAST		SD-INCORP		SD-SURFACE		SD-NFERT		CONTROL	
Date	Precip (cm)	Runoff (cm)	Cr	Runoff (cm)	Cr	Runoff (cm)	Cr	Runoff (cm)	Cr	Runoff (cm)	Cr
7/1	2.13	0.0013	0.1	0.0008	0.0	0.004	0.2	0.0008	0.0	0.0025	0.1
7/8	0.53	0.0035	0.7	0.0071	1.3	0.014	2.6	0.0013	0.2	0.0091	1.7
7/10	2.11	0.156	7.4	0.23	10.9	0.217	10.3	0.022	1.0	0.25	11.8
7/25	0.76	0.0015	0.2	0	0.0	0.0032	0.4	0.006	0.8	0.017	2.2
7/26	0.56	0.0002	0.0	0	0.0	0.0002	0.0	0.002	0.4	0.0018	0.3
8/1	2.36	0.361	15.3	0.048	2.0	0.477	20.2	0.315	13.3	0.443	18.8
8/5	2.84	0.105	3.7	0.0005	0.0	0.117	4.1	0.267	9.4	0.286	10.1
8/15	1.75	0.02	1.1	0.0001	0.0	0.024	1.4	0.01	0.6	0.099	5.7
8/19	1.93	0.0015	0.1	0	0.0	0	0.0	0.002	0.1	0.012	0.6
8/22	4.88	0.361	7.4	0.05	1.0	0.463	9.5	0.249	5.1	0.302	6.2
9/16	3.53	0.148	4.2	0.0001	0.0	0.015	0.4	0.151	4.3	0.097	2.7
11/3	4.17	0.191	4.6	0.073	1.8	0.213	5.1	0.083	2.0	0.144	3.5
12/2	2.16	0.375	17.4	0.388	18.0	0.368	17.0	0.223	10.3	0.405	18.8
TOTAL	29.71	1.725	5.8	0.7976	2.7	1.9154	6.4	1.3321	4.5	2.0684	7.0

EVENT PRECIPITATION

Manure Injection Study



STORM EVENT RUNOFF

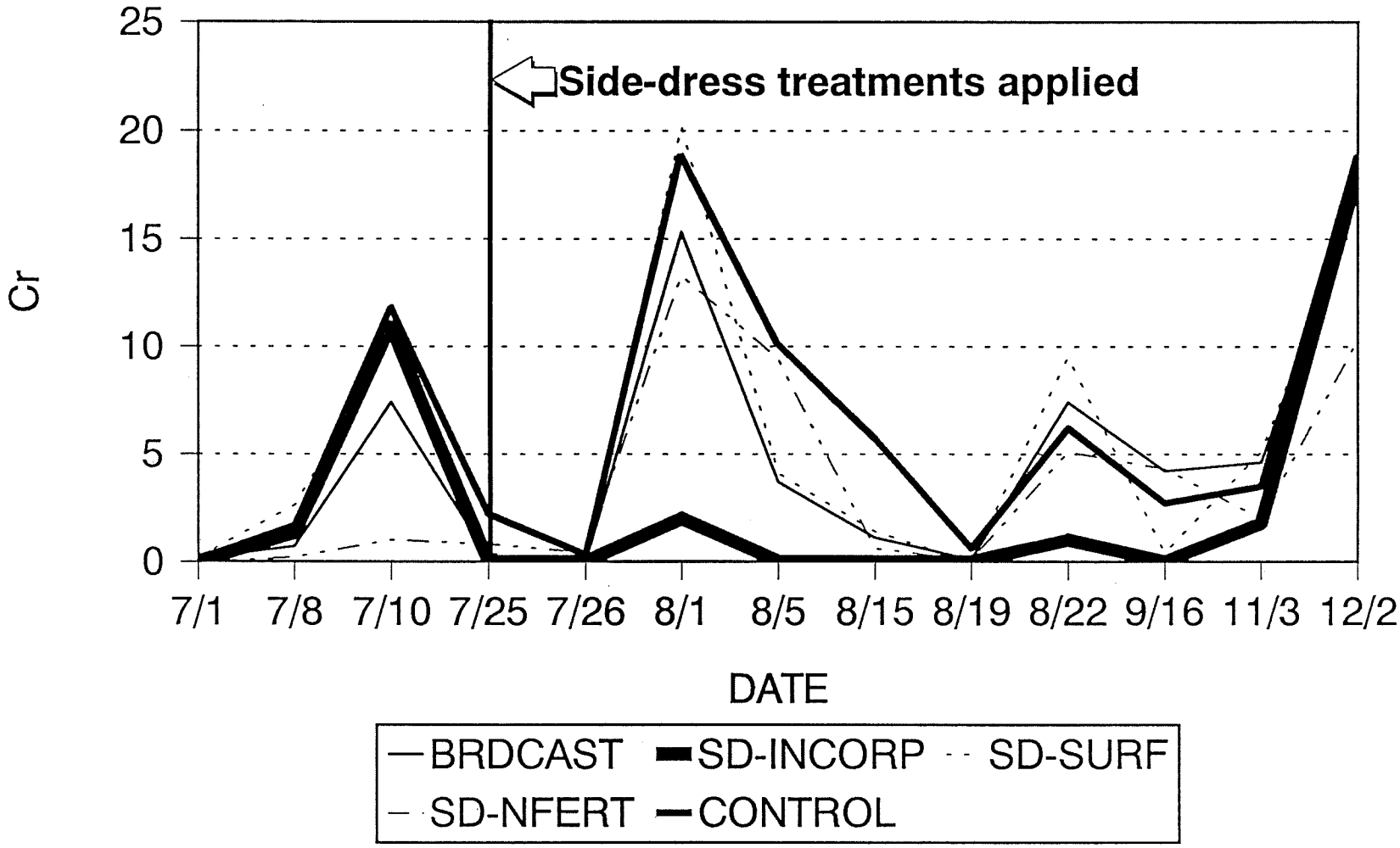


All treatments combined

Fig. 7

RUNOFF COEFFICIENTS

Manure Injection Study



Cr = (Runoff/Precipitation) x 100 = % of rainfall leaving plot

Fig. 8

TABLE 18

MEANS BY TREATMENT, THREE PRE-SIDEDRESS STORMS COMBINED

	BRDCAST	SD INCORP	SD SURF	SD NFERT	CONTROL
Runoff (cm)	0.006 a	0.011 a	0.023 a	0.002 a	0.018 a
[TP] (mg/l)	4.3 a	6.3 a	7.5 a	8.5 a	7.2 a
[TN] (mg/l)	32 a	34 a	34 a	47 a	34 a
[NO3] (mg/l)	7.9 b	3.2 a	3.6 a	1.8 a	2.9 a
[NH4] (mg/l)	0.4 a	0.6 a	0.5 a	0.7 a	0.4 a
[SRP] (mg/l)	0.05 a	0.03 a	0.07 a	0.04 a	0.06 a
TPX (g/ha)	1.6 a	5.20 a	17.5 a	0.6 a	13.2 a
TNX (g/ha)	25 a	23 a	102 a	2.5 a	84 a
NO3X (g/ha)	7.5 a	2.9 a	10.5 a	0.3 a	8.8 a
NH4X (g/ha)	0.4 a	0.6 a	1.6 a	0.2 a	1.3 a
SRPX (g/ha)	0.02 a	0.01 a	0.09 a	0.01 a	0.08 a

In each row, values followed by the same letter(s) are not significantly different, P<0.10

TABLE 19

MEANS BY TREATMENT, ALL POST-SIDEDRESS STORMS COMBINED

	BRDCAST	SD INCORP	SD SURF	SD NFERT	CONTROL
Runoff (cm)	0.03 bc	0.002 a	0.018 b	0.04 bc	0.077 c
[TP] (mg/l)	1.3 a	1.2 a	1.4 a	1.4 a	1.1 a
[TN] (mg/l)	6 a	6 a	6 a	8 a	7 a
[NO3] (mg/l)	0.5 ac	1.0 ab	0.9 ab	1.3 b	0.4 c
[NH4] (mg/l)	0.4 a	0.2 a	0.4 a	0.6 b	0.4 a
[SRP] (mg/l)	0.07 a	0.09 a	0.55 b	0.08 a	0.05 a
TPX (g/ha)	3.8 bc	0.11 a	2.0 b	5.7 bc	10.2 c
TNX (g/ha)	16.1 bc	0.2 a	6.5 c	33.5 b	61.2 b
NO3X (g/ha)	1.0 b	0.04 a	0.8 b	4.3 b	2.6 b
NH4X (g/ha)	1.0 bc	0.02 a	0.5 b	1.9 bc	2.4 c
SRPX (g/ha)	0.15 b	0.01 a	0.37 b	0.17 b	0.24 b

In each row, values followed by the same letter(s) are not significantly different, P<0.10

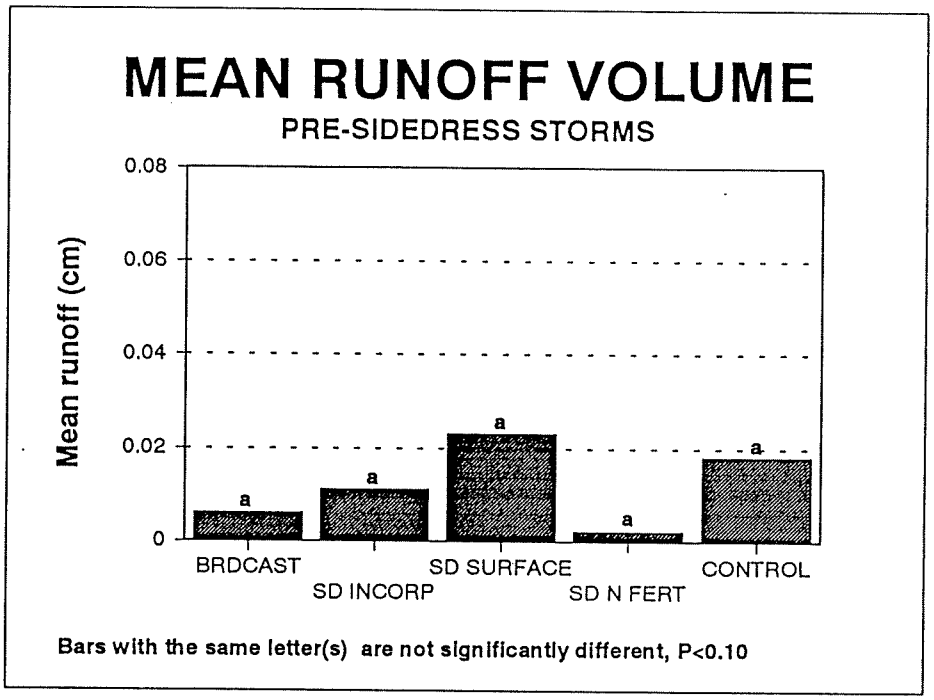

MEAN RUNOFF VOLUME
PRE-SIDEDRESS STORMS
Mean runoff (cm)
0.08
0.06
0.04
0.02
0
a
a
a
a
a
BRDCAST
SD INCORP
SD SURFACE
SD N FERT
CONTROL
Bars with the same letter(s) are not significantly different, P<0.10

Fig. 9

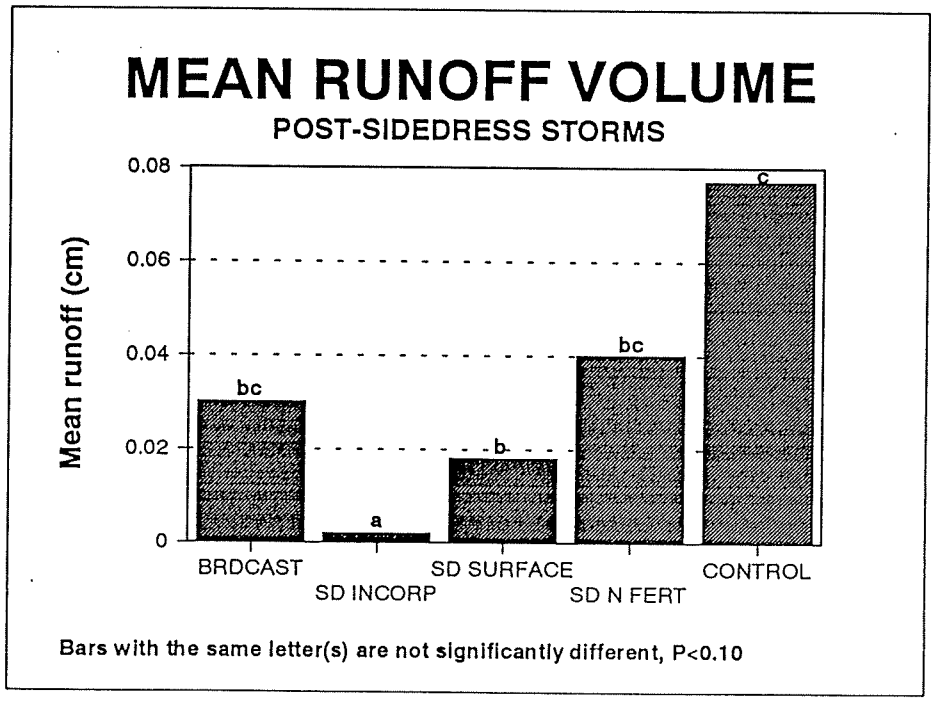

MEAN RUNOFF VOLUME
POST-SIDEDRESS STORMS
Mean runoff (cm)
0.08
0.06
0.04
0.02
0
bc
a
b
bc
c
BRDCAST
SD INCORP
SD SURFACE
SD N FERT
CONTROL
Bars with the same letter(s) are not significantly different, P<0.10

Fig. 10

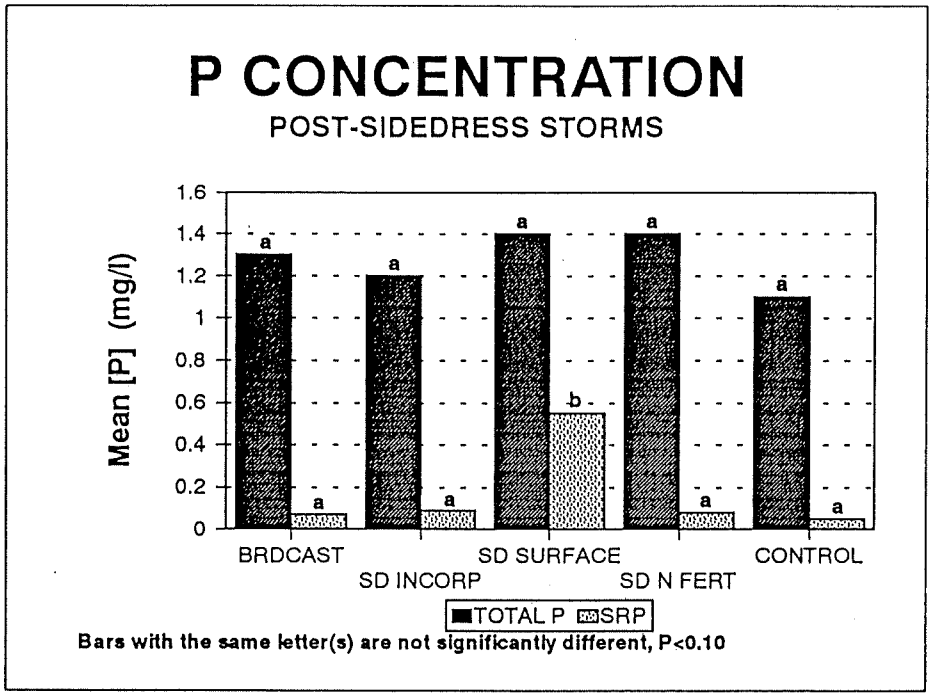

P CONCENTRATION
POST-SIDEDRESS STORMS
Mean [P] (mg/l)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
a
a
a
a
a
b
a
a
a
a
BRDCAST
SD INCORP
SD SURFACE
SD N FERT
CONTROL
TOTAL P
SRP
Bars with the same letter(s) are not significantly different, P<0.10

Fig. 11

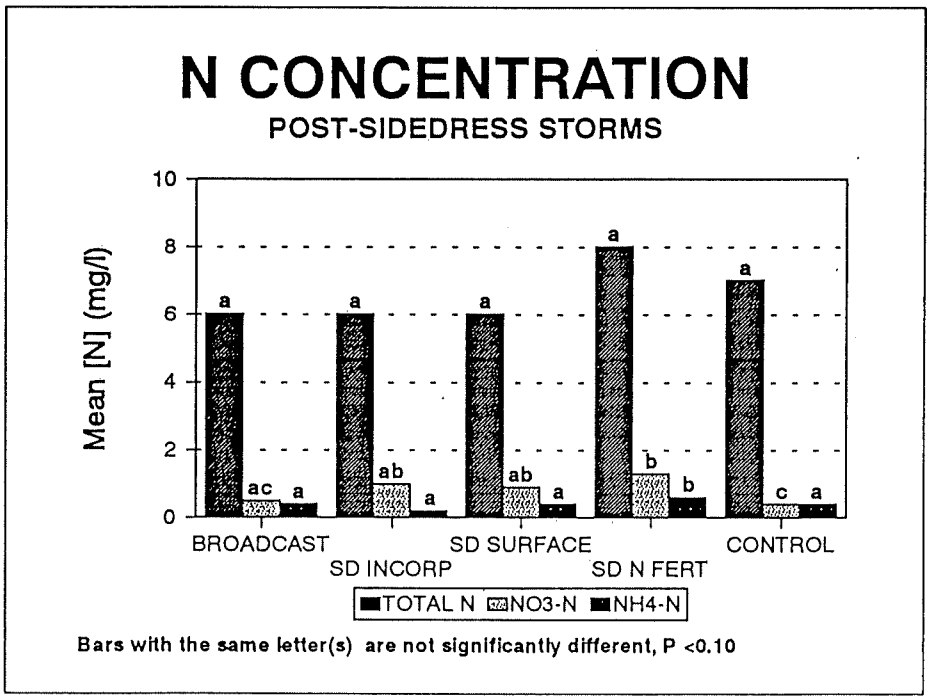

N CONCENTRATION
POST-SIDEDRESS STORMS
Mean [N] (mg/l)
10
8
6
4
2
0
a
ac
a
a
ab
a
a
ab
a
a
b
b
a
c
a
BROADCAST
SD INCORP
SD SURFACE
SD N FERT
CONTROL
TOTAL N
NO3-N
NH4-N
Bars with the same letter(s) are not significantly different, P <0.10

Fig. 12

concentrations from the SD-NFERT treatment plots were significantly higher than concentrations in runoff from the CONTROL or BRDCAST plots and NH_4-N levels in runoff from the SD-NFERT treatment plots were significantly higher than from other treatments or the control. Recall that the N was added to this treatment in the form of ammonium nitrate commercial fertilizer. Overall, with a few exceptions, phosphorus and nitrogen concentrations in runoff did not appear to differ dramatically between treatments.

There were, however, significant differences between treatments in mean nutrient export, obviously driven by the differences in runoff volume. As illustrated in Figure 13, mean Total Phosphorus export from the SD-INCORP plots over the post-sidedress storms was significantly lower than export from the other treatments. Mean TP export from the SD-SURFACE treatment was significantly higher than from the SD- INCORP treatment, but lower than from the control. No significant differences in average phosphorus export between the other treatments were observed. Mean Total Nitrogen export followed a similar pattern, as shown in Figure 14.

The difference in TP and TN export between the SD-INCORP treatment and the other treatments is dramatically illustrated in the cumulative export plots shown in Figures 15 and 16, respectively. In each of these figures, the line represents the summation of export up to and including the time of each monitored event. Clearly, export from the SD-INCORP treatment was substantially lower than from the other treatments. Furthermore, it is important to note that the majority of the nutrient export from this treatment (75% of the TP and 66% of the TN) occurred during the two post-harvest storms, November 3 and December 2, when differences in runoff between treatments were diminished, as noted earlier. Differences between other treatments in total export are likely not significant.

The information in Figures 13 and 14 showing mean TP and TN export, respectively should be compared with the information in Figures 15 and 16 with care. Figures 13 and 14 show mean TP and TN export per storm and these values are the anti-logs of the means of log-transformed values, i.e. essentially the geometric mean. In contrast, the data plotted in Figures 15 and 16 are cumulative sums of export measured in each storm (untransformed data). An arithmetic mean of these values, obtained by dividing the total export values shown by the number of storms, will not be the same as the geometric means plotted in Figures 13 and 14.

It is clear that both mean and total phosphorus and nitrogen losses from the SD-INCORP treatment were dramatically lower than from the other treatments. While mean losses from the SD-SURFACE treatment were significantly lower than losses from the BRDCAST and SD-NFERT treatments and the CONTROL, cumulative losses over the study period did not appear to differ substantially from other treatments.

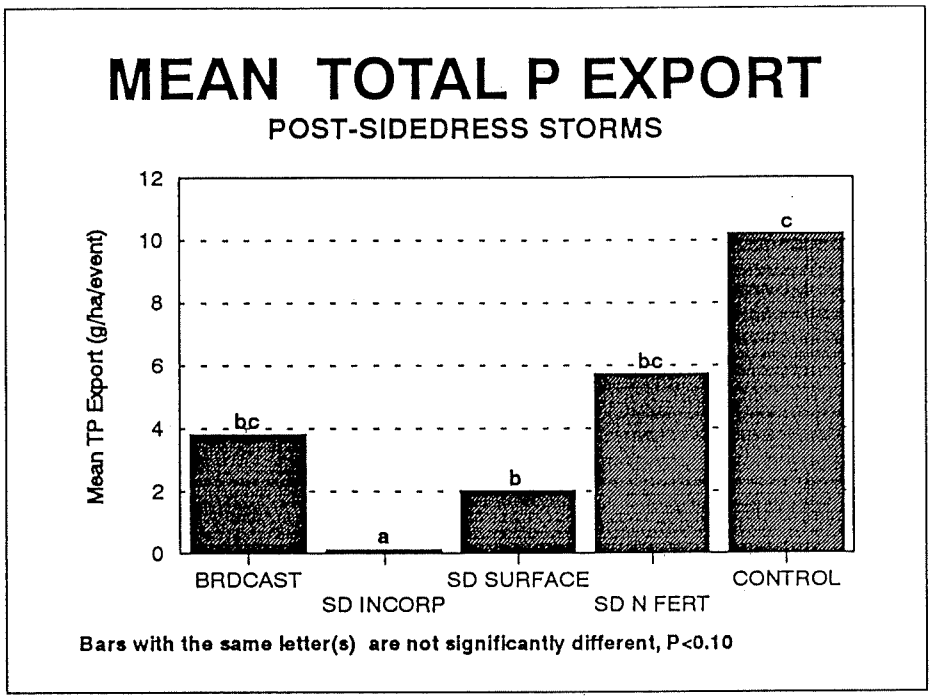

MEAN TOTAL P EXPORT
POST-SIDEDRESS STORMS
Mean TP Export (g/ha/event)
12
10
8
6
4
2
0
bc
a
b
bc
c
BRDCAST
SD INCORP
SD SURFACE
SD N FERT
CONTROL
Bars with the same letter(s) are not significantly different, P<0.10

Fig. 13

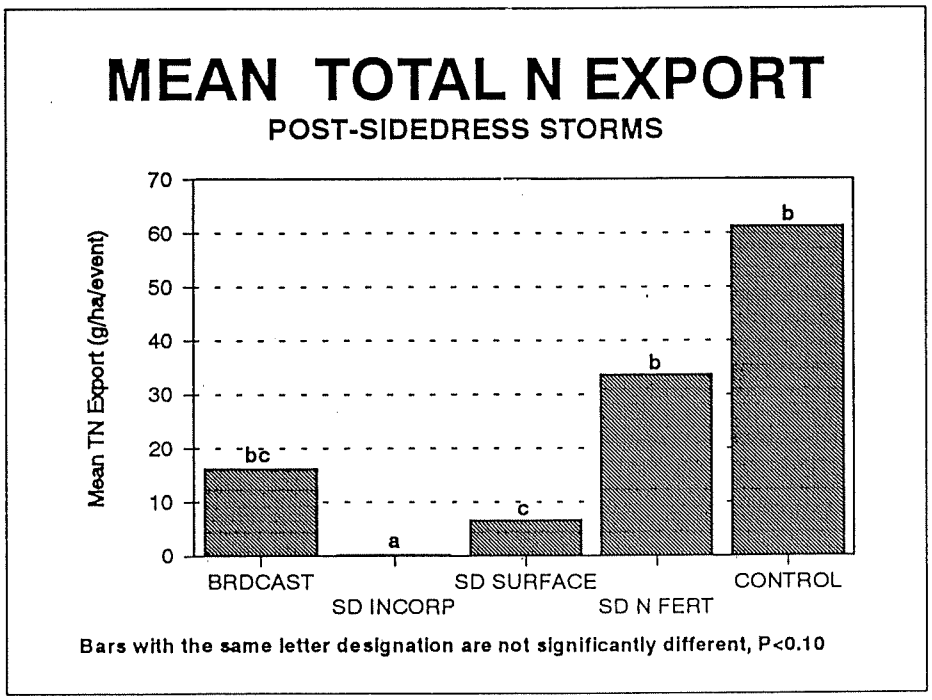

MEAN TOTAL N EXPORT
POST-SIDEDRESS STORMS
Mean TN Export (g/ha/event)
70
60
50
40
30
20
10
0
bc
a
c
b
b
BRDCAST
SD INCORP
SD SURFACE
SD N FERT
CONTROL
Bars with the same letter designation are not significantly different, P<0.10

Fig. 14

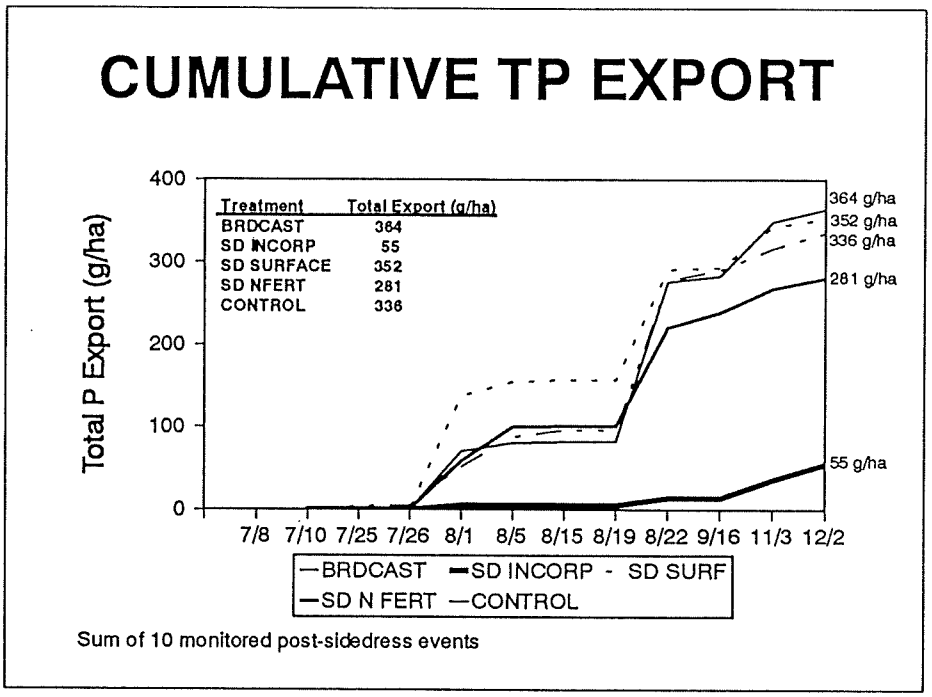

CUMULATIVE TP EXPORT
Total P Export (g/ha)
400
300
200
100
0
Treatment Total Export (g/ha)
BRDCAST 364
SD INCORP 55
SD SURFACE 352
SD NFERT 281
CONTROL 336
364 g/ha
352 g/ha
336 g/ha
281 g/ha
55 g/ha
7/8 7/10 7/25 7/26 8/1 8/5 8/15 8/19 8/22 9/16 11/3 12/2
—BRDCAST —SD INCORP - SD SURF
—SD N FERT —CONTROL
Sum of 10 monitored post-sidedress events

Fig. 15

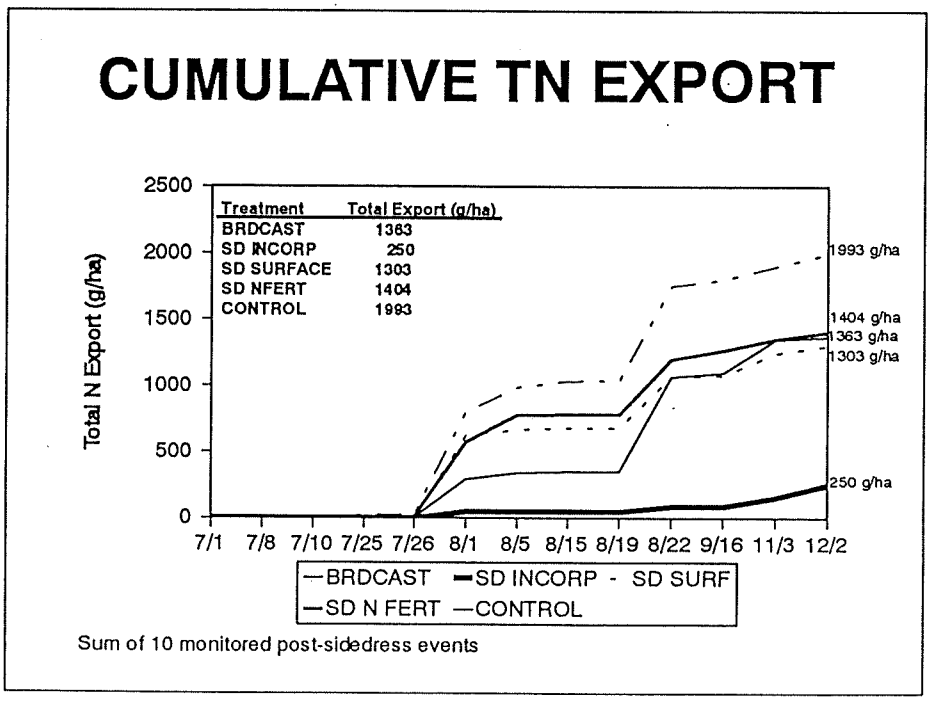

CUMULATIVE TN EXPORT
Total N Export (g/ha)
2500
2000
1500
1000
500
0
Treatment Total Export (g/ha)
BRDCAST 1363
SD INCORP 250
SD SURFACE 1303
SD NFERT 1404
CONTROL 1993
1993 g/ha
1404 g/ha
1363 g/ha
1303 g/ha
250 g/ha
7/1 7/8 7/10 7/25 7/26 8/1 8/5 8/15 8/19 8/22 9/16 11/3 12/2
—BRDCAST —SD INCORP - SD SURF
—SD N FERT —CONTROL
Sum of 10 monitored post-sidedress events

Fig. 16

Treatment Performance

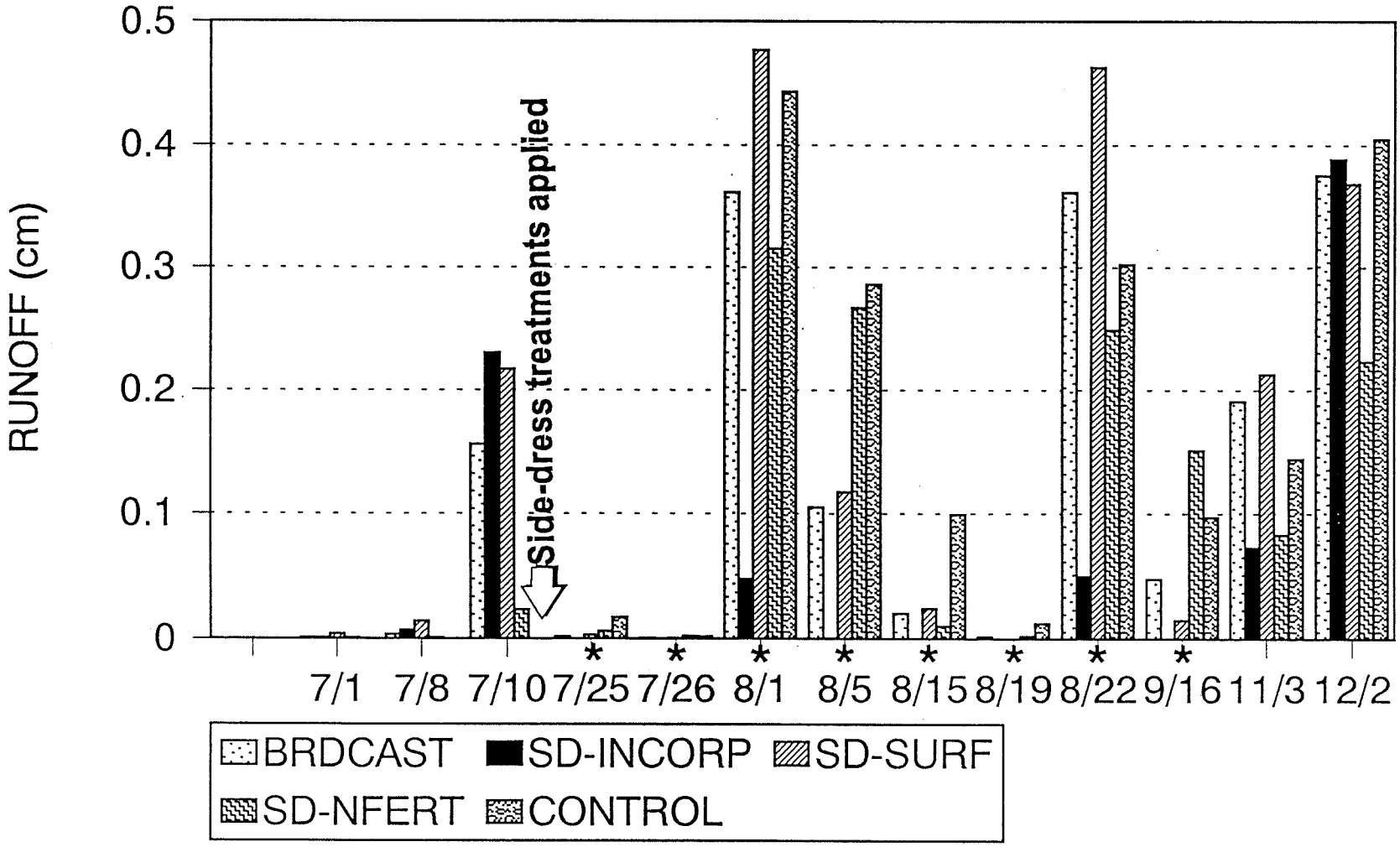
Water quality patterns within treatments were examined in more detail. The main effect of treatment has been shown to be significant reduction in mean runoff from the SD-INCORP treatment, compared to other treatments as well as to the control. This pattern is further confirmed when runoff volume is compared among treatments for the entire sequence of monitored storms, as shown in Figure 17. Runoff volume did not differ significantly between treatments during any of the three pre-sidedress storms. However, after the side-dress treatments were applied (July 15), runoff volumes from the SD-INCORP treatment were significantly lower than from other treatments and the control during each storm until harvest (October 11). Runoff differences between treatments disappeared during the two post-harvest storms, November 3 and December 2.

This effect on runoff may have been a response to changes in surface roughness, microtopography, and structure at the soil surface in response to tillage and the presence of manure. The action of manure application in the SD-INCORP treatment would tend to promote infiltration due to increases in surface roughness, while other treatments would tend to have less effect on these soil characteristics. This pattern was confirmed by field observations during the course of the summer. Sidedress surface-applied manure might also be expected to reduce surface runoff through increased surface roughness and detention storage (Young and Holt, 1977); in fact, the SD-SURFACE treatment did tend to show lower runoff volumes following treatment (Figure 10) but the differences were not statistically significant. It is also reasonable to expect this effect to diminish with time, as weathering would tend to return the soil surface to original conditions. The fact that the effect ceased after crop harvest suggests that canopy removal might have been an influence as well, but this seems unlikely since all treatments had essentially the same canopy coverage during the growing season. Wheel tracking and soil compaction from harvest operations probably also affected surface conditions, perhaps overwhelming the diminishing influence of some treatment effects on surface texture.

Comparisons of runoff, nutrient concentrations, and nutrient losses between treatments for each post-sidedress storm are shown in Table 20, along with indications of significant differences between treatments for each storm.

Although not shown in Table 20, runoff volumes differed significantly between storms in each treatment. As noted earlier, differences were not completely explained by total event precipitation. Runoff patterns in response to precipitation shown were generally similar across all the treatments, although differences in absolute runoff volumes were marked. The storms of August 1, August 22, and December 2 tended to produce the greatest runoff, while the July 25 and 26 and August 19 storms produced significantly lower runoff volumes. No runoff at all occurred from the SD-INCORP treatment during the smaller storms, while runoff volumes comparable to

RUNOFF BY TREATMENT



* Runoff differs significantly between treatments

Fig. 17

TABLE 20
Runoff Quantity and Quality by Treatment
Post-Sidedress Treatment Storms

	7/25	7/26	8/1	8/5	8/15	8/19	8/22	9/16	11/3	12/2
Runoff (cm)										
BRDCAST	0.0015 b	0.0002 ab	0.361 b	0.105 b	0.02 b	0.0015 b	0.361 b	0.048 bc	0.191 a	0.375 a
SD-INCORP	0 a	0 a	0.048 a	0.0005 a	<0.0001 a	0 a	0.05 a	<0.0001 a	0.073 a	0.388 a
SD-SURF	0.0032 b	<0.0002 a	0.477 b	0.117 b	0.024 b	0 a	0.463 b	0.015 b	0.213 a	0.368 a
SD-NFERT	0.006 b	0.002 b	0.315 b	0.267 b	0.01 b	0.002 b	0.249 b	0.151 c	0.083 a	0.223 a
CONTROL	0.017 b	0.0018 b	0.443 b	0.286 b	0.099 b	0.012 b	0.302 b	0.097 c	0.144 a	0.405 a
[TP] (mg/l)										
BRDCAST	2.4 a	0.9 a	1.9 a	1.0 a	0.8 a	0.3 a	5.3 b	1.5 a	3.4 a	0.4 a
SD-INCORP	--	--	1.1 a	0.3 a	1.2 a	--	1.6 a	--	3.0 a	0.5 a
SD-SURF	2 a	1.3 a	2.9 a	1.4 a	0.9 a	--	2.9 ab	1.4 a	2.3 a	0.3 a
SD-NFERT	1.5 a	0.9 a	1.8 a	1.5 a	0.9 a	0.3 a	4.8 b	1.2 a	3.4 a	0.6 a
CONTROL	2.7 a	1.7 a	1 a	1.2 a	0.9 a	0.1 a	6 b	1.2 a	1.8 a	0.5 a
[TN] (mg/l)										
BRDCAST	12 a	7 a	8 a	4 a	5 a	3 a	20 b	6 a	13 a	2 a
SD-INCORP	--	--	9 a	--	--	--	8 a	7 a	9 a	2 a
SD-SURF	10 a	--	13 a	4 a	5 a	--	8 a	6 a	8 a	2 a
SD-NFERT	11 a	8 a	18 a	8 a	7 a	3 a	17 b	5 a	9 a	2 a
CONTROL	14 a	10 a	17 a	6 a	5 a	2 a	24 b	5 a	7 a	2 a
[NO3] (mg/l)										
BRDCAST	2.2 b	2.3 ab	1.4 a	0.5 ab	0.2 a	0.1 a	0.5 a	--	0.7 a	--
SD-INCORP	--	--	1.5 a	0.4 ab	11.5 b	--	0.8 a	--	0.6 a	--
SD-SURF	4.5 b	1.5 a	1.9 a	0.8 b	0.1 a	--	0.8 a	--	0.8 a	--
SD-NFERT	5.3 b	16.2 b	1.6 a	1.0 b	0.6 b	0.5 a	0.9 a	--	0.8 a	--
CONTROL	0.7 a	1.2 a	0.8 a	0.3 a	0.1 a	0.1 a	0.3 a	--	0.7 a	--
[NH4] (mg/l)										
BRDCAST	1 a	0.7 a	0.29 a	0.2 b	0.35 a	0.47 a	0.69 b	--	0.3 a	--
SD-INCORP	--	--	0.5 abc	0.4 c	0.3 a		0.4 a	--	0.07 a	--
SD-SURF	1.9 a	--	0.5 bc	0.1 a	0.3 a	--	0.4 a	--	0.3 a	--
SD-NFERT	3.8 a	2.5 a	0.8 c	0.2 b	0.6 a	0.2 a	0.7 b	--	0.2 a	--
CONTROL	0.79 a	0.56 a	0.35 ab	0.12 a	0.36 a	0.36 a	0.69 b	--	0.25 a	--
[SRP] (mg/l)										
BRDCAST	0.17 a	0.06 a	0.03 a	0.06 a	--	--	0.15 b	--	--	--
SD-INCORP	--	--	0.19 b	0.01 a	--	--	0.1 a	--	--	--
SD-SURF	0.59 a	0.48 a	0.41 b	0.77 b	--	--	0.54 b	--	--	--
SD-NFERT	0.03 a	0.08 a	0.21 b	0.05 a	--	--	0.14 b	--	--	--
CONTROL	0.15 a	0.04 a	0.02 a	0.02 a	--	--	0.12 b	--	--	--

For each parameter, within each storm, values followed by the same letter(s) are not significantly different, $P<0.10$.

TABLE 20
Runoff Quantity and Quality by Treatment
Post-Sidedress Treatment Storms

	7/25	7/26	8/1	8/5	8/15	8/19	8/22	9/16	11/3	12/2
TPX (g/ha)										
BRDCAST	0.30 b	0.01 ab	70.50 b	10.20 b	1.60 b	0.04 b	193.00 b	7.30 ac	66.00 a	15.00 a
SD-INCORP	0 a	0 a	5.4 a	<.1 a	<.01 a	0 a	8.3 a	0 a	22.1 a	19.1 a
SD-SURF	0.4 b	<.1 a	137.7 b	16.6 b	2.3 b	0.0 a	133.4 b	2.1 b	49.6 a	10.3 a
SD-NFERT	0.68 b	0.26 bc	58.3 b	41.0 b	0.76 b	0.07 b	120.0 b	17.8 c	28.2 a	13.7 a
CONTROL	4.8 b	0.4 c	47 b	35.1 b	8.8 b	0.2 b	182 b	11.4 c	26.8 a	19.2 a
TNX (g/ha)										
BRDCAST	0.90 b	0.04 b	294.00 b	47.60 b	10.20 b	0.30 b	714.00 b	30.60 b	246.00 a	19.20 a
SD-INCORP	0 a	0 a	45 a	0 a	0 a	0 a	40 a	<1.0 a	69 a	95 a
SD-SURF	1.4 b	0.0	621.0 b	45.4 b	12.0 b	0.0 a	390.0 b	8.2 b	163.0 a	61.9 a
SD-NFERT	3.0 b	3.4 c	566 b	207.0 c	3.4 b	0.3 b	417.0 b	69.0 b	78.0 a	57.0 a
CONTROL	24 b	2.7 c	773 b	187 c	49.2 b	2.3 b	713 b	47.6 b	97.9 a	96.4 a
NO3X (g/ha)										
BRDCAST	0.30 a	0.01 ab	50.70 b	5.40 b	0.30 a	<0.01 a	17.10 a	--	14.00 a	--
SD-INCORP	0 a	0 a	7.2 a	<.1 a	<.1 a	0 a	3.9 a	0	4.2 a	--
SD-SURF	0.8 a	<.1 a	91.0 b	9.0 b	0.1 a	0.0 a	35.9 a	--	17.2 a	--
SD-NFERT	1.7 a	6.8 c	49.5 b	25.7 b	0.6 a	0.1 b	23.3 a	--	6.7 a	--
CONTROL	1.1 a	0.3 bc	35.6 b	9.6 b	1 a	0.1 b	8 a	--	9.6 a	--
NH4X (g/ha)										
BRDCAST	0.20 a	<0.01 ab	10.50 c	2.10 b	0.70 b	0.07 b	24.80 b	--	5.60 a	--
SD-INCORP	0 a	0 a	2.4 a	<.1 a	0 a	0 a	2.0 a	0	0.6 a	--
SD-SURF	0.4 a	0.0 a	25.0 b	1.1 b	0.8 b	0.0 a	19.6 b	--	5.6 a	--
SD-NFERT	1.3 a	1.0 c	26.8 b	6.4 b	0.5 b	0.03 b	18.6 b	--	1.7 a	--
CONTROL	1.4 a	0.05 bc	15.3 bc	3.4 b	3.6 b	0.4 b	20.8 b	--	3.7 a	--
SRPX (g/ha)										
BRDCAST	0.05 ab	0.00 a	0.90 a	0.80 b	--	0.00	5.30 b	--	--	--
SD-INCORP	0 a	0 a	0.94 a	<0.01 a	0	0	0.54 a	0	--	--
SD-SURF	0.17 b	<0.01 a	20.0 b	9.0 b	--	0.0	25.0 c	--	--	--
SD-NFERT	0.01 ab	<0.01 a	6.65 b	1.38 b	0	0	3.54 b	--	--	--
CONTROL	0.3 b	<0.01 a	1.1 a	0.7 b	--	--	3.8 b	--	--	--

For each parameter, within each storm, values followed by the same letter(s) are not significantly different, P<0.10.

those from the other treatments and the control did not occur until the December 2 storm.

Phosphorus and Nitrogen concentrations in runoff followed generally similar patterns in the BRDCAST, SD-SURFACE, SD-NFERT, and CONTROL treatments, as shown in Figures 18 and 19. The highest nutrient concentrations were not consistently associated with the largest storms nor were concentrations always similar in runoff from storms of similar rainfall amounts. Correlations between nutrient concentration and either precipitation or runoff volume were generally very weak. The patterns of nutrient concentration in runoff from all treatments combined shown in Figures 18 and 19 seem to suggest that timing of the storm may be important in determining nutrient concentrations in runoff. In these plots, with the exception of the largest storms (August 22 and November 3), nutrient concentrations in runoff were high in the first storm after treatment, then generally decreased later in the season. This phenomenon has been widely reported in studies of runoff losses of manure, fertilizer, and pesticides (Nat. Res. Council, 1993; Novotny and Olem, 1993) and may be related to the diminishing quantities of P and N available to be transported in runoff, either due to previous runoff losses, infiltration, or crop uptake. Continuing development of crop canopy through the growing season may also have had an effect. The two largest storms were obvious exceptions; runoff from these storms may have been sufficient in quantity or intensity to detach and move additional materials.

Nutrient concentrations from the SD-INCORP treatment showed a different pattern, or rather lack of pattern through the growing season (Figure 20). Early post-treatment storms generated no runoff and therefore no P or N loss. Even when runoff did occur, nutrient concentrations appeared to be less variable than for the other treatments and showed few significant differences between events of different magnitude. The large post-treatment event of November 3 did appear to generate somewhat higher P and N levels in runoff, but the differences were not statistically significant. Thus, in addition to reduction of runoff volume, the SD-INCORP also appears to have the effect of damping variations in nutrient losses in runoff.

Storm Events

At the broad study scale, differences due to sidedress treatment were primarily related to effects on surface runoff, specifically in substantial reduction of runoff from the SD-INCORP treatment. There appeared to be very little effect on nutrient concentration in runoff due to sidedress treatment when the entire sequence of storms was considered. However, there were some significant differences between treatments observed within individual storms.

Three storm events - August 1 (2.36 cm, 0.93 in), August 22 (4.88 cm, 1.92 in), and December 22 (2.16 cm, 0.85 in) - are compared in Figures 21 through 25. These tended to be the largest runoff-producing storms monitored during the post-treatment

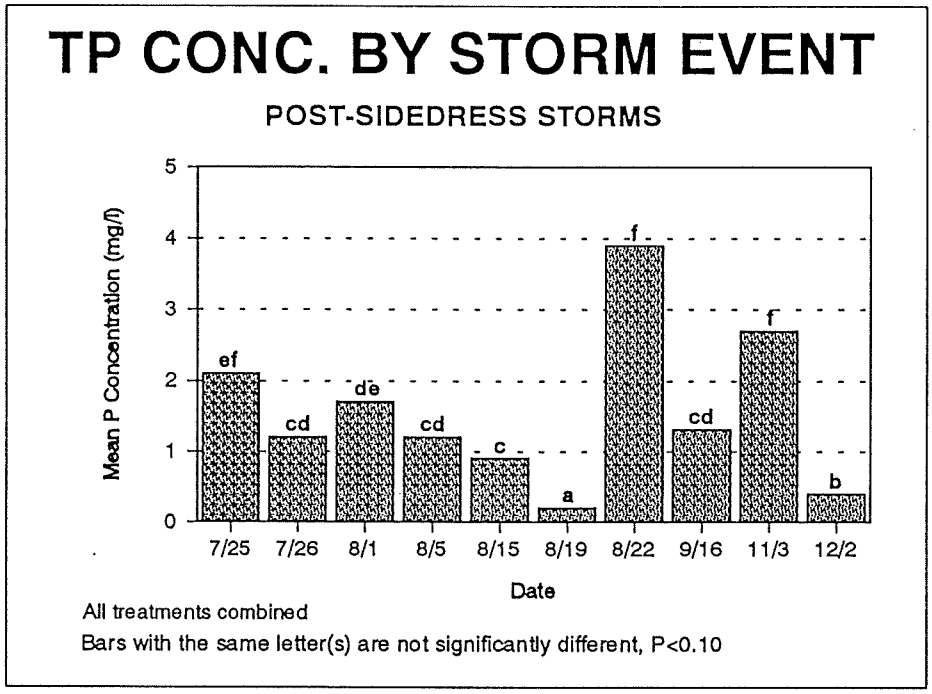

TP CONC. BY STORM EVENT
POST-SIDEDRESS STORMS
Mean P Concentration (mg/l)
0
1
2
3
4
5
ef
cd
de
cd
c
a
f
cd
f
b
7/25
7/26
8/1
8/5
8/15
8/19
8/22
9/16
11/3
12/2
Date
All treatments combined
Bars with the same letter(s) are not significantly different, P<0.10

Fig. 18

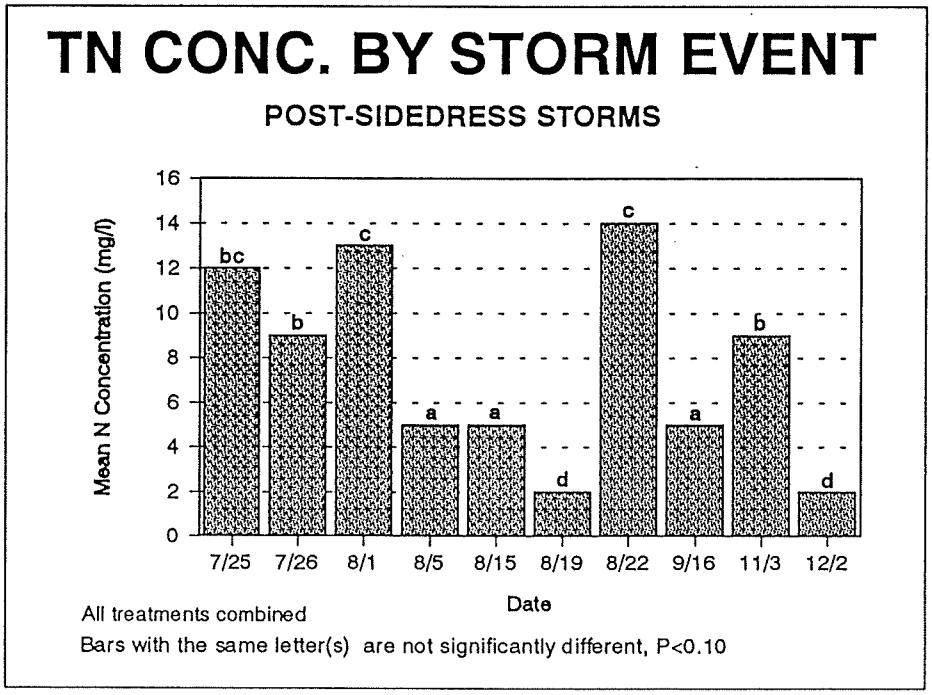
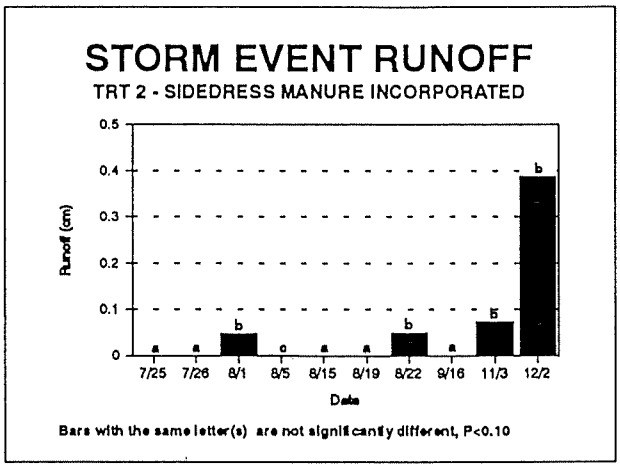
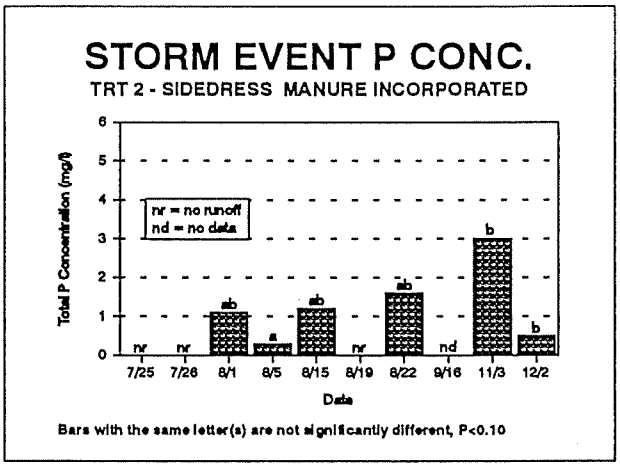

TN CONC. BY STORM EVENT
POST-SIDEDRESS STORMS
Mean N Concentration (mg/l)
0
2
4
6
8
10
12
14
16
bc
b
c
a
a
d
c
a
b
d
7/25
7/26
8/1
8/5
8/15
8/19
8/22
9/16
11/3
12/2
Date
All treatments combined
Bars with the same letter(s) are not significantly different, P<0.10

Fig. 19


STORM EVENT RUNOFF
TRT 2 - SIDEDRESS MANURE INCORPORATED
Runoff (cm)
0.5
0.4
0.3
0.2
0.1
0
a a b a a a b a b b
7/25 7/26 8/1 8/5 8/15 8/19 8/22 9/16 11/3 12/2
Date
Bars with the same letter(s) are not significantly different, P<0.10


STORM EVENT P CONC.
TRT 2 - SIDEDRESS MANURE INCORPORATED
Total P Concentration (mg/l)
6
5
4
3
2
1
0
nr = no runoff
nd = no data
nr nr ab a ab nr ab nd b b
7/25 7/26 8/1 8/5 8/15 8/19 8/22 9/16 11/3 12/2
Date
Bars with the same letter(s) are not significantly different, P<0.10

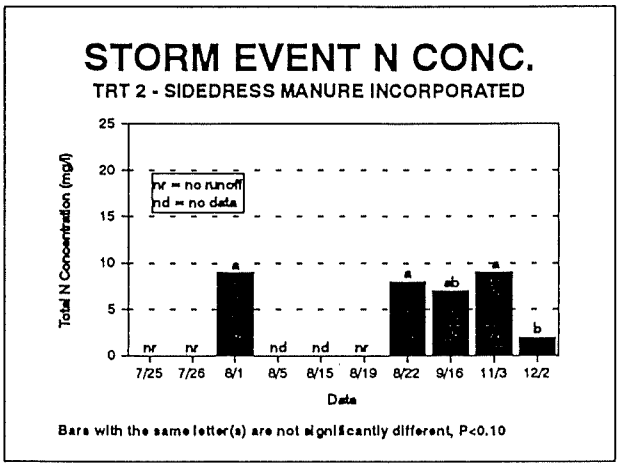

STORM EVENT N CONC.
TRT 2 - SIDEDRESS MANURE INCORPORATED
Total N Concentration (mg/l)
25
20
15
10
5
0
nr = no runoff
nd = no data
nr nr a nd nd nr a ab a b
7/25 7/26 8/1 8/5 8/15 8/19 8/22 9/16 11/3 12/2
Date
Bars with the same letter(s) are not significantly different, P<0.10

Fig. 20

period. As shown in Figure 21, runoff from these storms followed the same pattern noted earlier: significantly lower runoff from the SD-INCORP treatment for the first two storms, but no differences between treatments for the post-harvest storm. With regard to phosphorus and nitrogen concentration in runoff, no significant differences between treatments were noted for the August 1 storm, but both TP and TN concentrations were significantly lower in runoff from the SD-INCORP and the SD-SURFACE treatments. Runoff from the December 2 storm showed no significant differences in P or N levels between treatments and runoff concentrations were extremely low, again reflecting the overall trend over the study period noted earlier. Phosphorus and nitrogen losses from the treatments followed the same pattern, significantly lower export from the SD-INCORP treatment.

Finally, some observations from two smaller monitored storms should be noted. The storms of August 1 (2.36 cm, 0.93 in) and August 5 (2.84 cm, 1.12 in) were the first major storms after the July 15 treatment applications; they were not the largest storms of the post-sidedress period, but they were the first following treatment to generate substantial runoff. While TP and TN concentrations in runoff from these storms did not differ significantly, significant differences were observed in soluble nutrient forms. Runoff concentrations of NO_3-N, NH_4-N and SRP for the August 1 storm are shown in Figure 26. In this storm, ammonium concentrations in runoff from the three side-dress treatments were significantly higher than from BRDCAST treatment, which is reasonable considering that manure was applied and incorporated in the BRDCAST plots long before the runoff event occurred. Although not statistically significant (except compared to the control), NH_4-N concentrations were highest from the SD-NFERT treatment, where nitrogen fertilizer had been surface applied, among all the side-dress treatments. Runoff concentrations of SRP showed a similar pattern. SRP levels in runoff from the three side-dress treatments were significantly higher than from either the BRDCAST or the control plots. SRP concentration was highest from the SD-SURFACE treatment, where manure had been surface applied, although the difference was not statistically significant. Runoff concentrations of NO_3-N did not differ significantly between treatments in this storm.

Concentrations of NH_4-N, NO_3-N and SRP for the August 5 storm are shown in Figure 27. Nitrate concentrations were significantly higher in runoff from the SD-SURFACE and SD-NFERT treatments, compared to the control; runoff from the SD-NFERT and SD-SURFACE treatments showed the highest NO_3-N levels, but the differences were not significant from the BRDCAST or SD-INCORP treatments. Soluble reactive phosphorus concentrations were significantly higher in runoff from the SD-SURFACE treatment than from any of the other treatments or the control. Ammonium-nitrogen concentration in runoff from the SD-INCORP treatment was significantly higher than from any other treatment; NH_4-N levels in runoff were lowest from SD-SURFACE plots among all the sidedress treatments.

These patterns suggest that soluble nutrients were available for transport and loss in

COMPARISON OF 3 EVENTS

Runoff

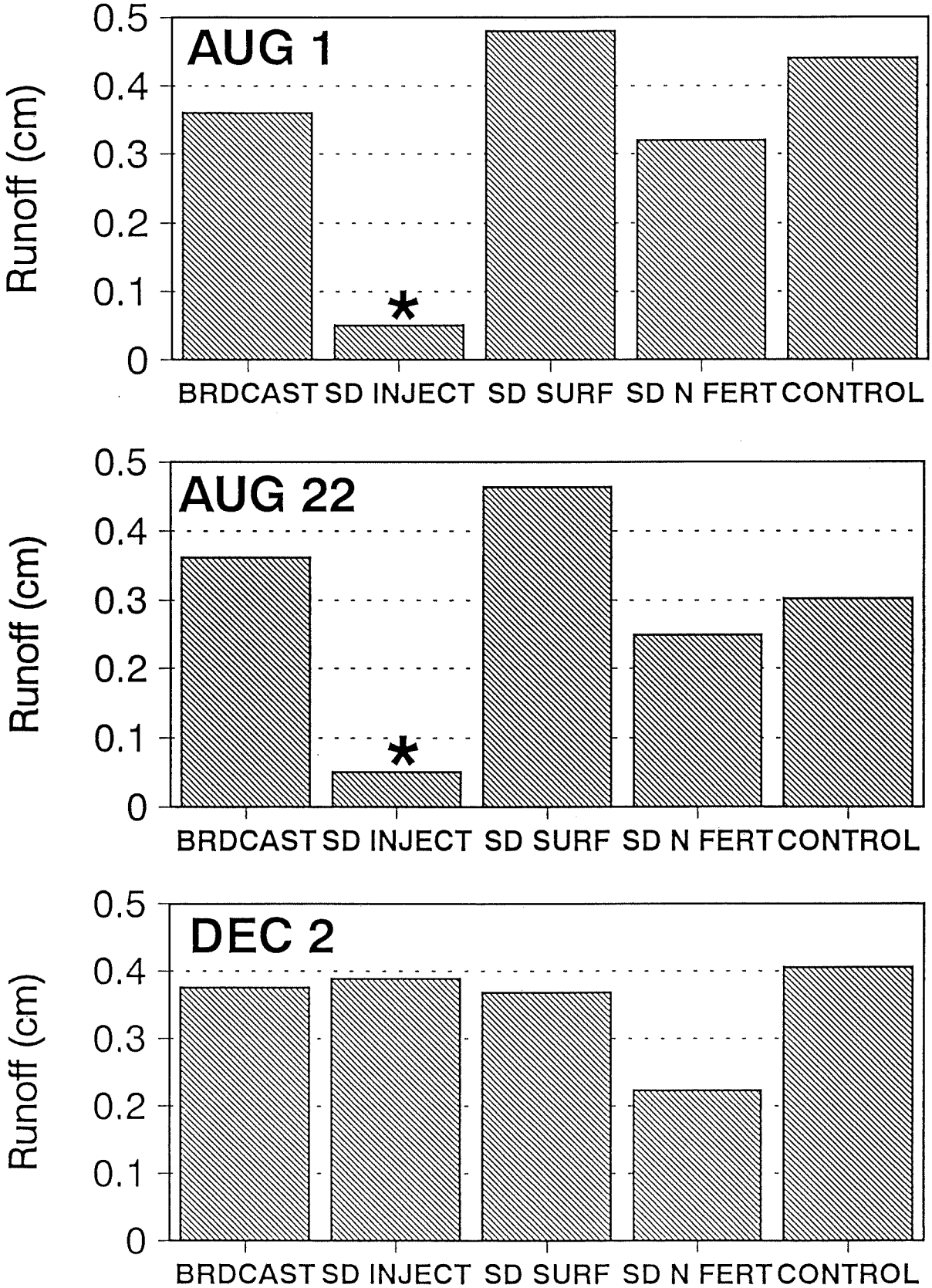


Fig. 21

COMPARISON OF 3 EVENTS

Total P Concentration

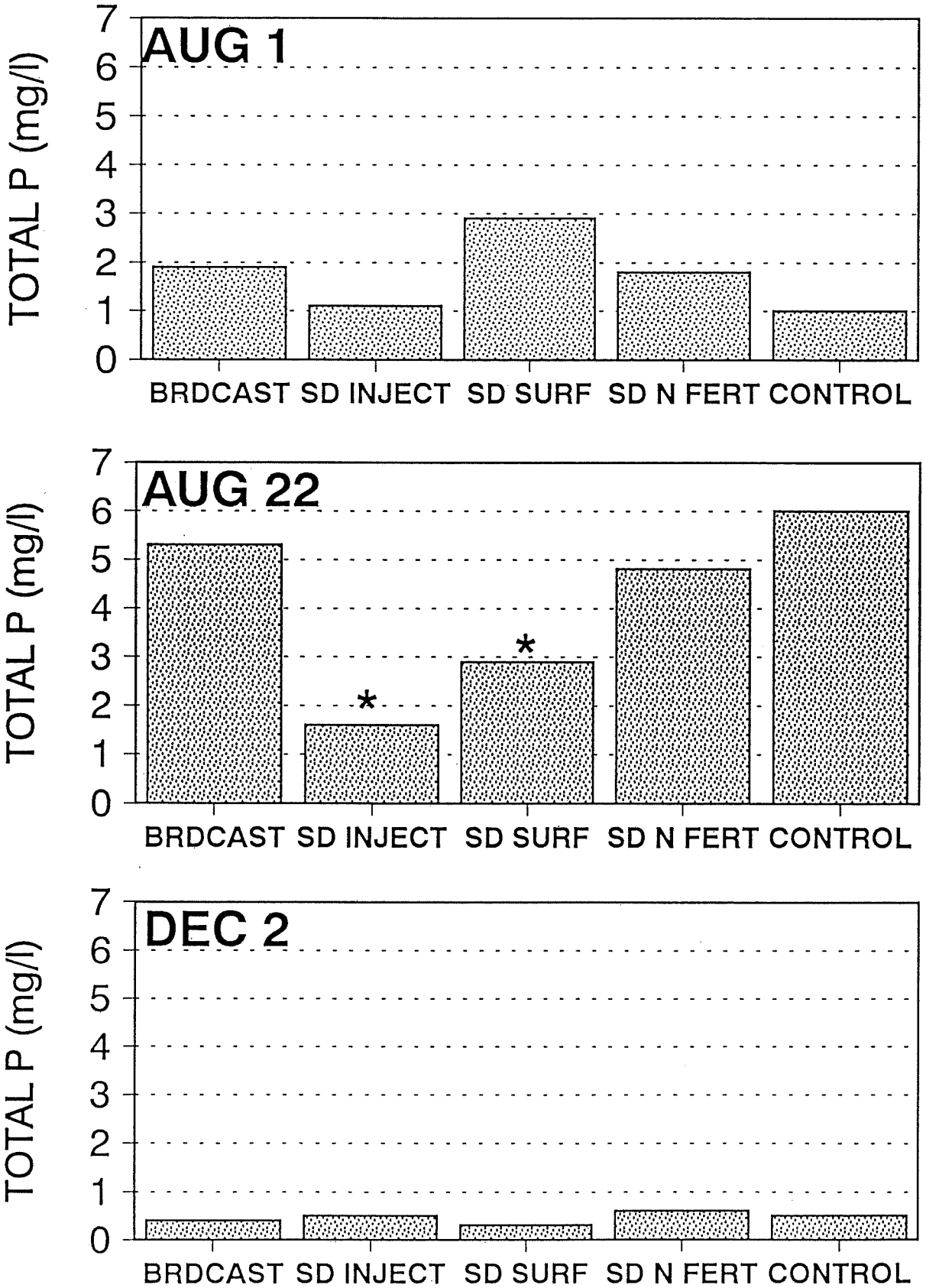


Fig. 22

COMPARISON OF 3 EVENTS

Total N Concentration

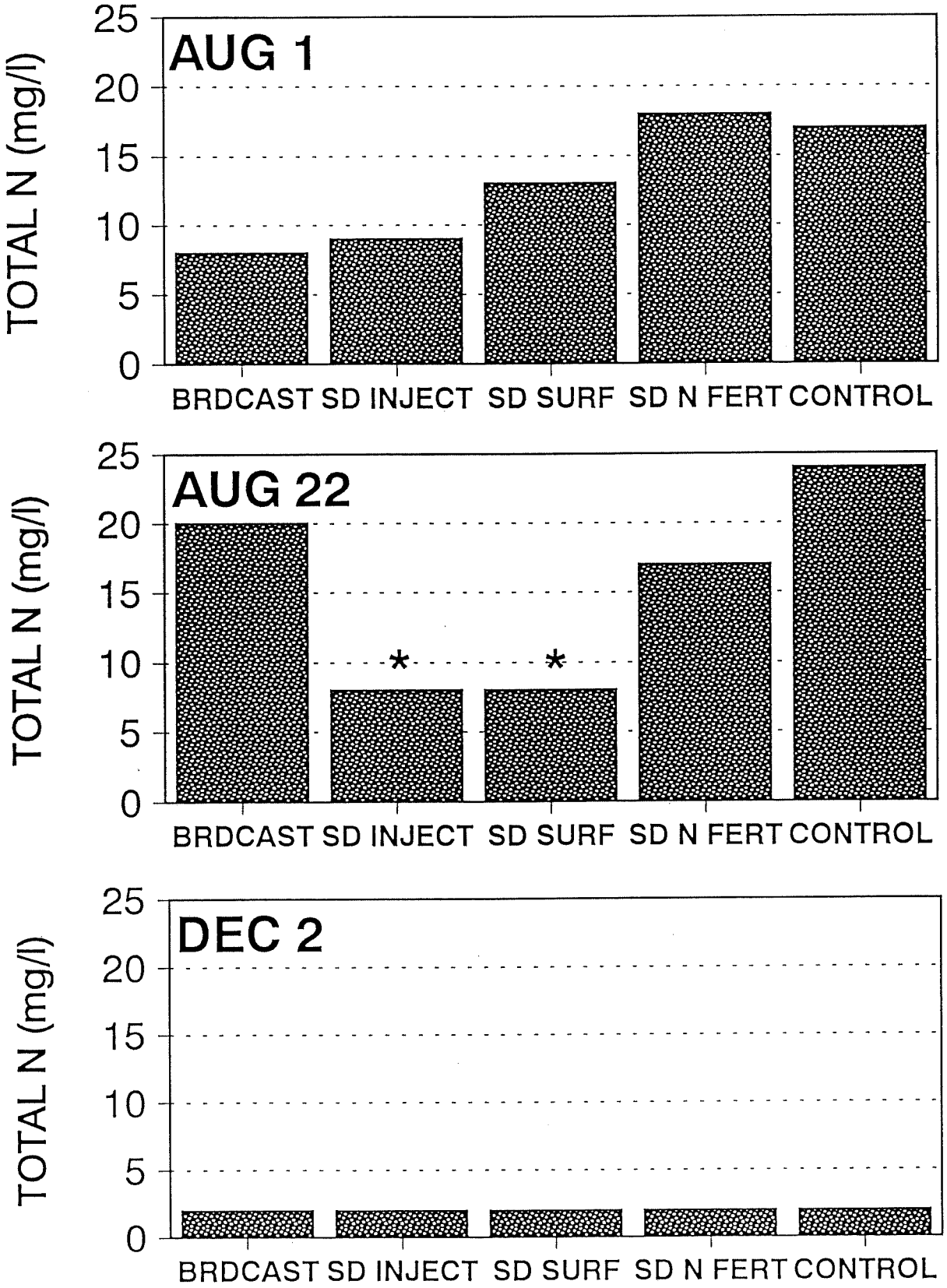


Fig. 23

COMPARISON OF 3 EVENTS

Total P Export

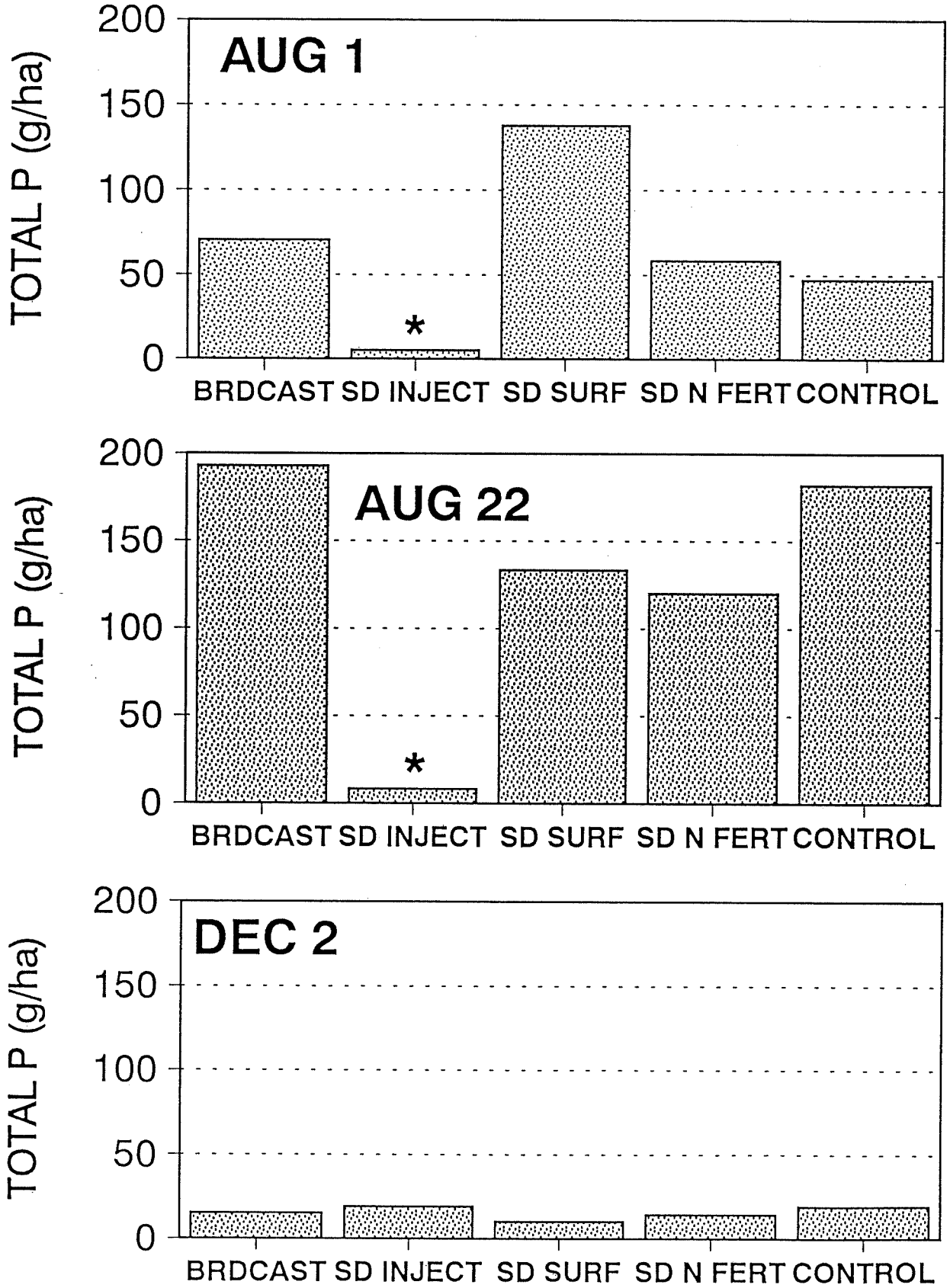


Fig. 24

COMPARISON OF 3 EVENTS

Total N Export

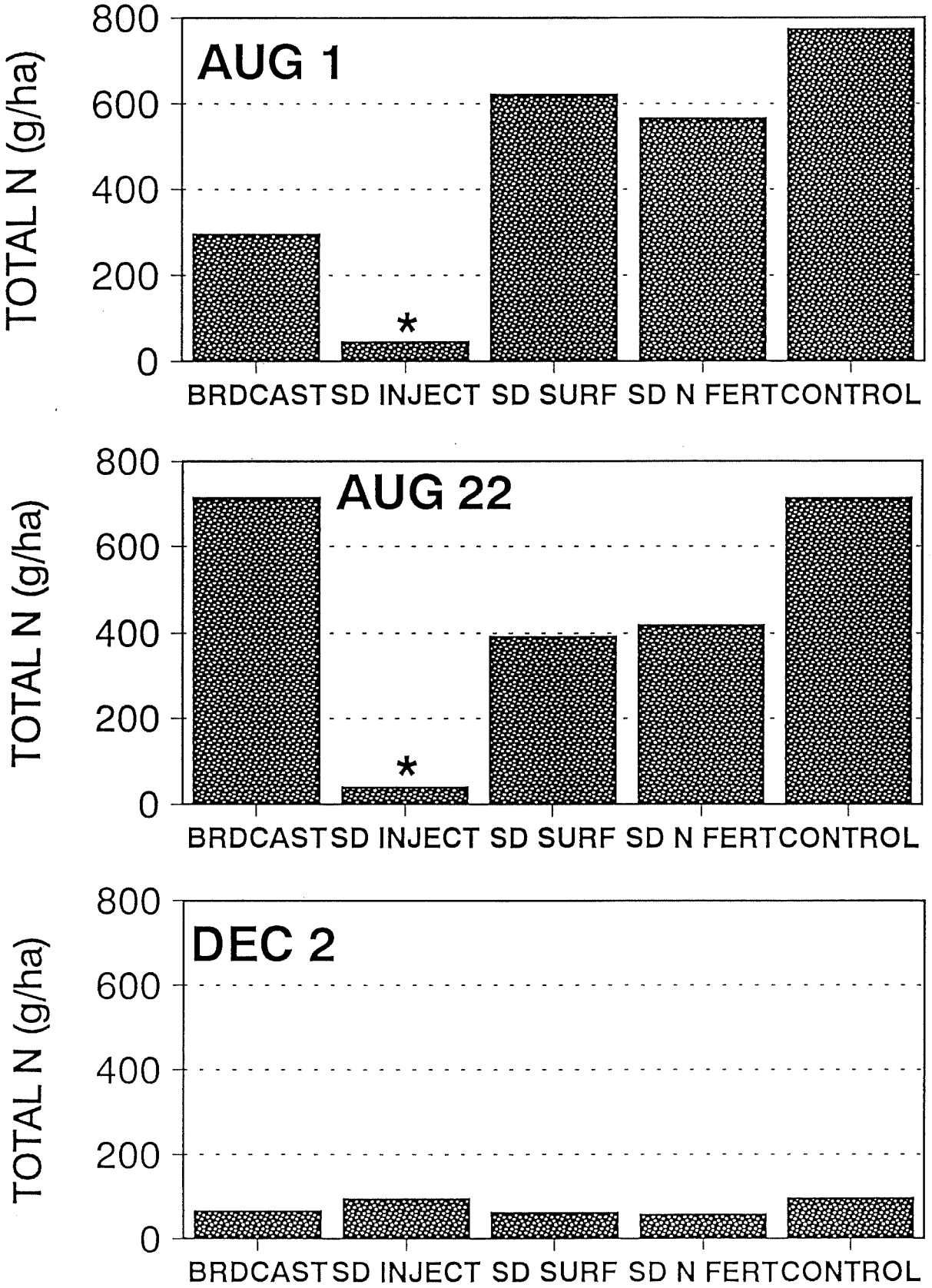


Fig. 25

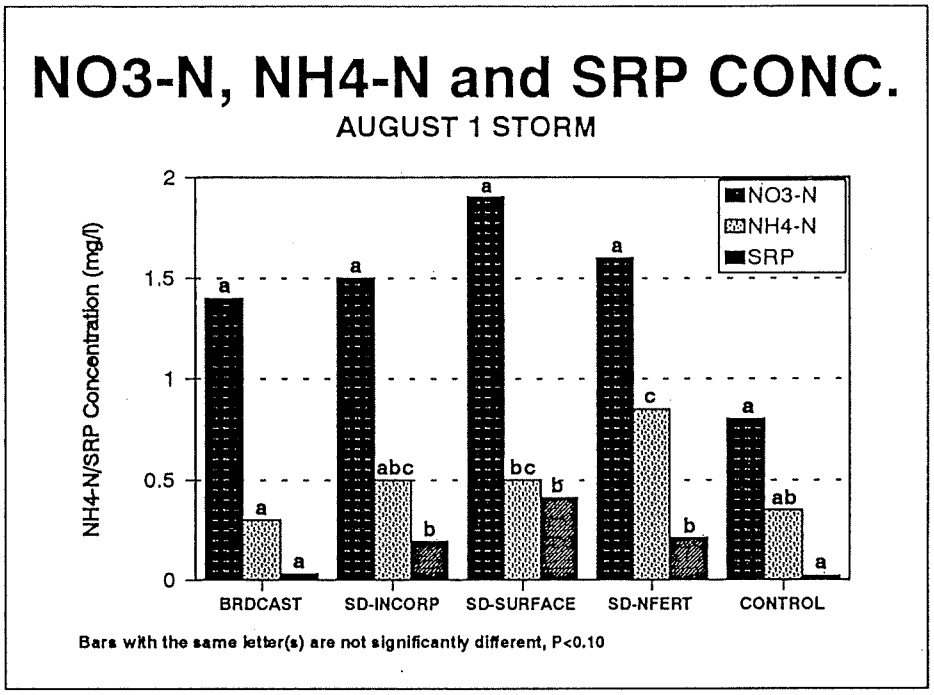

NO3-N, NH4-N and SRP CONC.
AUGUST 1 STORM
NH4-N/SRP Concentration (mg/l)
2
1.5
1
0.5
0
NO3-N
NH4-N
SRP
a
a
a
a
abc
b
a
bc
b
a
c
b
a
ab
a
BRDCAST
SD-INCORP
SD-SURFACE
SD-NFERT
CONTROL
Bars with the same letter(s) are not significantly different, P<0.10

Fig. 26

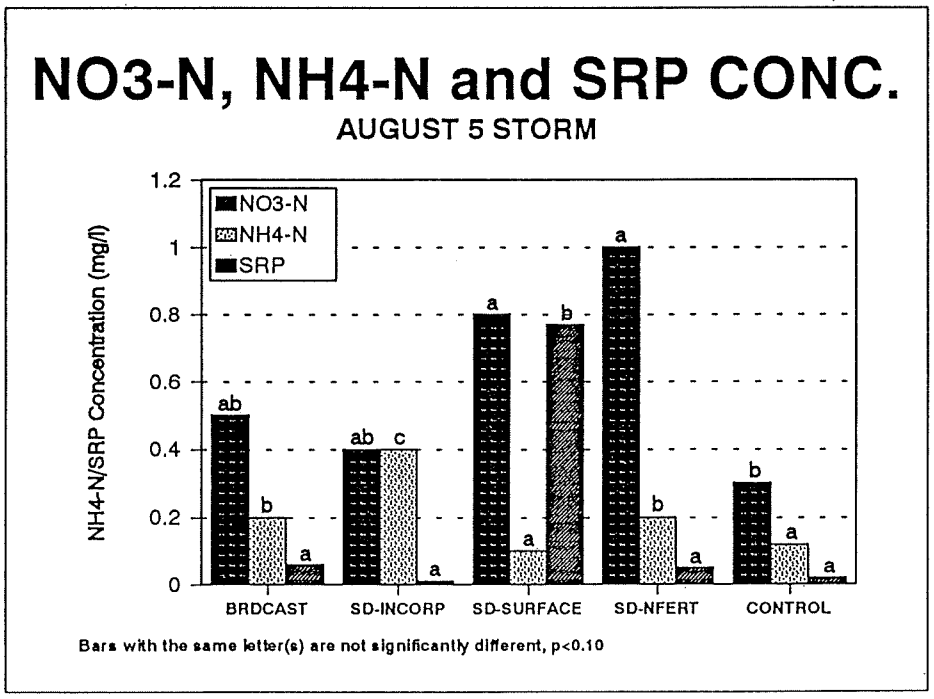

NO3-N, NH4-N and SRP CONC.
AUGUST 5 STORM
NH4-N/SRP Concentration (mg/l)
1.2
1
0.8
0.6
0.4
0.2
0
NO3-N
NH4-N
SRP
ab
b
a
ab
c
a
a
a
b
a
a
b
a
b
a
a
BRDCAST
SD-INCORP
SD-SURFACE
SD-NFERT
CONTROL
Bars with the same letter(s) are not significantly different, p<0.10

Fig. 27

significant rainfall events that occurred soon after treatment. Soluble nitrogen losses tended to be highest from the SD-NFERT treatment, where ammonium nitrate had been surface applied, while soluble phosphorus was significantly higher in runoff from the side-dress treatments, particularly from the SD-SURFACE, where manure had been surface applied. The fact that such differences in runoff concentrations disappeared suggests that, with time, the availability of soluble nutrients for runoff decreased with time, perhaps due to infiltration, plant uptake, soil adsorption, or, in the case of nitrogen, volatilization. The low NH_4-N concentration in runoff from the SD-SURFACE treatment may have been due to volatilization losses from the surface applied manure since the previous storm. It is worth noting that the next sizeable runoff event was more than two weeks later, allowing ample time for such processes to occur.

Nutrient Budgets

Field budgets were constructed for nitrogen, phosphorus, and potassium by comparing inputs from manure and fertilizer to removal via crop uptake and harvest and runoff losses (Tables 28, 29, and 30). For manure treatments, inputs of N were dominated by manure while inputs of P and K were more evenly divided between manure and fertilizer sources. Removal of all three nutrients was primarily by crop harvest as silage, runoff losses representing five percent or less of the total N and P removal in most cases (K in runoff was not measured). While runoff losses of P and N may be significant from a water quality perspective, they represent only a small portion of the nutrient budget of the fields.

Table 28. Nitrogen budget for Conant site, including change in soil NO_3-N in 4-ft profile. 1994.

	1 PP-BRDCST	2 SD-INCORP	3 SD-SURF	4 SD-NFERT	5 CONTROL
Inputs	lb N/acre				
Bdcst					
Starter Fert	20	20	20	20	20
SD Fert				65	
Manure	189	134	134		
Total	209	154	154	85	20
Removal					
Runoff	3	2	3	6	4
Uptake	123	120	96	108	83
Total	125	122	99	114	87
Net change (Inputs -Removal)	84	32	55	-29	-67
Soil NO_3-N, 0-4 ft, lb/acre					
May	69	61	63	63	61
Nov	60	54	45	72	41
Net Change	-9	-7	-19	9	-20

Table 29. Phosphorus budget for Conant site. 1994.

	1 PP-BRDCST	2 SD-INCORP	3 SD-SURF	4 SD-NFERT	5 CONTROL
Inputs	lb P_2O_5/acre				
Starter Fert	68	68	68	68	68
Manure	81	61	61		
Total	149	129	129	68	68
Removal					
Runoff	2	1	2	3	2
Uptake	56	54	46	48	41
Total	58	55	48	51	43
Net gain Inputs - Removal	91	74	81	17	25

Table 30. Potassium budget for Conant site. 1994.

	1 PP-BRDCST	2 SD-INCORP	3 SD-SURF	4 SD-NFERT	5 CONTROL
Inputs	lb K_2O/acre				
Bdcst	180	180	180	180	180
Manure	165	115	115		
Total	345	295	295	180	180
Outputs					
Runoff[1]	---	---	---	---	---
Uptake	135	123	105	113	85
Total	135	123	105	113	85
Net gain Inputs - Removal	210	172	190	67	95

[1]Not measured

The net change for N ranged from a +84 lb/acre for PP-BRDCST to -67 lb/acre for the CONTROL, primarily due to the large differences in inputs (Table 28). The N fertilizer treatment was also negative (-29 lb/acre), suggesting that this situation could not be maintained indefinitely without either depleting soil organic N or adding higher N fertilizer rates. One might expect a depletion in available N (NO_3-N) in the soil, but, on the contrary, the SD-NFERT treatment was the only one with an increase in profile over the growing season (Table 28). This is likely a function of greater efficiency of plant uptake of fertilizer N compared to manure N, especially when it is sidedressed.

The increase in N in the system was greater from the pre-plant manure than from the sidedress manure treatments because of the higher pre-plant application rate (189 vs 134 lb N/acre) with similar N uptake (Table 28). The 55 lb/acre N increase in the SD-SURF treatment is misleading because ammonia volatilization, probably quite substantial in this treatment, was not measured. However, the relatively low N uptake and soil NO_3 depletion similar to that in the CONTROL suggest that N was deficient and provide indirect evidence for NH3 volatilization. While the positive net change for the manure treatments might suggest that they have a greater potential for nitrate leaching the following winter, the higher amount of NO_3-N in the 4-ft profile from the N fertilizer treatment suggests an even greater leaching potential for the fertilizer treatment (Table 14 and Fig. 6). The possibility of greater mineralization from the manured plots, however, may contribute to increased leaching potential from those treatments.

The phosphorus budget (Table 29) showed a much greater increase where manure was applied, as would be expected, with the pre-plant treatment somewhat greater than the sidedress ones. This theoretically represents an increased potential for P runoff losses, however, soil analysis for available and reserve P showed higher values from both manured and N fertilized treatments compared to CONTROL (Table 12).

The potassium budget (Table 30) showed increases in the system over or approaching 200 lb/acre where manure was applied, while nonmanured treatment increases were less than 100 lb/acre. The SD-NFERT treatment had a lower net increase than the control because of the greater K uptake because of a higher yield. The fall K soil test results showed an increase over CONTROL (Table 12), but levels are still below optimum (Jokela, 1993).

VI. Farm Economics of Direct Incorporation Manure Methods

We used a partial budget analysis to evaluate the economic feasibility of using direct incorporation manure methods as compared to the more conventional method of spring broadcast. Partial budget analysis is useful in evaluating potential net gain/loss by estimating only those costs and incomes that are affected by the change in practice.

We assumed that all application costs (agitating, pumping, hauling, etc.) were the same for broadcast versus direct incorporated except for 1) differences in field time, 2) added costs of direct incorporated equipment, and 3) costs associated with incorporation following broadcast applications (ie., disking, chisel plowing, etc.). Therefore, only those costs were considered. However, there are many factors that can vary from farm to farm that need to be considered which are discussed below:

- Equipment Needs - This can vary depending on whether the farm only needs to retrofit incorporation implements to their present spreading equipment or if they need to purchase both the spreader and implements (i.e., they may not own any equipment if they are presently having their manure custom spread). In our analysis, we looked at a farm that presently spreads with their own equipment and retrofits direct incorporation equipment without any other requirements.

- Total acres will influence the fixed costs on a per acre basis. Our analysis comparing sidedress incorporation to spring broadcast is based on 100 acres of corn which is typical acreage for many dairy farms that grow corn in the Champlain Valley of Vermont and New York.

- The labor requirement at time of sidedress incorporation may be a problem on many farms. We assumed this not to be a problem for the 100 acres in our scenario.

- Crop nutrient requirement - In order to place a value on manure, we assumed that the land requires crop nutrients. This is an important consideration. Manure nutrients should not be credited when applied to fields requiring no additional nutrients.

We compared a conventional spring broadcast application of manure, incorporated with tillage, to one of two methods of direct incorporation -- sidedress with s-tine cultivators or use of concave covering disks (or sweep injectors) in the spring. While our use of non-sidedress direct incorporation in this project was limited to fall application with sweep injectors or covering disks, the same method would be suitable in the spring.

Partial Budget Analysis

Partial budget analysis assesses four factors when comparing a new practice to the conventional one: increased costs, reduced costs, increased income, decreased income.

Increased costs

Increased costs associated with direct incorporation were primarily associated with added labor and equipment. Table 31 compares the costs of two methods of direct incorporation to the conventional spring broadcast application. The difference in field capacity (acres/hour) show that labor requirements are far lower for spring broadcast compared to direct incorporation. This is primarily due to the difference in speed and the amount of coverage each method could do in a single pass.

We estimated field efficiency to be lower for the sidedress method because of the additional risk of emptying the spreader tank before coming to the end of the pass. This could result in either a part of the row not receiving any manure or an additional pass would have to be made. To avoid this risk, it is likely that some manure will be left in the tank between refills (Table 32) resulting in a lower field efficiency.

Direct incorporation equipment can range in purchase value from $3500 - $6500 depending on size and type of equipment. Values in Table 31 are typical. In addition, we added a $500 retrofitting charge although this may not be necessary for equipment made from the same manufacturer. With a five year depreciation and accounting for variable costs (labor, fuel, and lubricant), we estimate that the added cost of direct incorporation is between $12.50 and $13.80 per acre depending on type and size of equipment. For the net gain/loss analysis (Table 35), we used $13 per acre as a rounded figure for both methods.

Reduced Costs

Broadcast methods are usually followed by a separate operation such as disking or chisel plowing that incorporates the manure. Direct incorporation methods require no additional operations and, therefore, this cost could be considered a reduced cost. Typically disking or chisel plowing charges range from $5 to $10 per acre. If this is a normal secondary tillage operation regardless of manure incorporation, it should not be considered a reduced cost in this analysis.

Increased Income

Potential income is primarily from the savings of manure nutrients when using direct incorporation compared to broadcast methods. Potentially, a farmer could use less manure per acre by direct incorporation compared to broadcast since there is better utilization of nitrogen (Table 33). The difference is greatly influenced by the amount of time between broadcast spreading and actual incorporation. Typically, farmers incorporate sometime between one and three days; however, a three day delay

results in far less available nitrogen as indicated in Table 33.

With a lower manure requirement per acre when using direct incorporation, there are potential savings due to increased efficiency in manure nutrient use (Table 34). The manure nutrients saved could be applied to other acreage in need of nutrients, potentially resulting in reduced fertilizer costs. For corn with typical nutrient needs when the soil is at a medium test for P and K, our estimate of savings range from $11 to $80 per acre depending on method and timing of application.

Reduced Income

We are assuming no reduction in income as a result of direct incorporation. We have found no evidence of yield reduction as long as adequate amounts of manure nutrients are applied.

Table 31. Width, speed, field capacity and annual costs of direct incorporation and broadcast methods of liquid manure application on 100 acres of corn.

		Direct Incorporation Methods			
		Sidedress		Spring/Fall	
	Spring	S-Tine Cultivator		Concave Disc	
	Broadcast	4 Row	6 Row	10 Ft.	15 Ft.
Application Width, ft.	40	10	15	10	15
Speed, mph	6	4.5	4.5	5	5
Field Efficiency, %	70%	60%	60%	70%	70%
Field capacity, acres/hour	20.4	3.3	4.9	4.2	6.4
Total field time, hrs/yr	5	31	20	24	16
Purchase Cost, $	n/a	$4,000	$5,200	$5,000	$6,000
Depreciation, years	n/a	5	5	5	5
Retrofitting cost, $	n/a	$500	$500	$500	$500
Annual Cost, $/year	n/a	$836	$1,057	$1,020	$1,204
Labor, $/hr	$12	$12	$12	$12	$12
Fuel and lubricant, $/hr	$4.30	$4.30	$4.30	$4.30	$4.30
Annual cost, $/a for 100 acres					
Implement cost, $/a	0	8.36	10.57	10.20	12.04
Fuel and Lubricant, $/a	0.21	1.31	0.88	1.02	0.68
Labor, $/a	0.59	3.67	2.44	2.83	1.89
Total Annual Cost, $/a	$0.80	$13.34	$13.89	$14.04	$14.60
Added Annual Cost, $/a		$12.54	$13.09	$13.24	$13.80

Net Gain or Loss

Net gain/loss is the difference between increased income plus reduced costs minus the increased costs and reduced income. When comparing spring broadcast to spring direct incorporation, we found a net gain/loss ranging from -$2 to $57 per acre, and when compared to direct incorporation at sidedress, we found a net gain ranging from $12 to $66 (Table 35). The large range in values are dependent on whether or not broadcast incorporation charges are considered and if incorporation following spring broadcast is within one or three days. If a farmer can consistently incorporate within a day of broadcast application, there is far less economic benefit to the direct incorporation methods, particularly when comparing spring broadcast to spring direct incorporated. However, this is difficult to achieve on many farms and direct incorporation might be a viable option.

We conclude that direct incorporation for applying liquid manure can be a cost effective practice provided the farmer can properly utilize the savings in manure nutrients that resulted from this method. This will require sound nutrient management planning and accurate application rates.

Table 32. Row feet and number of passes required based on spreader capacity and spreading width at three application rates of liquid manure.

Spreader Capacity	Implement Width	Application Rate	Row Feet	No. of Passes (Down and Back) Length of Row (ft) 200	500	1000
gallons	ft	gal/a	ft			
3300	10	3500	4107	10.3	4.1	2.1
3300	10	5000	2875	7.2	2.9	1.4
3300	10	6500	2212	5.5	2.2	1.1
3300	15	3500	2738	6.8	2.7	1.4
3300	15	5000	1917	4.8	1.9	1.0
3300	15	6500	1474	3.7	1.5	0.7
5000	10	3500	6223	15.6	6.2	3.1
5000	10	5000	4356	10.9	4.4	2.2
5000	10	6500	3351	8.4	3.4	1.7
5000	15	3500	4149	10.4	4.1	2.1
5000	15	5000	2904	7.3	2.9	1.5
5000	15	6500	2234	5.6	2.2	1.1

Table 33. The effects of application method and timing of incorporation on available nitrogen, recommended manure application rate, and available P_2O_5 and K_2O applied to corn with typical fertility needs.*

Method	Time of Incorporation	Avail. N	Manure Rate	Available Nutrients P_2O_5	K_2O
	days	lbs/1000 g	gal/acre	lbs/acre	lbs/acre
Spring Broadcast	3	7.4	13,500	162	297
Spring Broadcast	1	11.6	8,600	103	189
Spring Direct	Direct	13.4	7,500	90	165
Sidedress	Direct	15.8	6,300	76	139
Sidedress	Direct	15.8	6,300	76	139

*Corn fertilizer needs (lbs/acre) are 100 N, 60 P_2O_5, and 120 K_2O.
*Manure analysis (lb/1000 gal.): 24 total N, 12 Amm. N, 12 P_2O_5, 22 K_2O.

Table 34. Nutrient difference and potential cost savings from sidedress direct incorporated compared to spring broadcast manure applications incorporated one and three days after application.

		Days to Incorporation of Spring Broadcast			
		1 day	3 days	1 day	3 days
Method	Nutrient	Nutrient Amount		Nutrient Value*	
		lbs/a	lbs/a	$/a	$/a
Spring Direct	N	15	80	4.42	24.12
Incorporated	P_2O_5	13	72	3.25	18.00
	K_2O	24	132	3.60	19.80
Total Value				$11.27	$61.92
Sidedress	N	36	114	10.90	34.13
Incorporated	P_2O_5	27	86	6.75	21.50
	K_2O	50	158	7.50	23.70
Total Value				$25.15	$79.33

*Based on fertilizer value ($/lb) of $0.30 N, $0.25 P_2O_5, and $0.15 K_2O.

Table 35. The net gain/loss of direct incorporated at sidedress compared to spring broadcast methods of liquid manure applications.

Time and Method	Broadcast Incorporation Change	Time of Broadcast Incorporation	Increased Income	Increased Costs	Reduced Costs	Net Gain/Loss
		days	$	$	$	$
Spring Direct	Yes	1	11	13	8	6
Incorporated	Yes	3	62	13	8	57
	No	1	11	13	0	(2)
	No	3	62	13	0	49
Sidedress	Yes	1	25	13	8	20
Direct	Yes	3	79	13	8	74
Incorporated	No	1	25	13	0	12
	No	3	79	13	0	66

VI. Summary and Conclusions

- Injection, or direct incorporation, methods were demonstrated and evaluated with a 1500-gallon slurry tank spreader, equipped with either shallow sweep injectors or with s-tine cultivators or paired covering disks which incorporated the manure into the soil as it was applied to the ground. Use of the equipment was successfully demonstrated for sidedress or fall application on cornland on six dairy farms in the Champlain Valley of Vermont and New York, including several field meetings attended by about 60 people.

- At the demonstration sites, soil testing (including PSNT for sidedress sites) and manure analysis were combined with optimum rate, timing, and method of manure application as part of a complete nutrient management package.

- Other educational and public activities, in addition to the field demonstrations, included presentations at several extension and LCBP meetings in Vermont and New York using slides and videotaped material prepared in this project, presentations at two major conferences in New York, TV coverage, and press release and newsletter articles.

- The intensive replicated field strip trial compared sidedressed liquid dairy manure, either directly incorporated with s-tine cultivators (SD-INCORP) or left on the surface (SD-SURF), with sidedressed nitrogen fertilizer (SD-NFERT), pre-plant broadcast manure incorporated with a harrow (PP-BRDCST), and a no-nitrogen control. There were no significant silage yield differences among the nutrient application treatments. However, a trend, supported by significant N uptake differences, showed highest yields from the pre-plant and sidedress incorporated manure and N fertilizer and lower yields from the surface manure and control.

- The potential for overwinter nitrate leaching, as indicated by the concentration of NO_3-N present in the 4-foot soil profile in November, appears to be greatest from the N fertilizer treatment and slightly greater for the pre-plant than the sidedress incorporated manure. None of the treatments show indications of leaching at the time of the fall sampling.

- The principal water quality effect was a significant reduction of runoff from the sidedressed incorporated manure treatment and a consequent decrease in export of phosphorus and nitrogen. Runoff losses of P and N from the sidedress-incorporated treatment were significantly lower than from any of the other treatments, including the control; a total of just 55 g/ha total P and 250 g/ha total N were lost from the sidedress-incorporated treatment, compared to 300-400 g/ha TP and 1300-2000 g/ha TN lost from the other treatments. This effect is probably due primarily to the loosening of the soil by the s-tine tillage, resulting in increased infiltration of rainfall and, therefore, less surface runoff. This effect was not

observed prior to the sidedress application and disappeared late in the season after harvest.

- Nutrient concentrations in runoff were not a direct function of precipitation quantity or runoff volume, but appeared to be generally related to the timing of storms relative to the application of nutrients. Although major storms did yield elevated phosphorus and nitrogen concentrations, there was a general trend toward decreasing runoff nutrient concentrations with time after treatment. Levels of P and N in runoff from the side-dress incorporated treatment did not show this pattern, but yielded low nutrient concentrations throughout the growing season until the post-harvest storms.

- While in general, nutrient concentrations in runoff did not vary significantly between treatments, some significant differences were noted for soluble nutrients in runoff from large storms that occurred soon after nutrient application. In these storms, soluble P and N concentrations tended to be higher in runoff from side-dress treatments, with soluble phosphorus particularly high in runoff from the manure side-dress surface applied treatment and soluble nitrogen concentrations elevated in runoff from the sidedress N fertilizer treatment. These effects were not apparent in later storms, possibly because of reduced nutrient availability due to infiltration, adsorption, or uptake in the intervening time.

- Variability among plots/runoff collectors was very high for most variables considered in this study. This variability severely reduced the statistical sensitivity of the study. If the treatments are investigated further, efforts should be made to reduce the variability in order to resolve some of the statistically non-significant, but highly suggestive results of this study.

- Nutrient budgets for the replicated trial showed that direct-incorporated sidedressed manure decreased the net P and N loading to the field, compared to conventional spring broadcast manure. This was primarily because a lower rate was needed, as indicated by the Pre-sidedress Nitrate Soil Test, because of the immediate incorporation and more efficient timing of application. Only a small portion of the applied nutrients, generally less than 2% for the manure treatments, were lost in surface runoff. It also represented only a small portion of the total amount of nutrients removed from the field, crop uptake removed as silage being the dominant mechanism.

- A partial budget economic analysis suggests a net gain in farm income for sidedress-incorporated manure application compared to spring broadcast, despite higher application costs. This analysis assumes the farm has adequate land that needs the nutrients gained by more efficient application methods. Highest net returns were estimated in comparison to broadcast manure with delayed incorporation.

- Based on the results of this preliminary study, sidedressed manure with direct incorporation appears to be a viable option for applying liquid manure to silage corn in the Champlain Valley. Corn yields were maintained, runoff losses of nutrients were minimized, and modest net gains in farm income were projected. Other expected benefits would be odor control and mechanical weed control. However, because of the short-term (one-year) nature and high variability encountered in the study, additional work should be conducted before the practice can be fully recommended.

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VIII. Appendix

A. Water quality from runoff collectors

B. "Manure injection part of the pollution puzzle". *Impact*. Fall, 1994.

APPENDIX A
WATER QUALITY DATA FROM RUNOFF COLLECTORS

STORM DATE	T*	PLT #	VOL** (l)	[TP]	[TN]	[NO3N]	[NH4N]	[SRP]	TPX	TNX	NO3X	NH4X	SRPX
					-------(mg/l)--------					-------(g/ha)------			
940701	1	101	0.06	2.5	-9	-9	-9	-9.00	0.4	-9	-9	-9	-9
940701	1	201	0.12	1.7	8	1.7	0.05	0.11	0.5	2.4	0.5	0.0	0.0
940701	1	303	0.04	0.2	-9	-9	-9	-9.00	0.0	-9	-9	-9	-9
940701	1	405	0.03	3.3	-9	-9	-9	-9.00	0.2	-9	-9	-9	-9
940701	2	103	0.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940701	2	202	-9.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940701	2	302	0.20	5.1	27	1.2	0.5	0.04	2.6	13.6	0.6	0.3	0.0
940701	2	404	0.20	3.9	51	1.3	1.1	0.14	2.0	25.7	0.7	0.6	0.1
940701	3	102	0.28	4.7	16	1	0.5	0.16	3.3	11.3	0.7	0.4	0.1
940701	3	204	0.21	4.1	21	3	0.6	0.06	2.2	11.1	1.6	0.3	0.0
940701	3	305	0.06	4.5	-9	-9	-9	0.52	0.7	-9	-9	-9	0.1
940701	3	403	0.20	9.2	24	2	0.4	0.20	4.6	12.1	1.0	0.2	0.1
940701	4	105	0.75	4.3	18	1	0.3	0.02	8.1	34.0	1.9	0.6	0.0
940701	4	203	0.19	7	27	1.4	0.5	0.03	3.4	12.9	0.7	0.2	0.0
940701	4	304	0.01	1	-9	-9	-9	-9.00	0.0	-9	-9	-9	-9
940701	4	402	0.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940701	5	104	0.27	6.3	23	1.2	0.2	0.09	4.3	15.7	0.8	0.1	0.1
940701	5	205	0.17	5.1	26	1.2	0.3	0.20	2.2	11.1	0.5	0.1	0.1
940701	5	301	0.09	5.7	24	-9	-9	0.62	1.3	5.4	-9	-9	0.1
940701	5	401	0.03	1.3	-9	-9	-9	-9.00	0.1	-9	-9	-9	-9
940708	1	101	0.17	5.6	21	4.1	0.4	0.03	2.4	9.0	1.8	0.2	0.0
940708	1	201	0.26	2.4	13	11.8	0.4	0.01	1.6	8.5	7.7	0.3	0.0
940708	1	303	0.06	1.4	-9	-9	-9	0.04	0.2	-9	-9	-9	0.0
940708	1	405	0.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940708	2	103	0.13	3.8	18	2.3	0.4	0.01	1.2	5.9	0.8	0.1	0.0
940708	2	202	-9.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940708	2	302	0.64	3.1	19	4.6	0.7	0.01	5.0	30.7	7.4	1.1	0.0
940708	2	404	0.27	0.7	8	6	0.5	0.03	0.5	5.4	4.1	0.3	0.0
940708	3	102	0.78	7.1	35	2.6	0.8	0.04	14.0	68.8	5.1	1.6	0.1
940708	3	204	0.87	3.1	19	4.3	0.3	0.04	6.8	41.7	9.4	0.7	0.1
940708	3	305	0.21	2.8	32	2.6	0.1	0.02	1.5	16.9	1.4	0.1	0.0
940708	3	403	0.64	1.8	14	5.9	0.5	0.01	2.9	22.6	9.5	0.8	0.0
940708	4	105	0.65	2.2	12	1.5	0.2	0.02	3.6	19.7	2.5	0.3	0.0
940708	4	203	1.45	4	23	7.7	0.9	0.04	14.6	84.1	28.2	3.3	0.1
940708	4	304	0.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940708	4	402	0.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940708	5	104	0.61	5	26	3.6	0.6	0.01	7.7	40.0	5.5	0.9	0.0
940708	5	205	0.77	2.9	21	4.6	0.2	0.04	5.6	40.8	8.9	0.4	0.1
940708	5	301	0.18	6.3	20	4	0.4	0.03	2.9	9.1	1.8	0.2	0.0
940708	5	401	0.21	4.4	24	2.6	0.3	0.03	2.3	12.7	1.4	0.2	0.0
940710	1	101	7.74	22.1	150	9.6	0.8	0.14	431.4	2927.9	187.4	15.6	2.7
940710	1	201	8.00	30.1	90	16.3	0.8	0.10	607.3	1815.8	328.9	16.1	2.0
940710	1	303	10.50	16.4	17	11.4	0.5	0.03	434.3	450.2	301.9	13.2	0.8
940710	1	405	2.25	15.5	62	13.2	0.7	0.05	88.0	351.8	74.9	4.0	0.3

APPENDIX A
WATER QUALITY DATA FROM RUNOFF COLLECTORS

STORM DATE	T*	PLT #	VOL** (l)	[TP]	[TN]	[NO3N]	[NH4N]	[SRP]	TPX	TNX	NO3X	NH4X	SRPX
					-------(mg/l)--------					-------(g/ha)------			
940710	2	103	8.75	44.8	138	3.8	0.5	0.04	988.6	3045.2	83.9	11.0	0.9
940710	2	202	-9.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940710	2	302	9.50	14.6	43	4.6	0.5	0.03	349.8	1030.2	110.2	12.0	0.7
940710	2	404	9.00	22.5	88	6.3	0.6	0.03	510.7	1997.3	143.0	13.6	0.7
940710	3	102	8.25	27.5	63	5.5	0.7	0.19	572.2	1310.7	114.4	14.6	4.0
940710	3	204	8.75	17.4	54	10	0.6	0.03	384.0	1191.6	220.7	13.2	0.7
940710	3	305	9.00	33.1	98	2.8	0.8	0.40	751.3	2224.3	63.6	18.2	9.1
940710	3	403	8.50	23.9	98	7.3	1.5	0.04	512.3	2100.7	156.5	32.2	0.9
940710	4	105	6.00	31.1	81	5.1	1	0.10	470.6	1225.6	77.2	15.1	1.5
940710	4	203	9.52	45.5	139	6.8	1.7	0.10	1092.4	3337.1	163.3	40.8	2.4
940710	4	304	9.74	73.5	333	0.1	2.8	0.09	1805.4	8179.5	2.5	68.8	2.2
940710	4	402	0.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940710	5	104	8.75	35.1	88	4.5	0.9	0.06	774.5	1941.8	99.3	19.9	1.3
940710	5	205	9.00	19.4	71	5.3	0.7	0.05	440.3	1611.5	120.3	15.9	1.1
940710	5	301	12.25	11.2	37	2.6	0.7	0.08	346.0	1143.0	80.3	21.6	2.5
940710	5	401	10.00	25.8	89	2.4	0.8	0.09	650.6	2244.5	60.5	20.2	2.3
940725	1	101	0.94	3.6	13	2.2	0.2	0.28	8.5	30.8	5.2	0.5	0.7
940725	1	201	0.86	1.6	11	2.2	5	0.10	3.5	23.9	4.8	10.8	0.2
940725	1	303	0.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940725	1	405	0.02	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940725	2	103	0.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940725	2	202	-9.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940725	2	302	0.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940725	2	404	0.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940725	3	102	0.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940725	3	204	1.18	3.2	8	8.9	2	0.58	9.5	23.8	26.5	6.0	1.7
940725	3	305	0.24	3.1	15	1.5	2.1	0.84	1.9	9.1	0.9	1.3	0.5
940725	3	403	1.00	0.8	8	6.8	1.7	0.42	2.0	20.2	17.1	4.3	1.1
940725	4	105	1.34	1	12	4.5	2.8	0.01	3.4	40.6	15.2	9.5	0.0
940725	4	203	3.36	1.5	10	13.1	3.4	0.01	12.7	84.7	111.0	28.8	0.1
940725	4	304	0.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940725	4	402	0.82	2.4	12	2.6	5.7	0.20	5.0	24.8	5.4	11.8	0.4
940725	5	104	0.11	2.1	31	0.9	0.7	1.00	0.6	8.6	0.2	0.2	0.3
940725	5	205	1.16	1.6	7	0.4	0.8	0.02	4.7	20.5	1.2	2.3	0.1
940725	5	301	1.05	3.7	15	0.9	1.4	0.34	9.8	39.7	2.4	3.7	0.9
940725	5	401	1.72	4.3	11	0.7	0.5	0.08	18.7	47.7	3.0	2.2	0.3
940726	1	101	0.19	1.3	6	2.3	0.7	0.01	0.6	2.9	1.1	0.3	0.0
940726	1	201	0.06	0.6	9	-9	-9	0.32	0.1	1.4	-9	-9	0.0
940726	1	303	0.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940726	1	405	0.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940726	2	103	0.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940726	2	202	-9.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940726	2	302	0.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940726	2	404	0.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9

APPENDIX A
WATER QUALITY DATA FROM RUNOFF COLLECTORS

STORM DATE	T*	PLT #	VOL** (l)	[TP]	[TN]	[NO3N]	[NH4N]	[SRP]	TPX	TNX	NO3X	NH4X	SRPX
					-------(mg/l)--------					-------(g/ha)------			
940726	3	102	0.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940726	3	204	0.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940726	3	305	0.05	1.3	-9	1.5	-9	0.48	0.2	-9	0.2	-9	0.1
940726	3	403	0.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940726	4	105	0.11	0.8	11	9.7	2.7	0.01	0.2	3.1	2.7	0.7	0.0
940726	4	203	0.25	1.4	6	27.2	2.3	0.01	0.9	3.8	17.1	1.5	0.0
940726	4	304	0.02	-9	-9	-9	-9	3.38	-9	-9	-9	-9	0.2
940726	4	402	0.03	0.7	-9	-9	-9	0.12	0.1	-9	-9	-9	0.0
940726	5	104	0.07	1.3	14	2.5	1.8	0.01	0.2	2.5	0.4	0.3	0.0
940726	5	205	0.21	1.2	8	0.6	1	0.01	0.6	4.2	0.3	0.5	0.0
940726	5	301	0.02	-9	-9	-9	-9	0.52	-9	-9	-9	-9	0.0
940726	5	401	0.08	3.4	9	1.2	0.1	0.06	0.7	1.8	0.2	0.0	0.0
940801	1	101	17.25	1	27	2.3	0.4	0.12	43.5	1174.6	100.1	17.4	5.2
940801	1	201	7.75	3.1	3	1.2	0.3	0.01	60.6	58.6	23.5	5.9	0.2
940801	1	303	17.75	1.8	6	1.4	0.2	0.04	80.6	268.6	62.7	9.0	1.8
940801	1	405	17.75	2.6	9	1	0.3	0.01	116.4	402.9	44.8	13.4	0.4
940801	2	103	1.35	1.6	6	0.4	0.2	0.40	5.4	20.4	1.4	0.7	1.4
940801	2	202	-9.00	-9.0	-9.0	-9.00	-9.00	-9.00	-9	-9	-9	-9	-9
940801	2	302	1.24	0.3	11	1.4	0.7	0.12	0.9	34.4	4.4	2.2	0.4
940801	2	404	4.25	3	12	5.6	0.9	0.14	32.2	128.6	60.0	9.6	1.5
940801	3	102	16.25	5.6	15	2.4	0.5	0.36	229.5	614.7	98.4	20.5	14.8
940801	3	204	21.25	0.5	12	2.5	0.5	0.40	26.8	643.1	134.0	26.8	21.4
940801	3	305	19.25	5.9	16	1.4	0.6	0.34	286.4	776.7	68.0	29.1	16.5
940801	3	403	19.25	4.2	10	1.6	0.5	0.60	203.9	485.5	77.7	24.3	29.1
940801	4	105	15.75	1	38	2.3	0.6	0.32	39.7	1509.3	91.4	23.8	12.7
940801	4	203	14.25	0.6	19	4	0.6	0.80	21.6	682.8	143.7	21.6	28.7
940801	4	304	13.25	4.5	12	1.1	1.6	0.20	150.4	401.0	36.8	53.5	6.7
940801	4	402	8.25	4.3	12	0.6	0.9	0.04	89.5	249.7	12.5	18.7	0.8
940801	5	104	17.75	0.7	20	1.4	0.3	0.18	31.3	895.3	62.7	13.4	8.1
940801	5	205	18.75	0.5	15	0.6	0.4	0.02	23.6	709.3	28.4	18.9	0.9
940801	5	301	18.25	0.6	18	0.7	0.3	0.01	27.6	828.4	32.2	13.8	0.5
940801	5	401	15.75	6	17	0.7	0.4	0.01	238.3	675.2	27.8	15.9	0.4
940805	1	101	5.75	1.6	5	0.9	0.2	0.66	23.2	72.5	13.1	2.9	9.6
940805	1	201	6.25	1	7	0.8	0.2	0.24	15.8	110.3	12.6	3.2	3.8
940805	1	303	3.75	0.7	3	0.2	0.2	0.01	6.6	28.4	1.9	1.9	0.1
940805	1	405	2.25	0.8	4	0.5	0.2	0.01	4.5	22.7	2.8	1.1	0.1
940805	2	103	0.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940805	2	202	-9.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940805	2	302	0.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940805	2	404	8.25	0.3	-9	0.4	0.4	0.01	6.2	-9	8.3	8.3	0.2
940805	3	102	3.25	1.4	3	1	0.1	0.56	11.5	24.6	8.2	0.8	4.6
940805	3	204	7.25	1.2	3	0.6	0.1	0.66	21.9	54.9	11.0	1.8	12.1
940805	3	305	5.25	1.5	5	0.5	0.1	0.90	19.9	66.2	6.6	1.3	11.9
940805	3	403	3.75	1.6	5	1.2	0.1	1.06	15.1	47.3	11.3	0.9	10.0

APPENDIX A
WATER QUALITY DATA FROM RUNOFF COLLECTORS

STORM DATE	T*	PLT #	VOL** (l)	[TP]	[TN]	[NO3N]	[NH4N]	[SRP]	TPX	TNX	NO3X	NH4X	SRPX
					-------(mg/l)--------					-------(g/ha)------			
940805	4	105	20.75	7.7	18	0.7	0.2	0.01	402.9	941.9	36.6	10.5	0.5
940805	4	203	13.75	1.5	8	1.6	0.2	0.30	52.0	277.4	55.5	6.9	10.4
940805	4	304	3.75	0.6	5	1.1	0.2	0.24	5.7	47.3	10.4	1.9	2.3
940805	4	402	11.75	0.8	5	0.7	0.4	0.01	23.7	148.2	20.7	11.9	0.3
940805	5	104	12.25	6.7	17	0.7	0.1	0.38	207.0	525.2	21.6	3.1	11.7
940805	5	205	11.50	0.8	9	0.2	0.1	0.01	23.2	261.0	5.8	2.9	0.3
940805	5	301	7.25	0.6	3	0.3	0.2	0.01	11.0	54.9	5.5	3.7	0.2
940805	5	401	16.25	0.7	4	0.3	0.1	0.01	28.7	163.9	12.3	4.1	0.4
940815	1	101	2.75	1.1	6	0.2	0.2	-9.00	7.6	41.6	1.4	1.4	-9
940815	1	201	0.65	0.4	3	0.2	0.6	-9.00	0.7	4.9	0.3	1.0	-9
940815	1	303	0.16	0.5	5	0.3	0.4	-9.00	0.2	2.0	0.1	0.2	-9
940815	1	405	1.50	1.6	7	0.05	0.3	-9.00	6.1	26.5	0.2	1.1	-9
940815	2	103	0.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940815	2	202	-9.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940815	2	302	0.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940815	2	404	0.04	1.2	-9	11.5	0.3	-9.00	0.1	-9	1.2	0.0	-9
940815	3	102	0.55	1	4	0.3	0.3	-9.00	1.4	5.5	0.4	0.4	-9
940815	3	204	1.25	1.1	6	0.2	0.6	-9.00	3.5	18.9	0.6	1.9	-9
940815	3	305	1.00	1	5	0.1	0.3	-9.00	2.5	12.6	0.3	0.8	-9
940815	3	403	1.25	0.7	5	0.05	0.2	-9.00	2.2	15.8	0.2	0.6	-9
940815	4	105	4.75	1.4	8	0.4	0.6	-9.00	16.8	95.8	4.8	7.2	-9
940815	4	203	4.25	0.6	7	1.1	0.7	-9.00	6.4	75.0	11.8	7.5	-9
940815	4	304	0.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940815	4	402	1.25	1	6	0.6	0.5	-9.00	3.2	18.9	1.9	1.6	-9
940815	5	104	1.75	1.1	6	0.1	0.7	-9.00	4.9	26.5	0.4	3.1	-9
940815	5	205	7.75	0.9	5	0.1	0.4	-9.00	17.6	97.7	2.0	7.8	-9
940815	5	301	3.75	1	5	0.1	0.2	-9.00	9.5	47.3	0.9	1.9	-9
940815	5	401	4.75	0.6	4	0.1	0.3	-9.00	7.2	47.9	1.2	3.6	-9
940819	1	101	0.52	0.3	3	0.3	0.3	-9.00	0.4	3.9	0.4	0.4	-9
940819	1	201	0.18	0.2	3	0.1	0.5	-9.00	0.1	1.4	0.0	0.2	-9
940819	1	303	0.16	0.3	3	0.1	0.7	-9.00	0.1	1.2	0.0	0.3	-9
940819	1	405	0.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940819	2	103	0.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940819	2	202	-9.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940819	2	302	0.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940819	2	404	0.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940819	3	102	0.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940819	3	204	0.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940819	3	305	0.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940819	3	403	0.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940819	4	105	0.75	0.2	2	0.1	0.4	-9.00	0.4	3.8	0.2	0.8	-9
940819	4	203	1.05	0.2	4	0.4	0.4	-9.00	0.5	10.6	1.1	1.1	-9
940819	4	304	0.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940819	4	402	0.06	0.6	-9	3.4	0.1	-9.00	0.1	-9	0.5	0.0	-9

APPENDIX A
WATER QUALITY DATA FROM RUNOFF COLLECTORS

STORM DATE	T*	PLT #	VOL** (l)	[TP]	[TN]	[NO3N]	[NH4N]	[SRP]	TPX	TNX	NO3X	NH4X	SRPX
					-------(mg/l)--------					-------(g/ha)------			
940819	5	104	0.65	0.3	2	0.1	0.4	-9.00	0.5	3.3	0.2	0.7	-9
940819	5	205	0.60	0.05	2	0.1	0.2	-9.00	0.1	3.0	0.2	0.3	-9
940819	5	301	0.24	0.1	2	0.1	0.5	-9.00	0.1	1.2	0.1	0.3	-9
940819	5	401	0.46	0.2	2	0.1	0.4	-9.00	0.2	2.3	0.1	0.5	-9
940822	1	101	11.75	5.4	21	0.7	0.8	0.22	160.0	622.3	20.7	23.7	6.5
940822	1	201	12.25	5.4	17	0.6	0.7	0.16	166.8	525.2	18.5	21.6	4.9
940822	1	303	12.25	8.2	33	0.4	0.8	0.10	253.3	1019.5	12.4	24.7	3.1
940822	1	405	23.75	3.4	13	0.3	0.5	0.13	203.6	778.6	18.0	29.9	7.8
940822	2	103	0.50	0.4	4	0.5	0.2	0.07	0.5	5.0	0.6	0.3	0.1
940822	2	202	-9.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940822	2	302	5.25	3.6	12	0.5	0.6	0.13	47.7	158.9	6.6	7.9	1.7
940822	2	404	3.25	2.9	10	1.8	0.4	0.11	23.8	82.0	14.8	3.3	0.9
940822	3	102	14.25	3.9	10	0.6	0.4	0.59	140.2	359.4	21.6	14.4	21.2
940822	3	204	15.75	2.1	7	0.5	0.5	0.51	83.4	278.0	19.9	19.9	20.3
940822	3	305	23.25	2.8	9	2	0.4	0.54	164.2	527.7	117.3	23.5	31.7
940822	3	403	21.75	3	8	0.6	0.4	0.51	164.6	438.8	32.9	21.9	28.0
940822	4	105	9.75	8.3	29	0.3	0.7	0.05	204.1	713.1	7.4	17.2	1.2
940822	4	203	12.25	8.5	27	0.3	0.7	0.18	262.6	834.1	9.3	21.6	5.6
940822	4	304	16.75	2.9	10	14.1	0.8	0.25	122.5	422.4	595.6	33.8	10.6
940822	4	402	4.75	2.6	10	0.6	0.8	0.18	31.1	119.8	7.2	9.6	2.2
940822	5	104	12.25	7.4	29	0.4	0.7	0.09	228.6	895.9	12.4	21.6	2.8
940822	5	205	11.75	4.1	17	0.2	0.6	0.16	121.5	503.7	5.9	17.8	4.7
940822	5	301	12.75	6.5	21	0.3	0.6	0.13	209.0	675.2	9.6	19.3	4.2
940822	5	401	11.25	6.7	30	0.2	0.9	0.13	190.1	851.1	5.7	25.5	3.7
940916	1	101	1.25	1	5	-9	-9	-9.00	3.2	15.8	-9	-9	-9
940916	1	201	0.75	1.5	8	-9	-9	-9.00	2.8	15.1	-9	-9	-9
940916	1	303	8.25	2.7	8	-9	-9	-9.00	56.2	166.4	-9	-9	-9
940916	1	405	1.75	1.3	5	-9	-9	-9.00	5.7	22.1	-9	-9	-9
940916	2	103	0.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940916	2	202	-9.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940916	2	302	0.00	-9	-9	-9	-9	-9.00	-9	-9	-9	-9	-9
940916	2	404	0.07	-9	7	-9	-9	-9.00	-9	1.2	-9	-9	-9
940916	3	102	0.35	2	8	-9	-9	-9.00	1.8	7.1	-9	-9	-9
940916	3	204	0.14	1.6	10	-9	-9	-9.00	0.6	3.5	-9	-9	-9
940916	3	305	6.75	1	3	-9	-9	-9.00	17.0	51.1	-9	-9	-9
940916	3	403	0.35	1.3	4	-9	-9	-9.00	1.1	3.5	-9	-9	-9
940916	4	105	4.25	1	4	-9	-9	-9.00	10.7	42.9	-9	-9	-9
940916	4	203	6.25	2	6	-9	-9	-9.00	31.5	94.6	-9	-9	-9
940916	4	304	21.25	0.7	3	-9	-9	-9.00	37.5	160.8	-9	-9	-9
940916	4	402	2.25	1.4	6	-9	-9	-9.00	7.9	34.0	-9	-9	-9
940916	5	104	2.25	1.8	6	-9	-9	-9.00	10.2	34.0	-9	-9	-9
940916	5	205	5.75	0.5	4	-9	-9	-9.00	7.3	58.0	-9	-9	-9
940916	5	301	3.25	1.5	6	-9	-9	-9.00	12.3	49.2	-9	-9	-9
940916	5	401	5.25	1.4	4	-9	-9	-9.00	18.5	53.0	-9	-9	-9

APPENDIX A
WATER QUALITY DATA FROM RUNOFF COLLECTORS

STORM DATE	T*	PLT #	VOL** (l)	[TP]	[TN]	[NO3N]	[NH4N]	[SRP]	TPX	TNX	NO3X	NH4X	SRPX
					-------(mg/l)--------					-------(g/ha)------			
941103	1	101	8.25	2.2	12	1.4	1.9	-9.00	45.8	249.7	29.1	39.5	-9
941103	1	201	5.75	4.1	14	0.3	0.2	-9.00	59.5	203.0	4.4	2.9	-9
941103	1	303	17.25	3.6	11	1.7	0.1	-9.00	156.6	478.5	74.0	4.4	-9
941103	1	405	4.00	4.3	15	0.4	0.2	-9.00	43.4	151.3	4.0	2.0	-9
941103	2	103	1.25	2.3	5	1.3	0.05	-9.00	7.3	15.8	4.1	0.2	-9
941103	2	202	3.00	2	9	0.6	0.05	-9.00	15.1	68.1	4.5	0.4	-9
941103	2	302	7.00	5	13	0.7	0.1	-9.00	88.3	229.5	12.4	1.8	-9
941103	2	404	2.85	3.4	13	0.2	0.1	-9.00	24.4	93.4	1.4	0.7	-9
941103	3	102	7.75	2.5	11	0.6	0.2	-9.00	48.9	215.0	11.7	3.9	-9
941103	3	204	11.25	2.4	7	0.8	0.2	-9.00	68.1	198.6	22.7	5.7	-9
941103	3	305	8.00	1.5	5	1.3	0.2	-9.00	30.3	100.9	26.2	4.0	-9
941103	3	403	7.25	3.3	9	0.7	0.6	-9.00	60.3	164.6	12.8	11.0	-9
941103	4	105	0.35	2.9	10	0.4	0.1	-9.00	2.6	8.8	0.4	0.1	-9
941103	4	203	3.25	3.9	12	0.5	0.2	-9.00	32.0	98.4	4.1	1.6	-9
941103	4	304	10.00	5.6	11	2.7	0.4	-9.00	141.2	277.4	68.1	10.1	-9
941103	4	402	10.25	2.1	6	0.7	0.2	-9.00	54.3	155.1	18.1	5.2	-9
941103	5	104	0.75	0.3	2	2.8	0.2	-9.00	0.6	3.8	5.3	0.4	-9
941103	5	205	7.50	2.6	11	0.3	0.4	-9.00	49.2	208.1	5.7	7.6	-9
941103	5	301	15.75	3.8	9	0.4	0.1	-9.00	150.9	357.5	15.9	4.0	-9
941103	5	401	11.75	3.9	11	0.6	0.5	-9.00	115.6	326.0	17.8	14.8	-9
941202	1	101	18.75	0.3	1	-9	-9	-9.00	14.2	47.3	-9	-9	-9
941202	1	201	17.25	0.3	2	-9	-9	-9.00	13.1	87.0	-9	-9	-9
941202	1	303	12.25	1.4	5	-9	-9	-9.00	43.3	154.5	-9	-9	-9
941202	1	405	12.25	0.2	1	-9	-9	-9.00	6.2	30.9	-9	-9	-9
941202	2	103	17.75	0.4	3	-9	-9	-9.00	17.9	134.3	-9	-9	-9
941202	2	202	14.25	0.3	1	-9	-9	-9.00	10.8	35.9	-9	-9	-9
941202	2	302	16.75	0.7	4	-9	-9	-9.00	29.6	169.0	-9	-9	-9
941202	2	404	13.25	0.7	3	-9	-9	-9.00	23.4	100.2	-9	-9	-9
941202	3	102	8.21	0.2	2	-9	-9	-9.00	4.1	41.4	-9	-9	-9
941202	3	204	18.25	0.2	2	-9	-9	-9.00	9.2	92.0	-9	-9	-9
941202	3	305	19.25	0.4	1	-9	-9	-9.00	19.4	48.5	-9	-9	-9
941202	3	403	15.75	0.4	2	-9	-9	-9.00	15.9	79.4	-9	-9	-9
941202	4	105	1.00	1.2	7	-9	-9	-9.00	3.0	17.7	-9	-9	-9
941202	4	203	15.25	0.8	3	-9	-9	-9.00	30.8	115.4	-9	-9	-9
941202	4	304	21.25	0.5	2	-9	-9	-9.00	26.8	107.2	-9	-9	-9
941202	4	402	18.75	0.3	1	-9	-9	-9.00	14.2	47.3	-9	-9	-9
941202	5	104	16.25	0.3	2	-9	-9	-9.00	12.3	82.0	-9	-9	-9
941202	5	205	22.75	0.7	4	-9	-9	-9.00	40.2	229.5	-9	-9	-9
941202	5	301	12.25	0.4	2	-9	-9	-9.00	12.4	61.8	-9	-9	-9
941202	5	401	14.75	0.6	2	-9	-9	-9.00	22.3	74.4	-9	-9	-9

***T = Treatment**

1 = BRDCAST
2 = SD-INCORP
3 = SD-SURFACE
4 = SD - NFERT
5 = CONTROL

****VOL = Runoff volume in liters,**
(liters) x 0.02523 = cm

-9, -9.00 = missing data