1995 Project Abstract
For the Period Ending June 30, 1997
This project was supported by the Minnesota Legislature, MN 1995, Chapter 220, Sec. 19, Subd. 5t, as recommended by the Legislative Commission on Minnesota Resources from the Oil Overcharge Money.

Title:	Recycled Biosolids Product Used To Reclaim Disturbed Areas
Program Manager:	Kathryn J. Draeger
Organization:	Power Plant Aggregates
Address:	904 St. Paul Ave., St. Paul, MN 55116 (612) 690-9668
Legal Citation:	ML 1995, Ch. 220, Sec. 19, Subd. 5t.
Appropriation Amt:	$200,000

Objectives:
This project proposed the development of disturbed landscape reclamation methodology using native plant mixes, nitrogen-fixing bacteria and N-Viro Soil™, a treated sewage sludge and recycled biosolids product.

Results and Discussion: N-Viro Soil proved to be more effective than topsoil and fertilizer in reclamation efforts. Six demonstration and experimental sites were established during this project. Reclamation methodology was developed through data collected at the six sites and research studies conducted at the University of Minnesota. The Minnesota Department of Transportation, Minnesota Department of Natural Resources, a private sand and gravel company, and the Wilder Foundation were collaborators on this project.

Soil nutrient content was measured over the two-year period at the sites. N-Viro Soil showed increases in valuable plant nutrient (N, P, and K) contents over the topsoil plus fertilizer treatment. N-Viro Soil increased the organic matter content of the soil by approximately 200%. The increase in organic matter reduced visible signs of erosion and increased vegetative establishment. Plant biomass and percent cover were highest in N-Viro Soil treated plots. Plant tissue and soils were analyzed for heavy metal content and exhibited no adverse signs to due N-Viro Soil treatment. Data supports the use of N-Viro Soil as a soil amendment and topsoil replacement for reclamation activities.

The U of MN collected over 250 nitrogen-fixing bacterial strains and evaluated 147 of those strains in glasshouse experiments against five different native prairie species for plant growth response. The best strains were then tested against levels of N-Viro Soil at 20, 40, and 60 tons/ha. All strains showed positive response to N-Viro Soil treatments when compared to no N-Viro Soil present. Four strains have been identified which promote equal or greater plant growth than those present in recommended commercial inoculants. *Chamaecrista fasiculata, Cassia hebecarpa* and *Glycyrrhiza lepidota* were identified as being good plant species for reclamation seed mixes using N-Viro Soil. The U of MN is working with MnDOT and will continue their studies in this area.

Project Results Use and Dissemination:
A handbook has been developed which outlines the principles for reclamation using N-Viro Soil. This publication is available to the public. A conference was held in April of 1997 in Eveleth, MN to promote the use of N-Viro Soil in mineland reclamation efforts of Northeastern Minnesota. Kathy Draeger was a guest lecturer at the U of MN Restoration Seminar series in 1995, 1996, and 1997 to discuss the project and results. The project was highlighted in an MPCA Land Application Conference in 1997 with Kathy Draeger as the session moderator. Project collaborators have given other lectures to cover a diverse audience during the project.

Date of Report: July 1, 1997

LCMR Final Work Program Update Report

I. Project Title and Project Number: Q-1, RECYCLED BIOSOLIDS PRODUCT USED TO RECLAIM DISTURBED AREAS

Program Manager:	Kathryn J. Draeger
Agency Affiliation:	Power Plant Aggregates
Mail Address:	904 St. Paul Avenue, St. Paul, MN 55116
Phone:	(612) 690-9668 Draeg001@tc.umn.edu

A. Legal Citation: ML 95, Chp. 220, Art. ___, Sec. 19 ___, Subd. 5t.

Total Biennial Budget: $200,000
Balance: $0.00

Appropriation Language:
This appropriation is from the oil overcharge money to the commissioner of administration for payment to the Metropolitan Council in cooperation with N-Viro Minnesota to increase the market for biosolids by demonstrating the use of N-Viro Soil for reclamation through a program of research, field and public demonstrations.

B. LMIC Compatible Data Language:

C. Match Requirement: Not Applicable

Match Required: $
Amount Committed to Date:
Match Spent to Date:

II. Project Summary:

This project proposes a systematic, stepwise approach to the development of a flexible methodology to reclaim environmentally disturbed areas by applying existing technology and conducting original research. This methodology will result in energy conservation, as petro-chemical inputs are replaced with a recycled product, N-Viro Soil , and through nitrogen fixation by the legume species use. N-Viro Soil and nitrogen fixing bacteria replaces anhydrous ammonia, an energy intensive fertilizer input. Research on, and application of biological nitrogen fixation in native and agronomic legumes will expand the energy conservation to agriculture and environmental reclamation. Successful reclamation requires a healthy, fertile soil substrate and a diverse and populous soil biota, which when combined will support plant growth. The methodology proposed here combines N-Viro Soil (NVS), microbial inoculants and plant mixes into a reclamation package to satisfy these basic requirements.

N-Viro Soil is a biologically active, nutrient rich soil like material which exceeds the U.S. Environmental Protection Agencies most stringent standards for biosolid quality and safety. N-Viro Minnesota and the Metropolitan Council's wastewater treatment facility produce NVS in Eagan by mixing cement kiln dust, coal combustion fly ash and dewatered municipal sewage sludge (biosolids). There is a strong public perception that any biosolids are high in heavy metal contents. The Twin Cities municipal wastewater treatment facilities have employed an effective pre-treatment program and have reduced the metal concentration in sewage sludge by more than 75% in the last ten years (Pers. comm. Steve Stark, Met Council Wastewater Services). This has allowed NVS to surpass the highest standards set by the U.S. E.P.A. for biosolids and achieve Exceptional Quality (EQ) status (Table 1.). The concentration of heavy metals in N-Viro Soil is comparable to those found in agricultural soil (Table 1).

N-Viro Soil is used as an agricultural soil amendment in Minnesota and elsewhere and has a nutrient analysis of 1:1:1 N-P-K, and high levels of carbon and calcium. This project draws on previous research conducted by the University of Minnesota on the use of N-Viro Soil in agriculture (Halbach et al., 1994). By expanding the use of N-Viro Soil to reclamation, we are replacing topsoil, a virgin natural resource, and expanding the market for this recycled product.

The research objective of this project is to develop an environmentally sound reclamation methodology using N-Viro Soil. Research questions answered through greenhouse, growth chamber, laboratory and field experiments will include; effects of N-Viro Soil on soil chemistry and biology of reclamation site strata; plant mixes suited to these particular soil stresses; rhizobia survival, nodulation and nitrogen fixation in N-Viro Soil; legume host/strain interactions; and plant population dynamics in field studies. Reclamation sites will be identified, in cooperation with public and private sector, and baseline data collected. Greenhouse and growth chamber experiments will be conducted under controlled conditions using site strata to determine appropriate application rate of N-Viro Soil, plant species mixes and microbial inoculants. Field experiments and a public demonstration will be designed and put into place based on the findings of the controlled experiments. The outcomes of this project will include the reclamation of disturbed areas, development of environmentally sound reclamation methodology and expanded use of a recycled product, N-Viro Soil.

III. Final Work Program Update Summary:

Project results are summarized as follows:

- **N-Viro Soil is an effective soil amendment in place of inorganic fertilizer treatments used in reclamation activities.**

- **N-Viro Soil is an effective topsoil replacement in reclamation activities.**

- **N-Viro Soil showed increased biomass and percent cover over topsoil treatments, resulting in greater soil protection.**

- **N-Viro Soil showed increased microbial activity over topsoil treatments.**

- **The use of N-Viro Soil did not significantly alter soil metal levels.**

Project collaborators in selecting sites were from the private gravel industry, non-profit organizations and state and federal government agencies. These collaborators included Met Council, DNR, MnDOT, U.S. Fish and Wildlife Service, Shiely Gravel, People of Phillips, and Wilder Forest. The DNR and Shiely Gravel committed some of their funds to address the use of N-Viro Soil for reclamation of mined areas. The DNR contribution was approximately $30,000 and the Shiely Gravel contribution was approximately $25,000. These funds supported objectives B, the field studies, and were used for a field researcher, soil and water analysis, and site earth work as needed. Some data regarding the effects of municipal solid waste were reported. This research was supported by the DNR outside of the context of the LCMR project.

In 1996, six field demonstration and experiment sites were established, more than the three required in our original workplan. The six sites were installed in the following areas in collaboration with the noted agencies and organization: Grey Cloud Island, demonstration site, with DNR; Grey Cloud Island, lysimeter plots, with DNR; Grey Cloud Island, U of Mn experimental site; Shakopee bypass, demonstration site, MNDOT; Shakopee bypass, U of Mn experimental plot, with MNDOT; and Wilder Forest gravel pit, test site, with Wilder Forest. The Met Council Environmental Services were excellent collaborators and provided N-Viro Soil to all the sites with great professionalism and speed. There was a great deal of effort put into getting the field sites installed. The team of people from N-Viro, the DNR, MNDOT staff, a group of volunteers from the U of M and Wilder Forest staff all contributed to the field work.

Information was gathered that was both practical and research oriented. Final analysis of all data indicated a positive response to the use of N-Viro Soil in reclamation activities. Vegetation, microbial activity, and soil characteristics exhibited benefits from the use of N-Viro Soil. Specific results are discussed in sections A, B, and C of this report. Compared to the treatments of topsoil and fertilizer and municipal solid waste, N-Viro Soil treatments exhibited the highest plant biomass, soil fertility, and microbial activity. Vegetative response was highest with N-Viro Soil as topsoil treatments produced half the response of NVS. Final data is summarized in graphs and tables at the end of this report. The University of Minnesota and the Department of Natural Resources will continue to do research and monitor the N-Viro Soil plots, respectively.

Project results have been disseminated through a variety of lectures during the course of the project. Kathy Draeger has been a guest lecturer at the University of Minnesota's Restoration Seminar Series in 1995, 1996 and 1997. In 1997, the project was highlighted at the MPCA Land Application of Biosolids Conference in which Kathy Draeger was the session's moderator. In April of 1997, a conference was organized through this project in cooperation with EvTAC Mining Company of Eveleth, MN. Conference attendees included individuals from the mining industry, the paper milling industry, local officials, and state regulators. Kathy Draeger, LCMR project manager, was a featured speaker at this event and promoted the use of N-Viro Soil in reclamation efforts of mining companies. Over 75 people attended the conference entitled *Earth to Earth* . This conference initiated interest in combining the properties of N-Viro Soil with the organic waste products of the paper industry for use in mining reclamation. Interested parties are beginning a dialog to further these efforts.

A handbook which offers guidance on the use of N-Viro Soil in reclamation activities was completed and submitted to the LCMR office. The handbook includes guidance on site selection, N-Viro Soil application, vegetation selection and planting, and special considerations for sand and gravel and roadside reclamation. The handbook has a reference section which lists regulators, seed sources, and soil sampling techniques.

A poster was developed which summarizes the project objectives and results. The poster was used to promote the project at the Earth to Earth conference and other functions.

This LCMR project has been nominated for the 1997 Beneficial Use of Biosolids Awards Program sponsored by the U.S. Environmental Protection Agency. Formal application materials were submitted to the EPA in May of 1997. Winners will be announced in July of 1997.

IV. Statement of Objectives:

A. Reclamation sites will be identified in cooperation with private gravel pit owners, the Department of Natural Resources and other interested agencies. The dialogue on possible sites is currently underway with the private operators identified in this proposal and the DNR. Three sites will be selected. Sites will vary in size with research areas to be no larger than three acres per site. Baseline data and site strata will be collected from those sites for initial growth chamber and greenhouse studies. Reclamation sites will be characterized and native vegetation determined from soil surveys and other pertinent records. Systematic studies will be initiated to determine combinations of N-Viro Soil, plant mixes and rhizobial inoculants that will successfully restore these disturbed areas.

B. Field studies will be conducted to determine the viability of selected plant species and microbial inoculants in the particular stress conditions found in disturbed areas. Studies will include soil chemistry and biology, plant germination, survival and population dynamics, soil microbial population, rhizobia survival and nodulation as affected by N-Viro Soil application. The overall objective of the field studies is to determine the most environmentally sound reclamation methods. A field demonstration of the reclamation package will be in place the third year for tour by pit owners/operators, public agencies and interested organizations. Public demonstrations is to generate interest in replicating the findings at other sites.

C. Results from this program will be documented in the form of scientific publications, articles in trade journals, a guidebook and resource guide for the use of N-Viro Soil in reclamation projects. Documentation and dissemination of a proven reclamation package will provide information and technology for other ongoing and future reclamation projects. The project will provide technical support to other ongoing reclamation projects where appropriate.

Timeline for Completion of Objectives:

	7/95	1/96	6/96	1/97	6/97
Objective A. Identify reclamation sites, collect baseline data at those sites and conduct initial growth chamber and greenhouse studies.	XXXXXXXXXXXXX				
Objective B. Field studies on effect of N-Viro Soil, plant mixes, and inoculants at 2 selected reclamation sites. Demonstration site in place for third year.			XXXXXXXXXXXXXX		
Objective C. Documentation of technology application and research findings for educational, scientific and outreach purposes.	XXXXXXXXXXXXXXXXXXXXXXXXXX				

V. Objectives/Outcome:

A. Title of Objective: Identification of reclamation sites, collection of baseline data at those sites, collection of site strata and initial growth chamber and greenhouse studies.

A.1. Activity: Identify reclamation sites and collect baseline data.

A.1.a. Context within the project: Site selection is a crucial aspect of the project. The type of sites will be representative of disturbed areas that are candidates for reclamation using N-Viro Soil, including gravel pits, roadsides, and mine wastes. Baseline data on the physical and biological composition of identified reclamation areas provides the soil and climate information necessary to formulate specific plant mixes, rhizobia inoculants and application rates of N-Viro Soil. Collection of native rhizobia will begin the first systematic study to find effective symbionts for native legumes of this region. Greenhouse, growth chamber and lab studies provide information on plant response, microbial populations and soil chemistry under controlled conditions. These studies provide a necessary first step in determining the field response to NVS, plant species and microbial inoculants.

A.1.b. Methods: The list of potential sites, including private and public lands, will be compiled in cooperation with gravel pit owners/operators, the DNR and other interested agencies. Meetings have been held with these parties and further discussions are planned. Potential sites will be identified and subjected to further examination. Criteria for consideration in sites selection include topography, location, cooperation of owners, public acceptability and exhibiting environmental disturbance that is representative of other areas in Minnesota.

When sites have been identified, baseline data will be collected. Soil samples will be collected randomly across the site using a hand soil corer, and pooled to form a composite sample for analysis. Samples will be analyzed for texture, macro- and micronutrients, trace elements, pH, and electrical conductivity. A most probable number (MPN) test will be conducted to determine initial microbial population in the site strata. Soil health and quality are correlated to soil microbial diversity and population, therefore soil microbe populations will be determined and monitored for the duration of the project.

Site substrate samples will be collected for further testing under greenhouse and growth chamber conditions. Climatic information, temperature and rainfall, will be obtained for the location of the sites. The native plant ecology of the site area will be determined for consideration in formulation of plant mixes. Determination of native vegetation will be based on soil surveys, which contain such information, and historical records in cooperation with collaborators from Prairie Restoration Inc. and the University of Minnesota.

Rhizobium species will be collected from native legumes by removing root nodules and isolating the symbiotic nitrogen fixing bacteria in the laboratory using standard isolation methodology. In order to receive the nitrogen fixation benefit from the legume symbiosis, the appropriate rhizobia must be present, either occurring naturally in the soil or by inoculation. In highly disturbed areas topsoil is absent, subsequently the native rhizobia are also absent. This project will collect the rhizobia necessary for native legumes growth, which have not been studied in the past. Sources for native rhizobia include native prairies preserved and cultivated by the Nature Conservancy, who have expressed interest and the University of Minnesota Arboretum native prairie site.

A.1.c. Materials: Soil sampling will require a soil corer, and a vehicle to visit reclamation sites and haul soil samples. The leased vehicle will be used for all aspects of the project that require transportation. Soil analysis will be conducted by the Soil Science Department, U of M. Climatic and ecological data will be gathered from data bases, including soil surveys, and historical records. Access to Minnesota soil surveys is widely available in hard copies and computerized GIS (geological information service). In addition to information on soils, soil surveys also contain information on native vegetation. Computerized soil surveys will be utilized with the assistance of Dr. Terry Cooper, U of M Soil Science Department. A laptop computer, will be purchased for use in this project. The computer will be used in the collection of data (mass balance compatible), data analysis, report and article writing. The computer will be used mainly by the project manager, and research assistant, and available to those working within the project. At the end of the project the computer, if purchased, will be bought back by N-Viro Minnesota at a depreciated rate or turned over to an appropriate state agency.

Isolation of rhizobia will require a standard microbiological laboratory, provided by the University of Minnesota *Rhizobium* Research Lab, including incubators, rotary shaker, autoclave, and laminar flow hood. Supplies necessary to isolate and culture rhizobia strains are disposable sterile petri plates, nutrient solution, agarose, pipets, graduated cylinders, scales, glassware and growth pouches. Most probable number tests to determine soil and site substrate microbial populations require the same supplies for the isolation of rhizobia, with the addition of milk dilution bottles.

A.1.d. Budget:

Total Biennial LCMR Budget:	$40,000
LCMR Balance:	$0.00

A.1.e. Timeline:

	7/95	1/96	6/96	1/97	6/97
Compile list of potential sites including private and public lands, in cooperation with the DNR and other state agencies	XXX				
Reclamation site selection	XXXXX				
Soil samples collected and site strata collected for further greenhouse testing	XXX				

Soil samples analyzed, computer data base set up	XXXXX	
Collect rhizobia from native legumes in the field, isolate and culture.	XXXX	XXXX

A.1.f. Final Workprogram Update:

Site selection was modified over the months to reflect the research needs for the LCMR project, the DNR and MnDOT. Final selection of sites resulted in six separate sites being set up in May and June of 1996. Details of the site layout are included in this workplan under Section B. Field Experiments. The final list of sites installed in the 1996 field season is as follows:

#1. Grey Cloud Island- Demonstration site. 9 acres in conjunction with the DNR and Shiely Sand and Gravel.
#2. Grey Cloud Island- Lysimeter plots. With the DNR and Shiely Sand and Gravel.
#3. Grey Cloud Island- U of Mn experimental plots. With the DNR.
#4. MnDOT, Shakopee bypass- Standard MnDOT mix site.
#5. MnDOT, Shakopee bypass- Native MnDOT plant material.
#6. Wilder Forest Farm- gravel pit reclamation site- native sand prairie plants.

The project concluded with full analysis of the aforementioned sites for the 1996 and part of the 1997 growing seasons. New sites were not established in 1997 due to the project completion date of July 1. There would not have been enough time to gather vegetative data._MnDOT is looking for sites and has internalized the biosolids project as part of their ongoing activities. The LCMR project started the initial two field sites and now MnDOT is developing their own research program. While we may not be involved with future research, we are happy to have started the interest in beneficial reuse and recycling at MnDOT.

A.2. **Activity:** Conduct initial growth chamber and greenhouse studies to determine appropriate plant mixes, rhizobia inoculants and N-Viro Soil application rates.

A.2.a. Context within the project: To develop a successful, environmentally appropriate reclamation package using N-Viro Soil, plant mixes and inoculants, each must be tested separately and in combination under controlled conditions. Greenhouse studies will test plant species in site strata under varying rates of NVS, representing 0 to approximately 250 tons per acre applications. Plant species will be evaluated to determine the degree of hardiness of different plant species to the environmental stresses encountered in highly disturbed areas. In addition, soil micronutrients such as copper, may be found to be either deficient or toxic depending on various factors. N-Viro Soil contains copper and other micronutrients at levels in the range of a normal agricultural soil (Table 1.). However, due to the high level of calcium carbonates, copper and other micronutrients may be chemically immobilized and therefore unavailable for plant uptake, which could be expressed in deficiency symptoms.

A.2.b. Methods: Controlled studies will be conducted under laboratory, growth chamber and green house environments. Growth chamber and greenhouse pot studies will determine plant vigor, and rhizobial nodulation under varied nutrient regimes created by varying the amount of N-Viro Soil mixed into the collected site substrate. These replicated pot studies will also include a coarse sand control to determine plants survival and biomass production under controlled conditions. Greenhouse studies will test plant species in site strata with varying rates of NVS, representing 0 to approximately 250 tons per acre to determine optimal nutrient levels. Parameters for analysis will include plant biomass production, tissue analysis for macro and micronutrients, nodulation in legumes, nodule dry weight and position. Studies will includes plant tissue analysis for micronutrient deficiencies or toxicities.

The selection of plant species to be used in these studies will be based on the long term restoration and reclamation needs in Minnesota. Plant species selection will take into account those species that are currently used by various agencies. Emphasis will be given to native plants in cooperation with Prairie Restoration Incorporated (PRI). Native legumes that are winter hardy were suggested by Dr. Pengra, University of South Dakota and include *Astragalus* spp., *Lotus* spp., *Lupinus* spp., *Petalastumu*n spp., *Glycyrhiza* spp. and *Vicia* spp. (Shave and Pengra, 1974). Winter hardy species known to survive under environmental stress were suggested by Dr. Larry Robertson, International Center for Agricultural Research in Dry Areas, Legumes Division, and Dr. Clive Francis, University of Australia, in communications concerning this project. These plant species include; *Trifolium ambigulum, Trifolium hybridum, Lathyrus* spp., *Vicia* spp. and vetches.

This phase of research will identify the most efficient *Rhizobium* species and strains for native legumes. The efficiency of the legume/strain relationship will be determined in growth pouch studies based upon plant biomass production, nodule number, nodule weight and position of the nodule in relation to the tap root. Survival of rhizobia and other native soil microbes will be determined under varying levels of N-Viro Soil application using most probable number (MPN) methodology. The most efficient strains will be made available through the University of Minnesota *Rhizobium* Research Lab USDA national collection and distributed throughout Minnesota upon request.

A.2.c. Materials: Greenhouses and growth chambers are supplied by the Department of Soil Science, University of Minnesota. Some regular maintenance of growth chamber units will be required including replacing light bulbs and possible minor repairs. Pot studies conducted in the green houses will require pots, coarse sand, nutrient solution in some cases, seeds of the selected plant species, inoculant for legumes, carboys and glassware. A scale is necessary and will be purchased for this and all other project needs. Rhizobia host/strain interaction experiments will require petri plates, growth pouches, nutrient solutions, glassware, graduated cylinders, scales and microbiological laboratory equipment provided by the *Rhizobium* Research Lab in the Soil Science Dept., U of M. In order to preserve the native rhizobia strain indefinitely, a freeze drying apparatus in the Soil Science Department must be repaired.

A.2.d. Budget:

Total Biennial LCMR Budget: $50,000
LCMR Balance: $0.00

A.2.e. Timeline:	7/95	1/96	6/96	1/97	6/97
Growth chamber exps. to determine effect of NVS on plants species and soil microbes		XXXXXXXX		XXXX	
Determine the viability of rhizobia and native soil microbes in NVS using the MPN methodology		XXXXXXXXXXXXXX			
Greenhouse experiments to determine appropriate NVS applications, plant mixes and inoculants		XXXXXXX		XXXX	
Evaluate NVS impact on soil and water chemistry in greenhouse pot and laboratory studies		XXXXXXX			
Test collected rhizobia for nitrogen fixation efficiency, preserve and distribute the highest performing strains		XXXXXXXX			

A.2.f Final Workprogram Update:
This portion of the workplan was done in conjunction with the University of Minnesota, Department of Soil, Water and Climate. Most Probable Number (MPN) experiments were conducted on the N-Viro Soil. During the 1995 field season we collected native prairie soils to isolate native rhizobia species. Eight prairies from SE Minn to NW Minn were sampled to find native rhizobia for the prairie legumes and determine the soil status of a healthy native prairie. To this end native rhizobia were collected from the prairie soils, isolated and were tested for 5 native legume species (see Table 2 and 3).

University of Minnesota laboratory and greenhouse experiments continued to assess the impact of Nviro Soil on plant growth and germination. Further research to determine the effectiveness of the collected rhizobia species found significant difference between the strains for two native prairie plants. Petalostemum purpureum was tested with 40 different strains of rhizobia and compared to a no nitrogen, no rhizobia control. The results indicated that inoculation with rhizobia could increase plant dry weight by as much as %300. There was a difference between strains as to increased plant biomass production and a number of strains stood out superior. The results of this study can be found in Table 5. Similar results were found for *Chamaecrista*, another native prairie legume species. Plant growth was more than doubled by the addition of rhizobia. The strain collected by the U of Mn for *Chamaecrista* were evaluated and compared to the standard commercial rhizobia inoculant. Four of the strain collected in this project out performed the current commercial strain. Results from this study can be found in Table 6. Agricultural legumes were tested to determine the effect of NVS on plant germination. The results indicated that increasing amounts of NVS applied to the soil had varying effects on plant germination. These results, while not conclusive, show that chickpea and cowpea had increased germination with increased amounts of NVS, common bean, and pea showed no correlated response to NVS levels, and soybean appeared to have decreased germination. However, the control germination of soybean began at 20%, which is below the expected germination rate. Please see Table 7 for a summary of these results.

At project completion, the U of Mn had collected and identified over 250 strains from native prairie and other sources. This is reported in Table 11 which is an updated version of Table 1 reported earlier during the project. All strains are preserved, stored at the U of Mn, and available upon request. Photo 2 shows Astragalus canadense response to four strains. Note the growth response to strain 6318. Of the over 250 strains, 147 were evaluated in the greenhouse for plant nodulation response. These data are shown in Tables 12,13 and 14. Data in Table 12 show that *Dalea* had an overall poor response to selected strains that were specific for *Dalea*. The mean plant fresh weight was only 21.9 mg when compared to 97.0 mg for the *Astragalus* study (Table 13). This poor response prompted further investigation in which a variety of *Dalea* species were inoculated with strains that were identified in this project as well as commercial strains that are currently recommended for use with *Dalea* species. Data indicated that response is very host specific (Table 15). This data is valuable at it provides new strain possibilities to be included in commercial inoculant mixes for optimum nodulation results. The U of Mn has established field sites in Becker, MN to investigate *Dalea* response to strains in a field setting and is seeking new sources of funding to continue investigating the best combination of strains for *Dalea* species.

Seed germination of native legumes was a particular hindrance to overcome during the course of this project. Native legumes are naturally sensitive to extreme cold temperatures and require a vernalization period before they will germinate. Natural vernalization can be difficult to duplicate in artificial or forced conditions. The U of MN developed a protocol which overcame germination problems by treating the seeds with sulfuric acid. The results of this study are given in Table 16.

The U of MN inoculated native prairie legumes (*Chamaecrista* , *Desmodium, and Lespedeza* species) with the two best nitrogen-fixing strains (as determined earlier in the project) to test plant response at N-Viro Soil treatments of 0, 20, 40 and 60 tons/ha. All species responded positively to the presence of N-Viro Soil when compared to the absence of NVS. However, plant response to different levels of N-Viro Soil was species dependent. N-Viro Soil present at 60 tons/ha had the greatest plant response in *Chamaecrista* species while *Desmodium and Lespedeza* species generally performed the best at N-Viro rates of 20 tons/ha . The results from this experiment are given in Graphs 1-3.

Other native prairie legumes were inoculated with a commercial inoculant and tested at the same rates of N-Viro Soil as in the previous study. *Glycyrrhiza lepidota* showed little variation in plant response for all levels of N-Viro Soil (Graph 4). *Astragalus canadensis* showed increased plant growth with increased levels of N-Viro Soil (Graph 4). *Amorpha canescans* and *Petalostemum perpureum* responded best at N-Viro Soil at 40 tons/ha (Graph 5). The wild legume collected at Grey Cloud Island (*Vicia* species) responded well to N-Viro levels of 40 and 60 ton/ha (Graph 6).

Two native grasses were tested for growth response to N-Viro Soil levels of 20, 40 and 60 tons/ha. Both *Andropogon gerardi* and *Sorghastrum nutans* showed increased growth with increased levels of N-Viro Soil (Graph 7). The grasses showed a 5-fold increase in biomass at the highest NVS levels over the control.

B. Title of Objective: Field demonstration and study of N-Viro Soil, plant mixes and inoculants at reclamation sites in Minnesota.

B.1. Activity: Field studies of N-Viro Soil, plant mixes and inoculants to determine most environmentally sound reclamation methodology.

B.1.a. Context within the project: Field studies will be based on the results of green house, growth chamber and laboratory studies conducted under objective A. The information collected in objective A. under controlled conditions will be adapted and further tested in field conditions. Experimental field plots will be located at the different reclamation sites in Minnesota, and will include sites in the seven county metro area and also in greater Minnesota. Field studies will take place during the 1996 and 1997 growing season and will test, under actual environmentally disturbed conditions, the three part methodology package employing N-Viro Soil, plant mixes and inoculants adapted to the specific sites and regions. Field studies will include monitoring and evaluation of soil chemical and biological parameters of soil health and environmental quality. The public demonstration plot will display a successful reclamation methodology to encourage other private and public organizations to replicate the findings at other sites.

B.1.b. Methods: Fields experiments will be conducted at the previously selected and studied reclamation sites. If necessary, as in the case of recently abandoned gravel pits, the site slope will be adjusted by standard mechanical means to a gradient of 2.5:1 or less. This is considered the maximum slope for establishment of vegetation and long term stability (Buttleman, 1992). Test plots size will be based on the nature of the experimental treatments, but not expected to exceed 10 m^2 per treatment. Standard randomized block designed experiments will be conducted to provide information on a quantitative scale. The plots will receive one application of N-Viro Soil ranging from 0 to the maximum determined in Objective A., and in conjunction with the MPCA regulations. N-Viro Soil is applied with regular farm machinery such as a fertilizer or manure spreader for larger acreages. On smaller sites, such as experimental plots, the NVS can be applied with a lawn fertilizer spreader or by hand. Application equipment is readily available that monitor application rate. A rule of thumb is that a 100 tons per acre application rate of NVS is equivalent to a 1 inch thick layer. Previous experimental designs used by the University of Minnesota

(Halbach, 1994) and University of Ohio (Dr. Terry Logan, per. comm.) applied NVS at a maximum rate of approximately 80 tons per acre and 200 tons per acre, respectively. The U of M study which compared NVS as a nitrogen source to conventional nitrogen sources found no significant difference in the heavy metal concentration in soils receiving N-Viro Soil treatments compared to the control treatments even at these high rates.

Based on green house and growth chamber studies three plant mixes will be developed for field testing. Because this project has as its objective the practical application of technology, plant mixes will be based on perceived and stated needs of organizations involved in environmental reclamation. Plants shown by previous studies to be hardy under environmentally stressed conditions will be included. The three plant mixes will include a native plant mix, a Minnesota Department of Transportation specification plant mixture and a mixture of hardy grasses, forbes and legumes. Native plants are used in ecological restoration projects and are commonly specified for revegetation. Working with our collaborator Prairie Restoration Inc., we will develop and test native plants to formulate a hardy plant mix for reclamation purposes. The Minnesota Department of Transportation (MNDOT) uses specification plant mixes for the revegetation of disturbed areas (MNDOT, 1988). Plants used in the MNDOT mixes will be tested in both field and greenhouse studies. A hardy plant mixture is of importance for those areas that r require immediate soil stabilization and revegetation.

Experimental plots will be developed to study plant species in pure stands and also in mixes. Pure stands of each plant species will be studied for percent germination and survival, biomass production, and tissue analysis for micro and macro nutrients. Legumes will be studied individually for nodulation and nitrogen fixation under inoculated and uninoculated treatments. Stands that consist of plant mixes will be analyzed for germination and survival, percent ground cover, biomass production, and plant population dynamics.

Soil quality will be monitored and evaluated through analysis of soil chemical and biological parameters. Soil samples will be collected and full soil analysis performed at the beginning and end of each growing season. After July 1, 1997 when this LCMR project expires, the sites will continue to be monitored by N-Viro Minnesota staff or the Metropolitan Wastewater Service Soil Scientist. Data collected from field experiments and entered into the computer data base for further statistical analysis will include plant biomass, nodule weight, plant tissue analysis, soil analysis, plant population dynamics, emergence and climatic information. This information will be used to establish a "N-Viro Soil" response curve that demonstrates the N-Viro application rate and plant species composition best suited for environmentally disturbed conditions. The soil microbial ecology will be monitored throughout the field season and across the treatments. One of the hypothesis of this project is that environmentally disturbed areas (characteristically low in soil microbes) will exhibit increases in soil quality through increased soil microbe populations, determined using most probable number methodology.

The objective of the public demonstration plot is to show how different plant mixtures respond to varied application rates of N-Viro Soil. Demonstration plot design will be a non-replicated contiguous site with a N-Viro Soil application gradient across the site. Plant mixes will be planted across the gradient and all legumes will be inoculated. The demonstration plot can be established on less than one acre, but exact site size will be determined by the site selection process.

B1c. Materials: Field studies/public demonstrations require rented equipment to haul, spread and incorporate the N-Viro Soil. Regular yard equipment can be used to plant the seed mixes. Field materials such as measuring tapes, plot markers, flags and posts will be needed. Plant and soil data will be collected and require a drying oven and testing facilities, provided by the U of M. Soil biological data will require the same supplies listed in A.1.c.

B1d. Budget:

Total Biennial LCMR Budget: $100,000
LCMR Balance: $0.00

B1e. Timeline:

	7/95	1/96	6/96	1/97	6/97
Randomized block field experiment testing the reclamation package in field situation.			XXXXXXX		XXX
Plots with a gradation design for public demonstration as well as scientific information			XXXXXXX		XXX
Collect data and samples from field plots: Plant population dynamics, emergence, soil, and tissue samples			XXXXX		XX
Analysis of Field data (soil and tissue) : Data entered into database				XXXXXXXXXXXXX	

B.1.f. Final Workprogram Update

Six field sites were installed in the beginning of the 1996 field season, including three randomized experiments, and three demonstration sites. The sites and the design were tailored to the end users needs. For example, MnDOT wanted information on how the NVS would perform with both a standard MnDOT plant mix and a MnDOT native plant mix, so we added another test site to study both plant mixes.

The following description of the Grey Cloud Island site is presented in great detail to demonstrate the process of setting up the controlled experiments. Grey Cloud Island provides a unique opportunity to address the use of N-Viro Soil for gravel pit restoration. The Shiely Sand and Gravel Company was engaged in and supportive of the research and demonstration project that is currently in place on Grey Cloud Island. There are three test sites on Grey Cloud Island. 1.) Demonstration slope, 9 acres that failed to revegetate after three years of effort and expense. 2.) Lysimeter Plots at a sandy location, previously reclaimed. The purpose of this site is to test water quality impacts of different soil amendments to topsoil, and 3.) NVS experimental plots to test NVS as a topsoil substitute.

HYPOTHESIS:
There are two hypothesis being tested at these sites. They are A.) When topsoil is readily available, N-Viro Soil can be used in place of fertilizer for the reclamation of disturbed areas and, B.) N-Viro Soil can replace both topsoil and fertilizer for the reclamation of environmentally disturbed areas and/or areas devoid of topsoil.

BENEFITS:
There are various environmental, social and economic benefits of finding uses for N-Viro Soil in environmentally disturbed areas. Benefits to the environment are accrued as nutrients in biosolids are returned to the soil, closing the leaky nutrient loop. In areas where there are no beneficial reuse programs for biosolids, treated (or untreated) sewage is incinerated or landfilled. Developing environmentally sound methods of utilizing the organic matter and nutrients found in biosolids removes those nutrients from other inappropriate places in the environment, namely the air and water, and avoids concentrating them in landfills.

This LCMR project was funded by Oil Overcharge money. This project seeks to conserve energy through decreasing dependence on synthetic fertilizers. The production of inorganic fertilizers is highly energy dependent and energy intensive.

DEMONSTRATION PLOTS:
PRE-TREATMENT TESTING: Soil samples were collected from each of the demonstration sites. Three transects were made across the plots, collecting approximately 35-50 soil cores and mixing them to form a composite sample.

NVS APPLICATION:
5/8/96, Wednesday: 146 tons of NVS were delivered by Met Council Environmental Services to the Grey Cloud Island site in the late morning.

5/9/96, Thursday 9th: Approximately 140 tons of NVS were applied to the three acre demonstration site using the PSG compost spreader. The NVS application worked very well with the side slinger style spreader, designed for compost spreading. Comments from the operators were positive, in terms of material handling and odor. There were no complaints or concern from the operators and no problems with the application.

SITE LAYOUT: TOPSOIL APPLIED TO ALL PLOTS- Analysis Attached

NVS @ 46 tons per acre	topsoil + fertilizer 12-12-12 @ 330 #/acre	MSW compost + fertilizer Approx. 20 dry ton/acre 165 # of 12-12-12 fert.	topsoil - fert.

*NVS site had high compaction at 4-6 inches below the surface. Dennis Kilmer, plant operator, attributes the failure to revegetate to the compaction.

EXPERIMENTAL SITE:
The experimental site is the controlled study of NVS application and impact on plant germination, growth and establishment in washed sand, a by-product of Shiely's Sand and Gravel operation. This site is also the field site for graduate student, Julie Grossman's thesis experiments.

Site Design:

100*	200*	300*	400*	500*

*Qualitative test of NVS @ 100,200 etc. tons/acre in $1m^2$ plots

Site design cont...

NVS 60	NVS 60	Topsoil + fertilizer (proposed 15 t/acre NVS)
Topsoil + fertilizer (propose 15 t/acre NVS)	NVS 30	Topsoil
MSW Compost	Topsoil	NVS 30
Topsoil	Topsoil + fertilizer (propose 15 t/acre NVS)	MSW Compost
NVS 30	MSW Compost	NVS 60

CALCULATION OF APPLICATION RATE FOR NVS AND MSW COMPOST:

FACTS:

U of M recommendation	U.S. Standard conversion	Applied (tons/acre)	Metric equiv. Applied	Pounds per parcel applied
80 Mg/ha NVS	35 tons/acre	60		815
40 Mg/ha NVS	18 tons/acre	30		408
Proposed NVS		15		204
MSW compost	20 dry ton/acre	20 dry tons/acre		381

CALCULATIONS:
Plot size is 11m X 2.5 m
11m X 3.28ft/m = 36ft
2.5m X 3.28 ft/m = 8.2ft
Total Square ft = 295.2 sq. ft per pot
295.2 sq. ft / 43,560 sq. ft per acre = .0068 of an acre

60 ton per acre application:
.0068 acres X 60 tons/acre X 2000#/ton = 816 # per plot
816# / 30# per pail = 27.2 pails applied per plot (5 gal. pail = 30#/pail)

30 tons per acre application:
.0068 acres X 30 tons/acre X 2000#/ton = 408 # per plot
408#/30# per pail= 13.6 pails per plot

15 tons per acre application:
.0068 acres X 15 tons/acre 2,000#/ ton = 204# per plot
204#/30# per pail= 6.8

Five 1 M square plots were set up next to the controlled experiment to test plant growth (qualitatively) in sand amended with 100, 200, 300, 400, 500 tons per acres. The calculations for the application rates are as follows:
3.28ft/m X 3.28 ft/m = 10.76 sq. ft. / 43,560 ft^2/acre = .000247 acres
.000247 X 100 t/acre X 2000# = 49.4 t/acre
100 T/acre = 50#/plot
200 T/acre = 100#/plot
300 T/acre = 150#/plot
400 T/acre = 200#/plot
500 T/acre = 250#/plot

Municipal Solid Waste Compost Application Rate:
.0068 acres/plot X 28 tons of MSW compost* X 2000#/ton = 381#/plot
*MSW compost is .69 solids, therefore 28t/acre is equivalent to 20 dry tons/acre

381#/21# per 5 gal. pail = 18 pails per plot

Mycorrhizal data collected by Dr. Charvat showed that the biosolids treatment at the MnDOT site produced nearly twice as many mycorrhizal spores than the control treatment (Figure 1). The control side of the research plot produced approximately 4.5 spores per gram of soil. The N-Viro

Soil treatment produced nearly 9 spores per gram of soil. The exact cause of the increase in spore production is not speculated upon here. Mycorrhizae are beneficial soil fungi that form a symbiotic relationship with many plant species and are considered an important factor in prairie re-establishment.

The 1996 growing season was very dry. Graph 8 shows the below normal precipitation values for Grey Cloud Island in 1996. Data was collected during the course of and at the end of the growing season. The MnDOT sites were more difficult to evaluate as the plots were planted at different times. The control plots were established 3-4 weeks before the N-Viro Soil plots were planted. Data collected from the MnDOT sites showed soil organic matter at unusually high levels. A rich prairie soil can have soil organic matter content as high as 8% but the MnDOT sites had average organic matter content over 12%. One explanation is that other materials, like wetland muck, were placed at the site (Table 8).

Per plant biomass data from Grey Cloud Island indicated that the N-Viro Soil produced the most plant biomass (Table 9). Biomass production data from mixed stands also indicated that the N-Viro Soil produced the most plant biomass. Other microbial data collected by the U of Mn at the Grey Cloud Island was not sufficient to show any certain impacts of the N-Viro Soil on rhizobia and nodulation (Table 10). (Rhizobia are bacteria that form a symbiotic relationship with legumes and produce nodules that convert atmospheric nitrogen into a plant available form.) The dry growing season especially impacted the growth and establishment of the U of Mn plots. The plant species that were planted in individual rows did not establish well. There were also indications that they may have been planted to deep. Emergence and survival of native species planted at the Grey Cloud Island experimental plots was analyzed. Initial germination rates were low for all the species in every soil treatment. This can be attributed to below normal precipitation, some technical difficulties in planting the seeds, and the grazing habits of local deer and other wildlife. Data gathered in 1996 is presented in Graphs 9-12. *Chamaecrista fasiculata* consistently showed the highest germination rates over all soil treatments. *C. fasiculata* lost some stand to winter kill, but observations from 1997 indicated that it had spread and seeded itself in plots that did not exhibit the species in 1996. This observation as well as data from *Cassia hebecarpa* and *Glycyrrhiza lepidota* suggests that these species may be good candidates for reclamation efforts.

Vicia species was identified at Grey Cloud Island in 1996 and observed again in 1997 growing in plots treated with N-Viro Soil. The plant appeared to respond favorably to N-Viro Soil treatments and the harsh conditions at the site. This may also be another candidate for future reclamation activities.

Soil samples were collected from the Grey Cloud Island experimental plots treated with topsoil, MSW, and N-Viro Soil at 15, 30 and 60 tons/ac. and analyzed for microbial presence. Microbial activity is an indicator of soil health and can contribute to the soil's ability to support plant life. All samples were diluted in water to get the microorganisms into solution for analysis. Soil organisms taken from the soil samples were assayed on three different growth media (Graph 13a, 13b,,and 13c). Microbial counts were highest in the BYMA media for the NVS at 60 tons.ac samples. NVS at 15 tons/ac gave the highest microbial count in PDA media with MSW and NVS at 60 tons/ac showing a strong response in the TY media. All data shows good microbial activity in the N-Viro Soil treated plots when compared to the control and topsoil treatments.

In August of 1996, biomass and percent cover data were collected by the DNR from the Grey Cloud Island demonstration slope, lysimeter plots, and the experimental washed sand plots. Raw data is given in Table 17. Data taken from the demonstration slope (the best data) is summarized in Figure 2. The portion of the slope treated with NVS outperformed the other soil treatments with an average vegetative cover of 61%. The N-Viro Soil treatment also showed the highest biomass with an average 22.5 grams per 0.5 m^2. The MSW treatment was a close second at 21.9

grams per 0.5 m^2. These results support the results from a biomass study done by the U of Mn on the demonstration slope. The N-Viro Soil treatment showed the highest biomass with an average of 99.27 dry grams per 1 m^2 (Table 18).

The samples collected by the U of Mn in the aforementioned biomass study were also tested for plant tissue nutrient levels and metal content. Metals were analyzed to evaluate if the vegetation was acting as a sink for metals that may be present in the soil treatments. Plant nutrient analysis showed a beneficial increase in nitrogen, phosphorus, and potassium levels in vegetation from plots treated with NVS and MSW (Graph 14). Plant tissue analysis did not reveal any adverse or phytotoxic levels of metals in vegetative tissue from any of the treatments (Graph 15 and 16).

Soil samples were collected in 1996 and 1997 from the experimental plots at Grey Cloud Island. Samples were analyzed for nutrient content, pH, organic matter and metal concentrations to examine the impacts of N-Viro Soil and other soil amendments on soil quality and plant nutrient availability. Plots treated with N-Viro Soil consistently showed the greatest benefit to soil quality. Necessary plant nutrients such as nitrogen, phosphorus, and potassium were most available in biosolids-treated plots (Graphs 17, 18, and 19). MSW and N-Viro Soil applied at 60 tons/ac provided the highest levels of organic matter at 0.7 % compared to the control at 0.2 % (Graph 20). This is approximately a 200% increase in organic matter over the original soil. All soil treatments appeared to have an impact on soil pH (Graph 21) although this data is suspect as the topsoil treatment shows a higher pH than the control sample.

Soil samples were tested for concentrations of metals listed in the 40 CFR 503 Regulations which define the limits for an Exceptional Quality biosolids product (Table 1). In general, metal concentrations slightly increased in 1996 after N-Viro Soil and MSW application. These levels tended to be reduced after year 2 based upon the 1997 data (Graph 22 and 23). In conclusion, N-Viro Soil did not significantly alter soil metal levels.

C. Title of Objective: Documentation for educational, scientific and outreach purposes.

C1. Activity: Information produced by this project will be documented through a guidebook, scientific publications and available public media for widespread distribution. The project will provide technical support and share the methodology with other ongoing reclamation projects.

C1a. Context within the project: The objective of this project is to create a reclamation methodology using N-Viro Soil in order to expand the market for recycled biosolids. Once the methodology is established, distribution of the information is necessary to introduce public and private sectors to the beneficial use of N-Viro Soil. This will be accomplished through various media, including a guidebook on the use of N-Viro Soil in reclamation, scientific publications, and outreach activities.

C1b. Methods: The guidebook will be a joint effort of the collaborators on this project, with the project manager having the final responsibility for its compilation. Results from the greenhouse and field studies will be translated into a flexible methodology that can be duplicated for various reclamation projects. The book will offer a complete resource guide for reclamation projects including source of N-Viro Soil, seed distributors, state agencies that render assistance and private companies that can contribute to reclamation.

Scientific publication will reach the academic community and contribute to the body of knowledge in the area of reclamation and restoration. Some recent works in the field acknowledge the beneficial use of recycled biosolids products in reclamation, such as *Municipal Sludge Use in Land Reclamation* (1993), but do not include the type of biosolids produced in the

Twin Cities. Publication in various scientific and trade journals will be accomplished by building on a sound research base, using this innovative approach to reclamation. Authors include, but are not limited to, professors at the University of Minnesota contributing to various aspects of the project, the research assistant supported by the project, and project manager. All such publications are subject to peer review.

An outreach program to familiarize public and private sectors with N-Viro process and product is an ongoing effort by N-Viro Minnesota and the Met Council Wastewater treatment division. The project will make contact and whenever feasible work with the Minnesota Department of Natural Resources, Department of Transportation, US Bureau of Mines, gravel pit owners and operators and other appropriate parties to expand the use of N-Viro Soil to ongoing reclamation projects.

C1c. Materials: Materials necessary for this objective include a computer and software for both data and word processing. This is the same computer mentioned in objective A. and will be used for all project needs. Literature reviews for the writing and research portions of the project will require copy cards for Xeroxing pertinent papers. Outreach materials and guidebook will require printing.

C1d. Budget:

Total Biennial LCMR Budget: $10,000
LCMR Balance: $0.00

C1e. Timeline:

	7/95	1/96	6/96	1/97	6/97
Literature review Project manager, research assistant, graduate students and others involved will collect and read publications in the fields of reclamation, soil science and ecology	XXXXXXXXXXXXXXXXXXXXXXXX				
Guidebook: Will be written as the project progresses and contain a flexible reclamation methodology developed by the project, public and private reclamation resources, and sources of seed, N-Viro Soil, inoculum, planters, etc..			XXXXXXXXXXXXXXXX		
Scientific and trade publications: Will be written as the project progresses and submitted for publication at the earliest possible time. Actual publication is dependent on peer review and acceptance			XXXXXXXXXXXXXXXX		

C.1.f Final Workprogram Update:

A comprehensive review of literature was conducted and compiled. This review of literature was shared with the U of Mn researchers and DNR Minerals Division.

Project results were disseminated through a variety of lectures during the course of the project. Kathy Draeger was a guest lecturer at the University of Minnesota's Restoration Seminar Series in 1995, 1996 and 1997.

In April of 1997, a conference was organized through this project in cooperation with EvTAC Mining Company of Eveleth, MN. Conference attendees included individuals from the mining industry, the paper milling industry, local officials, and state regulators. Kathy Draeger, LCMR project manager, was a featured speaker at this event and promoted the use of N-Viro Soil in reclamation efforts of mining companies. Over 75 people attended the conference entitled *Earth to Earth* . This conference initiated interest in combining the properties of N-Viro Soil with the organic waste products of the paper industry for use in mining reclamation. Interested parties are beginning a dialog to further these efforts. A conference brochure is attached to this report.

A handbook which offers guidance on the use of N-Viro Soil in reclamation activities has been completed and is submitted with this final report. The handbook includes guidance on site selection, N-Viro Soil application, vegetation selection and planting, and special considerations for sand and gravel and roadside reclamation. The handbook has a reference section which lists regulators, seed sources, and soil sampling techniques.

A poster was developed which summarizes the project objectives and results. This poster has been used to promote the project at the Earth to Earth conference and other meetings. Photo 1 shows the poster.

This LCMR project has been nominated for the 1997 Beneficial Use of Biosolids Awards Program sponsored by the U.S. Environmental Protection Agency. Formal application materials were submitted to the EPA in May of 1997.

The project attracted the attention of wastewater operators, the MPCA and others. We presented the project work and result to a group of 300 wastewater operators at the MPCA Land Application of Biosolids conference in February of 1997. Kathy Draeger, the project manager, presided over the session which included presentations by the mine owner/operator and the DNR. The MPCA sent out 2600 program announcements for the workshops. We submitted an abstract of the project to Land and Water magazine for their consideration. The DNR will be publishing their results in The Volunteer..

VI. Evaluation: The project will be evaluated through meeting the following objectives:
1.) Development of a flexible reclamation methodology using NVS, plant mixes that include natives, and microbial inoculants. This will be documented through field experiments and accompanied by public demonstration at a reclamation sites.

2.) Expanding the use of N-Viro Soil to reclamation. This will increase the demand pull for N-Viro Soil, a recycled product produced by the Met Council Wastewater Services.

3.) The actual reclamation of environmentally disturbed areas. Reclamation meaning that the site supports plant and microbial life.

4.) Increased public awareness of the benefits of N-Viro Soil. This will be accomplished by selected outreach to public agencies and private companies, publication in trade and scientific journals, and any popular press coverage possible.

The potential impacts of the projects are many faceted. This project offers an innovative approach to environmental reclamation and will produce a practical guidebook with a flexible methodology. This could benefit actual reclamation projects. In the process of reclaiming disturbed areas using this methodology, topsoil, a virgin natural resource will be preserved by replacing it with a recycled product, N-Viro Soil.

Important to the project manager is the transformation of the public perception of waste. Our society is increasingly seeing the value in things we previously considered waste. I would like to see sludge and sludge products considered a valued resource rather than a problem to be dealt with. By expanding the use of NVS, we are increasing the value of recycled products.

VII. Context within the field:

Environmental reclamation is an increasingly multidisciplinary and multi-sectoral activity. Ecologist, soil scientists, entomologists are finding that they can study plant, insect, and microbial ecology in actual reclamation projects- an artificial evolution and succession of sorts (Cairns, 1986). Restoration of damaged ecosystems can advance theoretical ecology while returning a site to a previous state of higher species diversity and vigor. While this is considered positive, some fear that our ability to restore damaged areas will cause us to create more disturbance (Cowell, 1993). Reclamation and restoration of original habitats is viewed by applied ecologist as a method for conserving biological diversity (Jordan et al., 1988). This projects takes a multidisciplinary approach, combing ecology, plant and soil sciences to develop a holistic reclamation methodology.

Reclamation is sometimes viewed as simply the restoration of plant species. However, in many cases whole ecosystems have been removed or destroyed. This requires an approach which considers the whole system, including soils (Bradshaw, 1987). Soil quality is considered a key biological and ecological index (Parr et al., 1992). This project examines the reclamation site substrate and uses N-Viro Soil to provide a biologically active and nutrient rich soil substrate, similar to topsoil. While this is the first time such work has been undertaken in Minnesota, N-Viro Soil was studied for reclamation potential of acidic mine spoils in Ohio. Dr. Terry Logan, University of Ohio, found in greenhouse studies that N-Viro Soil treatments produced more plant biomass than equivalent chemically fertilized treatments (Logan, 1992)

N-Viro Soil is produced at the Seneca Wastewater Treatment Facility, Eagan, Minnesota, by mixing dewatered sewage sludge with a combination of cement kiln dust and fly ash. These materials are high in alkalinity, namely calcium oxide, and cause a rapid rise in pH and temperature when mixed with the organic biosolids. This exothermic reaction in effect pasteurizes the sludge, yielding a stable soil like material. The pasteurization process kills all disease causing organisms (pathogens) and the product is not attractive to disease carrying organisms (vectors). Heavy metal concentrations in NVS fall within the range of normal agricultural soils (Table 1.). In addition, the wastewater treatment facilitates in the Twin Cities metropolitan area reduced the metal levels in sludge by more than 75% over the last ten years through an effective point source program.

In 1993 the United States Environmental Protection Agency promulgated the 40 C.F.R. 503 Regulations establishing enforceable rules for the utilization of wastewater sludges, also known as biosolids. The Part 503 rule is designed to protect public health and the environment from any reasonably anticipated adverse effects of certain pollutants and contaminants that may be present in biosolids. The requirements of the Part 503 rules are based on the results of an extensive multimedia risk assessment (EPA, 1994).

The 40 C.F.R. 503 regulations have created an "Exceptional Quality Biosolids" (EQ) protocol that sets the highest standards for risk reduction in biosolids. Biosolids that meet the criteria as Exceptional Quality are regarded by the EPA as products requiring no further regulation (EPA, 1994). EQ biosolids are regulated similar to fertilizers. The N-Viro Soil product created by the N-Viro Process at the Seneca Wastewater Treatment Facility in Eagen, Minnesota exceeds the stringent Exceptional Quality protocol.

The University of Minnesota Soil Science Department initiated a research project in 1991 comparing N-Viro Soil to conventional nitrogen fertilizers for producing corn in Dakota and Scott Counties. The following section of the final report, published in 1994, is an important statement addressing the concerns regarding heavy metal contamination of soils due to biosolids application.

> "...after three consecutive applications of N-Viro Soil at high application rates, there were no significant differences in soil elemental composition between the N-Viro Soil and control plots at any soil depth for any of the seventeen elements evaluated. This is important because it shows we would not anticipate any negative environmental effects on soil elemental composition when applying N-Viro Soil at similar rates..." (Halbach et al., 1994)

In essence, applying NVS to agricultural soil is similar to adding a high calcium and N-P-K fertilizer to soil. While this maintains corn yields equivalent to nitrogen fertilizer (Halbach, 1994), it can be of special value to the fertility of reclamation sites. In these area topsoil has been removed leaving only subsurface soil or parent material. This substrate is a very poor medium for plant growth and results in the characteristically barren site that are candidates for reclamation. Application of NVS to these sites provides a high organic soil like surface, similar to that of topsoil. This promotes vegetation and the natural processes of soil regeneration and nutrient cycling that had been disrupted by mining, construction or other disturbances.

Fertile soils have a diverse, interactive and large population of soil organisms (Lee and Pankhurst, 1992). An index of soil health is the degree of soil organism biodiversity; as soil organisms are the basis of nutrient cycling, and stable topsoil and plant communities (Munshower, 1994). Plant and soil interactions are an integral part of undisturbed and evolved ecosystems (Perry and Amaranthus, 1990). This project will consider soil organism population as an indicator of ecosystem health. Microbes will be introduced through application of N-Viro Soil and inoculation of legume plant species with the appropriate nitrogen fixing bacteria, known as rhizobia. With the appropriate rhizobia strains and plant varieties, nitrogen fixation can occurs under environmentally stressful conditions (Graham, 1992) and is a major source of soil nitrogen in plant communities. Establishing soil microorganism has previously been shown to benefit reclamation of environmentally degraded sites (Perry and Amaranthus, 1990).

In addition to the importance of a soil substrate and soil microorganisms, plant species are crucial to the reclamation of disturbed areas. Various native and agronomic species are noted for there ability to colonize environmentally degraded areas (Harker et al., 1993). Plants selected to establish in these areas must be carefully chosen in order to accomplish short and long term goals. Short term goals are soil stabilization and erosion control. One long term goal may be ecosystem re-establishment (Cairns, 1990). Prairie restoration will be a part of this project in those areas that where originally prairies. Working with Prairie Restoration Inc., we will incorporate native plants mixes in the study of this reclamation methodology. Prairie restoration is appropriate for much of the area in Minnesota and surrounding states (Kline and Howell, 1987; Cottam, 1987). Legumes are of particular importance to the restoration of native ecosystems as they contribute to the nutrient cycle through nitrogen fixation. There are at least 43 legumes species, distributed in 19 genre, that are native to this region (Pengra, 1976).

This project will develop a flexible reclamation methodology that draws on various disciplines in a combined program of research and application of proven technology. By collaborating across academic boundaries, we can create a holistic methodology that takes into consideration soil microbial and plant ecology, physical and chemical soil properties, and ecosystem dynamics.

VIII. Budget Context: In the two year period ending June 30th, 1995, Power Plant Aggregate, the parent company of N-Viro Minnesota, has financially supported the project manager, Kathryn Draeger, in the preparation of the LCMR proposal. The MWCC has supported the ongoing outreach program of N-Viro Minnesota. As of late outreach includes meetings with the DNR and contact with the Minnesota Department of Transportation on the potential of N-Viro Soil in reclamation of disturbed areas.

For the two year period beginning July 1, 1995, N-Viro Minnesota and N-Viro Resources will contribute $29,000 of in-kind and cash contribution towards the use of N-Viro Soil in reclamation projects. The in-kind contribution will include time contribution of the staff agronomist and other staff members. Cash contribution will include purchase of office supplies, communications costs and other incidentals over the two year period of the project. In addition, the former MWCC committed $15,000 of in-kind contribution for the two year period. This is likely to include staff contribution and the N-Viro Soil. Prairie Restoration Inc. has committed $4,800 to this project for native seed and staff contributions.

IX. Dissemination: Outreach is an important and integral part of this project. As part of this project a practical reclamation guidebook will be produced and distributed. In addition, findings will be published in trade and scientific journal and in the form of outreach materials. For detailed description, see objective C.

Sites for public demonstration of the reclamation methodology will be in place for the 1997 growing season. Invited publics will include state and federal agencies, gravel pit owners and operators, environmental groups such as the Nature Conservancy, and the general public.

In addition, the project will take advantage of popular media releasing information to TV, radio and newspapers. We are especially interested in public radio and television as they produce various programs focused on environmental innovations.

There are numerous professional organizations that would be interested in this work. When feasible, results will be presented in these forums. Different academic departments at the University of Minnesota conduct weekly seminar series. Preliminary presentation to the Ecology and Soil Science Departments could provide valuable feedback. Results of the project will also be disseminated through this venue , as will the graduate students thesis defense.

X. Time: All the research and demonstration plots will be in place on July 1, 1997. No additional monies are needed to complete work after this date. The public demonstrations will continue through the 1997 field season without additional cost to the project.

XI. Cooperation: The project manager will spend 50% of her time on this project. Time will be divided between the three objectives and dictated by field season and laboratory requirements, and the administrative needs of the project.
Prairie Restoration Incorporated (PRI) is donating the times of staff member Mike Casey to cooperate and have lead responsibility for PRI's collaboration. PRI is a private company that is involved with restoration projects throughout Minnesota. They are specialty growers and propagators of plants native to this region of the county. Their seeds and expertise have been sought for state and federal projects, as well as private individuals and companies, and non-profit organizations. Mr. Casey's will contribute approximately 10% of his time, as an in-kind contribution to the project, advising on native seeds and seed mixes, and field visits over the two year period. He will have input into objectives A, B, and C.

Dr. Peter Graham, Department of Soil Science at the University of Minnesota, will be directly involved with the project, conducting research and advising the research assistant a graduate and undergraduate student involved in this project. He is contributing approximately 20% of his time at no cost to the project and the use of his laboratories, greenhouse and growth chamber space. In addition, he has agreed to use the *Rhizobium* Research Laboratory as a repository for the *Rhizobium*, strains collected from native plants for this project. Other scientists at the University of Minnesota will be drawn on for various aspects of the project. It is hoped that the graduate student hired to work on this project can be a joint appointment between the Soil Science Department and the newly relocated Ecology Department. The Soil Science Department is contributing the use of laboratory, greenhouse and growth chamber facilities. Fully furnished office space will be provided for the graduate student. Computer facilities available to the project through the Soil Science Department include Macintosh and IBM compatible computers, laser printers, and slide makers. It is unlikely that the Soil Science Department will have additional monies available to donate to the project.

The gravel pit owners/operators, Palmer Peterson and Peter Fischer, have agreed to cooperate on this project by considering their pits as potential sites for a reclamation project. Their inclusion in the project will depend on the characteristics and availability of appropriate sites. The owner/operators actual time spent on the project would constitute a small portion of time. When choosing project sites, we will be certain to include privately owned pits as candidates.

The former Metropolitan Waste Control Commission, now under the Met Council is the municipal agency that produces the N-Viro Soil. Bryce Pickart, Operational Planning and Engineering Manager, has a knowledgeable and capable staff with expertise in the production and use of N-Viro Soil. Their contribution will include the N-Viro Soil itself and some staff time advising the project. Steve Stark, the staff Soil Scientist/Agronomist, has been involved with the field application of NVS since its introduction to the state of Minnesota. His continued oversight and involvement will be utilized by this project.

XII. Reporting Requirements: Semiannual six-month workprogram update reports will be submitted not later than January 1, 1996, July 1, 1996, January 1, 1997, and a final six month workprogram update and final report by June 30, 1997.

XIII. Required Attachments:
1. Qualifications: See attached vitae of Project Manager, Kathryn Draeger and Dr. Peter Graham, Department of Soil Science.
2. Project Staffing Report: Attached

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Table 1. Comparison of heavy metal concentrations in N-Viro Soil and agricultural soil, and the limits placed on Exceptional Quality (EQ) biosolids for land application

Element	**Range in Agricultural Soils** (mg/kg)[1]	**Mean in N-Viro Soil** (mg/kg)[2]	**EPA limits for land application of EQ Biosolids** (mg/kg)[3]
Arsenic	.01-8	7.61	41
Cadmium	.01-2.4	.83	39
Copper	2-250	134	1,500
Lead	2-300	48	300
Molybdenum	.2-5	1.38	no limit set
Nickel	2-1000	54.7	420
Selenium	.01-2	1.69	36
Zinc	10-300	186	2,800

1. B.J. Alloway. 1990. *Heavy Metals in Soils*. p. 38. J. Wiley Press, New York..
2. Logan, T. and B. Harrison. 1993. Chemical and Physical Properties of 28 N-Viro Soils from Facilities in the U.S., U.K. and Australia. Research Summary, Dept. of Agronomy, Ohio State University.
3. Environmental Protection Agency. 1994. EPA Guide to Part 503 Biosolids Rule. Office of Wastewater Management. Washington, D.C.

Table 2. Rhizobia species collected from prairie areas in Minnesota, and rhizobia species collected from existing cultures

Collected strains- N-Viro project Dec. 1995

- Prairie species
  - Amorpha 44
  - Astragalus 70 (26 now evaluated)
  - Chamaecrista 75
  - Lespedeza 4
  - Petalostemum 58 (28 being tested)
- Known species
  - Pisum (etc) 5 selected strains
  - Phaseolus 5 selected strains
  - 11 Australian inoculant cultures
  - 12 American inoculant cultures

Table 3. Results of U of M study of native legume and rhizobia species- host/strain trials

Astragalus canadensis strain trial: Dec. 1995

Strain /Treatment	Nodule weight (mg fr wght/pl)	Plant weight (mg dry wght/pl)
- N	0	26
Special 1 inoculant	9	30
Average all 26 strains	10	29
Selected strains:		
<> UMR6300	24	29
<> UMR6313	18	38
<> UMR6317	16	40
<> UMR6320	12	36
<> UMR6321	23	38

Table 4.

Soil nutrient levels in prairie locations sampled for rhizobia

Prairie sampled	pH	%N	P_{B1}	Ca	Mg	K	Mn	Fe	Zn	Cu
			⟨---------- ppm Mehlich III ----------⟩							
Weaver Dunes	6.0	0.07	58	451	69	50	18	96	2.1	0.27
	6.0	0.08	48	437	68	34	15	95	1.6	<0.26
Pankratz	8.0	0.34	9	4387	1524	135	161	63	1.95	3.61
	8.0	0.36	10	3967	1467	123	147	67	1.65	3.73
Bluestem	7.3	0.14	27	1584	265	90	108	152	2.08	1.14
	7.0	0.41	19	2900	664	135	189	115	9.77	1.40
Ana Gronseth	7.7	0.48	15	5570	562	181	203	77	6.13	3.80
	7.6	0.49	15	5390	592	259	195	85	4.94	3.76
Chippewa	6.1	0.34	11	2996	523	201	74	166	2.73	1.81
	6.1	0.40	10	3126	537	219	71	172	3.43	1.92
Des Moines River	6.9	0.31	6	3167	542	150	103	111	1.90	1.65
	6.8	0.30	7	3089	529	251	93	91	1.33	1.77
Cottonwood River	6.5	0.40	17	3317	503	134	72	126	2.61	1.30
	6.3	0.33	18	2699	426	143	53	114	3.49	0.98
Joseph Tauer	6.4	0.14	33	1591	277	152	40	117	0.81	0.70
	7.9	0.15	4	3161	731	82	128	103	1.19	1.61

Table 5.

Response of *Petalostemum purpureum* to inoculation in the growth chamber.

Strain tested	mg dry weight/plant
6820	15
6843	14
6831, 6839	13
6813 , 6808, 6805	12
6826, 6837 ,6822	11
- Nitrogen control	5
Average for 40 strains	9.7

Table 6.

Plant growth and nodulation scores for strains of *Chamaecrista* rhizobia evaluated in the growth chamber (Feb-March, 1996

Strain	Plant Growth (mg/plant)	Nodulation Score (0 to 5)
6437	113	3.0
6436	114	2.8
6434	107	3.5
6433	108	2.4
6431	104	3.0
Nitragin Inoculant	97	1.8
6400	37	0
- N	52	0
Average for 30 strains	78	

Table 7.

Effect of N-VIRO amendment on % germination of selected legumes (Glasshouse, 1996)

LEGUME	N-VIRO LEVEL(tons/ha)				
	0	10	20	40	80
Phaseolus bean	85	75	80	50	70
Soybean	20	15	20	10	0
Chickpea	95	80	95	100	100
Pea	85	60	85	60	70
Cowpea	90	80	70	85	90

Table 8

Impact of N-Viro Soil on Soil Nutrient Composition
MNDOT Site--Shokopee, MN

	% Organic Matter	NH4 (ppm)	NO3 (ppm)
N-Viro Soil	11.7	8	14.7
N-Viro Soil	12.8	17.5	5.4
N-Viro Soil	13.7	6.2	11.2
ave.	**12.73**	**10.6**	**10.4**
ave.dev.	0.69	4.62	3.36
Control	16.4	8.7	5.6
Control	14.7	4.3	5.6
Control	6.8	4.3	4.4
ave.	**12.63**	**5.8**	**5.2**
ave.dev.	3.89	1.96	0.53
	Carbon	**O.M.**	**P (Bray)**
	%	%	ppm
	(ave.)	(ave.)	(ave.)
N-Viro Soil	6.2	9.6	0.26
Control	7.1	10.4	0.3
n=3			
Source: Dr. Riz Charvat			
Data from newly constructed wetland/prairie near Shokopee, MN.			

Table 9. Grey Cloud Island Plant Biomass Data

Average Biomass/Plant (g): Grey Cloud Isl
Days After Planting: 90

Treatment	Weight (g)
NV 15	1.47
NV 30	0.39
NV 60	0.67
MSW	0.54
Topsoil	0.54

Table 10. Grey Cloud Island Nodulation Data

Average Nodule Weight/Plant (g)
Days After Planting: 90

Treatment	Weight (g)
NV 15	0.001
NV 30	0
NV 60	0
MSW	0
Topsoil	0.01

Table 11

Source of the rhizobia for prairie legumes collected for strain evaluation. The sources include Scientific Nature Areas, MnDOT revegetation sites and other strain collections.

	A.canescans	A.canadense	C.fasciculata	D.purpurea	L.capitata[1]
Pankratz	1	6	2	4	0
Anna Gronseth	1	5	0	0	0
Weaver Dunes	6	7	29	6	0
Bluestem	8	10	3	2	0
Chippewa	14	8	7	6	0
Springfield	1	1	7	6	0
Windom	5	1	11	5	0
Warren	0	3	0	0	0
Roscoe	12	12	0	2	0
New Ulm	0	4	5	1	0
Arboretum	1	2	0	4	3
USDA collection	2	5	0	0	0
China	0	13	0	0	0
MnDOT	0	0	0	17	1
Other	0	0	3	9	0
Total	51	77	67	62	4

[1] Only limited efforts were made to collect *Lespedeza* rhizobia since this species accepts the same rhizobia as *Chamaecrists.*

Table 12

Response to inoculation in *Dalea purpurea*

- Date of experiment: March, 1997
- Strains evaluated: 38
- Response of strains selected for futher evaluation

Strain	Nodules plant $^{-1}$	Plant fresh weight (mg)
6815	11.0	54.3
6834	10.8	44.3
6803	6.5	40.6
6808	7.0	41.6
6813	10.0	33.8
Mean of 38 Tested Strains	6.1	21.9

Table 13

Response to inoculation in *Astragalus canadense*

· Date of experiment:

December 1995 April 1997

· Response of strains selected for futher evaluation

Strain	Pl.d.wt (mg)	Strain	Pl.f.weight (mg)
6300	29	6349	176
6313	38	6318	153
6317	40	6305	150
6320	36	6316	122
6321	38	6315	103
Mean of 26 tested strains	29	Mean of 13 strains	97

Table 14

Response to inoculation in *Chamaecrista fasciculata*

· Date of experiment:

Feb/March 1996 — October 1996

· Response of strains selected for futher evaluation

Strain	Pl.f.wt (mg)	Strain	Pl.f.weight (mg)	Nod. mass (mg)
6404	101	6404	427	94
6418	92	6423	390	170
6433	108	6439	456	192
6434	107	6434	419	156
6435	114	6437	435	154
-N control	52		45	0
Commercial Inoc	97		182	78
Mean 30 strains	77			

Table 15

Growth of selected *Dalea* species (mg fresh st pl^{-1}) following inoculation with effective prairie rhizobia, or with Liphatec inoculant preparations[1, 2, 3]

Host species	6803	6834	6843	6850	F	M
D. purpurea	100	94	60	90	155*	75
D.enneandra	190	285*	165	160	200	230
D.aurea	110	220*	115	115	185	195
D.candida	300	295	215	70	370*	280
D.ieporina	300*	230	100	240	240	260
C.cornata	175	165	190	180	345	385*

[1]Both F and M inoculants were included because *Coronilla* inoculant is sometimes used for *Dalea.*

[2] Only evaluated with two replicates per strain because of limited seed availability. Experiment will be repeated when additional seed is available.

[3] We have also tested strains for nodulation of Pisum sativum, Medicago sativa, Trifolium repens, Phaseolus vulgaris and M.atropurpureum. Only P.vulgaris was nodulated and the nodules formed were ineffective.

Table 16

Percent Germination of *Chamaecrista fasciculata* seeds following scarification for varying periods of time with concentrated sulfuric acid.

	Period of exposure to acid (Mins)					
Days after treat	0	2.5	5	7.5	10	15
2	0	4	8	10	8	25
5	1	8	14	25	18	39
9	2	9	15	27	21	44

Table Summary of 1996 biomass and percent cover data.

Site	Treatment	Biomass (g/0.5 m^2)					Percent Cover					
		n	Min	Max	Mean	S.D.	n	Min	Max	Mean	Median	SD
Demo slope	NVS Top	4	12.685	28.690	19.756	8.265	24	15.0	97.0	57.271	62.5	23.851
	Middle	4	9.215	35.309	19.699	11.058	24	37.5	85.0	54.896	62.5	16.656
	Bottom	4	4.789	65.916	28.063	28.008	24	37.5	99.5	70.688	73.75	19.239
	All	12	4.789	65.916	22.506	16.816	72	15.0	99.5	60.951	62.5	21.049
"	Fert. Top	4	7.491	19.996	11.652	5.710	24	3.0	85.0	40.583	37.5	23.887
	Middle	4	1.821	10.612	5.511	3.700	24	15.0	85.0	43.750	37.5	14.670
	Bottom	4	1.010	32.042	13.840	13.740	24	15.0	85.0	49.167	62.5	18.660
	All	12	1.010	32.042	10.334	8.813	72	3.0	85.0	44.500	37.5	19.496
"	MSW Top	4	1.946	20.302	10.609	7.678	24	15.0	97.0	56.438	62.5	19.873
	Middle	4	12.858	41.147	27.461	14.695	24	15.0	85.0	56.875	62.5	22.033
	Bottom	4	6.396	43.442	27.506	17.671	24	15.0	85.0	56.146	62.5	18.867
	All	12	1.946	43.442	21.859	15.138	72	15.0	97.0	56.486	62.5	20.015
"	Control Top	4	3.298	6.823	5.141	1.464	24	15.0	85.0	49.167	62.5	18.660
	Middle	4	9.469	10.939	10.004	0.644	24	3.0	62.5	22.958	15.0	18.709
	Bottom	4	2.759	6.448	4.183	1.983	24	3.0	62.5	21.042	15.0	15.665
	All	12	2.759	10.939	6.648	2.965	72	3.0	85.0	31.056	37.5	21.740
Lysimeter plots	NVS	3	1.242	11.290	7.659	5.573	24	37.500	97.000	68.875	n/a	18.280
"	MSW	3	6.418	29.726	15.457	12.503	24	37.500	97.000	71.250	n/a	19.247
"	Fertilizer	3	6.513	9.284	7.802	1.395	24	37.500	97.000	76.042	n/a	17.884
Washed sand plots	NVS 60	3	0 (no sample)	7.15	3.575	n/a	24	3.000	85.000	28.208	n/a	19.906
"	NVS 30	3	12.95	36.15	24.55	n/a	24	15.000	62.500	45.104	n/a	16.656
"	NVS 15	3	1.11	11.18	6.145	n/a	24	15.000	62.500	22.604	n/a	13.032
"	MSW	3	4.43	7.69	6.06	n/a	24	3.000	37.500	11.438	n/a	8.069
"	Topsoil	3	3.84	5.52	4.68	n/a	24	0.500	15.000	4.688	n/a	4.784
"	Topsoil+Fert.	3	6.79	10.18	8.485	n/a	24	15.000	85.000	34.271	n/a	20.397

Note: The relatively small number of percent cover and biomass samples on the lysimeter plots and the washed sand plots produced results that should be considered to be less reliable than the results of the demonstration plots. For example, the location of a biomass plot on the lysimeter or washed sand plots may happen to fall on a bare patch of ground, so that the biomass value is anomalously low, but if the sample had instead been collected a few feet away it may have included a single large plant, which would have produced a much higher biomass value. On the demonstration plot, where many more sample were collected, the effects of such localized variations are minimized.

Table 18

Comparison of Soil Treatments and Their Impact on Plant Biomass

	NVS	MSW	Fert.	Control
Plant	**131.6**	**54.3**	**53.6**	**57**
Biomass	**48.5**	**53.8**	**112.49**	**16.9**
Dry Wt. (g)	**117.7**	**66.46**	**35.1**	**21.3**
ave.	**99.27**	**58.19**	**67.06**	**31.73**
ave.dev.	33.84	5.52	30.28	16.84

Data from demonstration slope, Grey Cloud Island.

NVS=N-Viro Soil

MSW=Municipal Solid Waste Compost

Fert=fertilizer

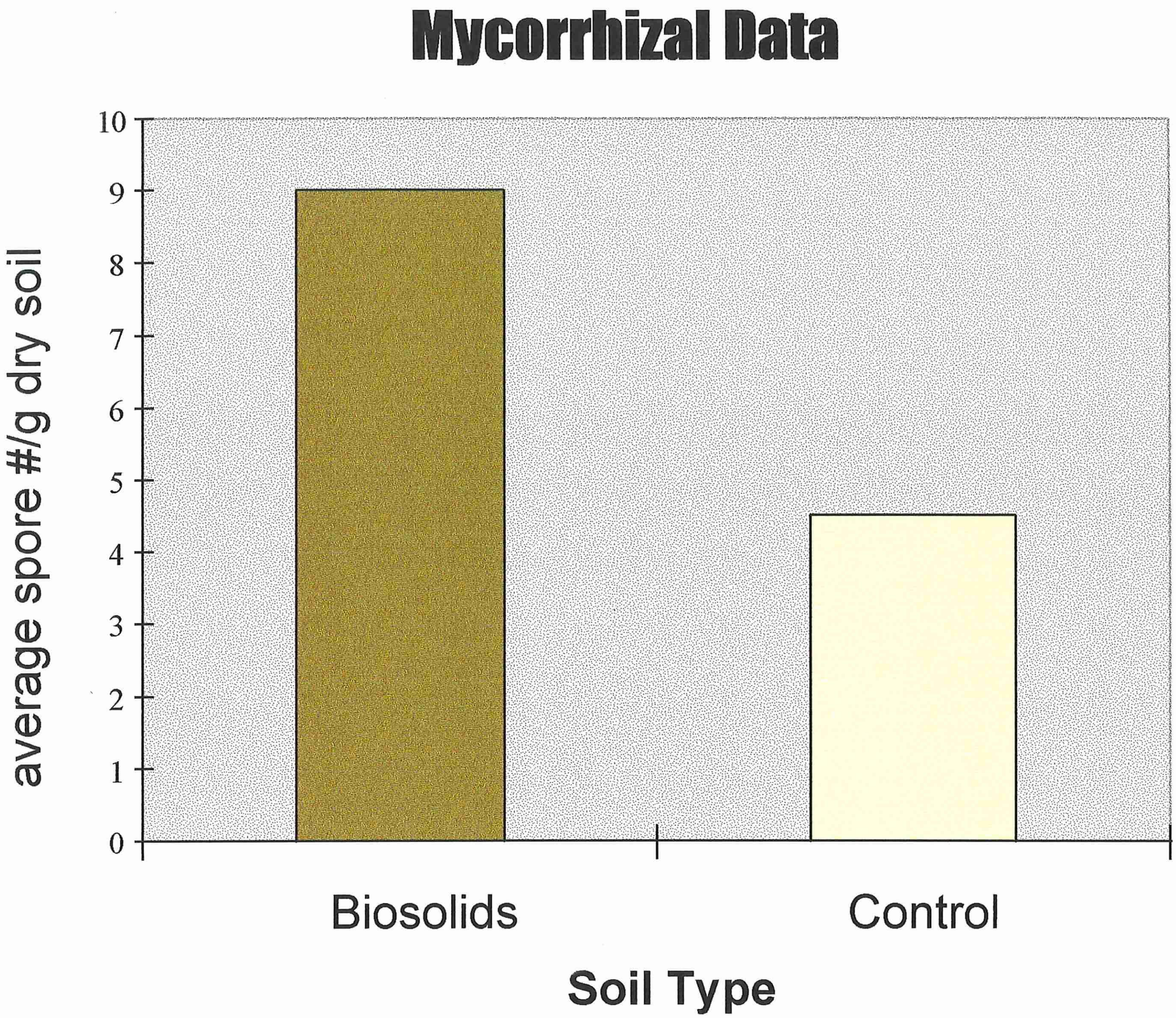
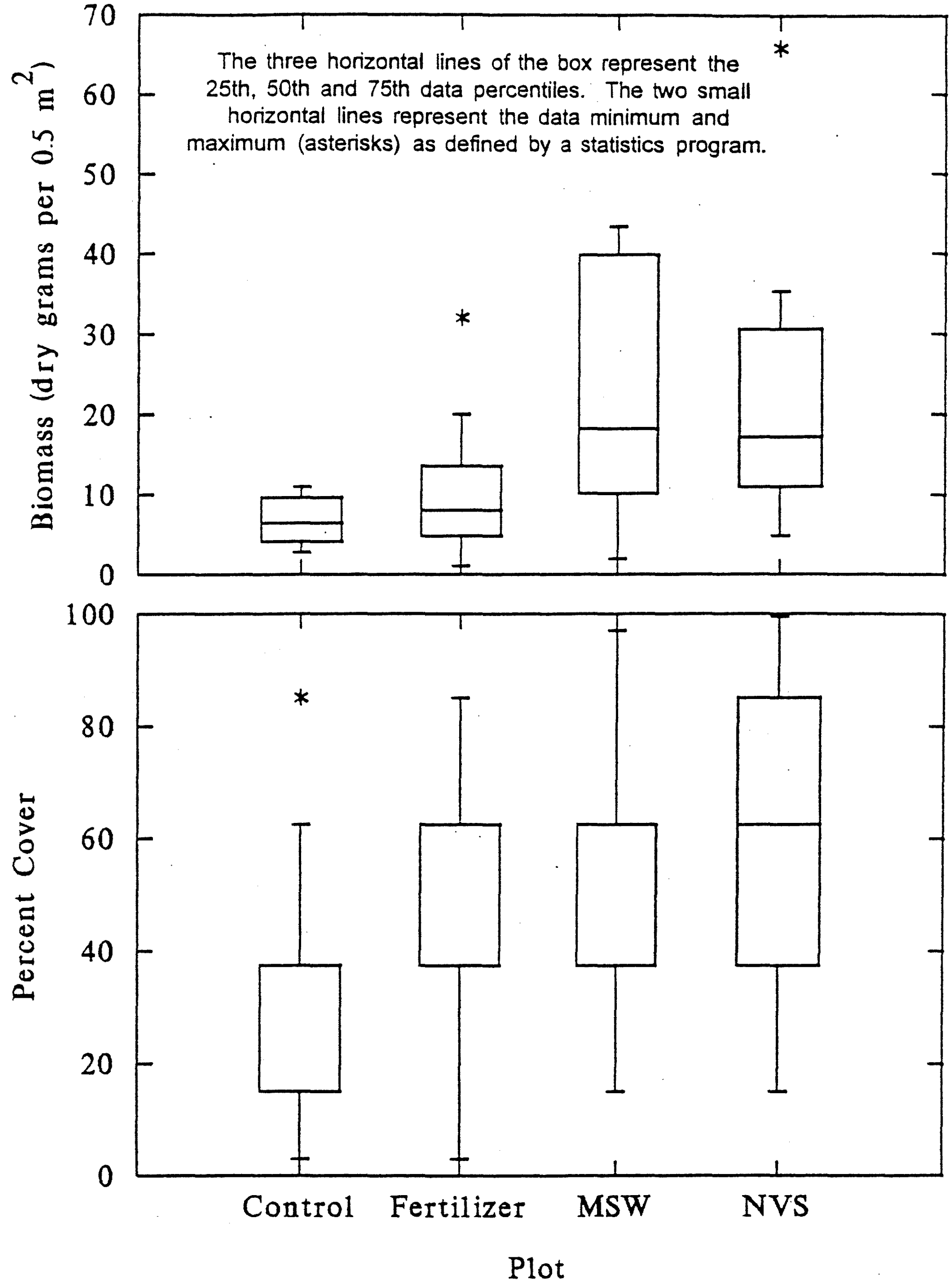


Figure 1: Comparison of average spore number between area treated with biosolids and an area left untreated at a newly created wetland/prairie near Shakopee, Minnesota. Bars show standard error.

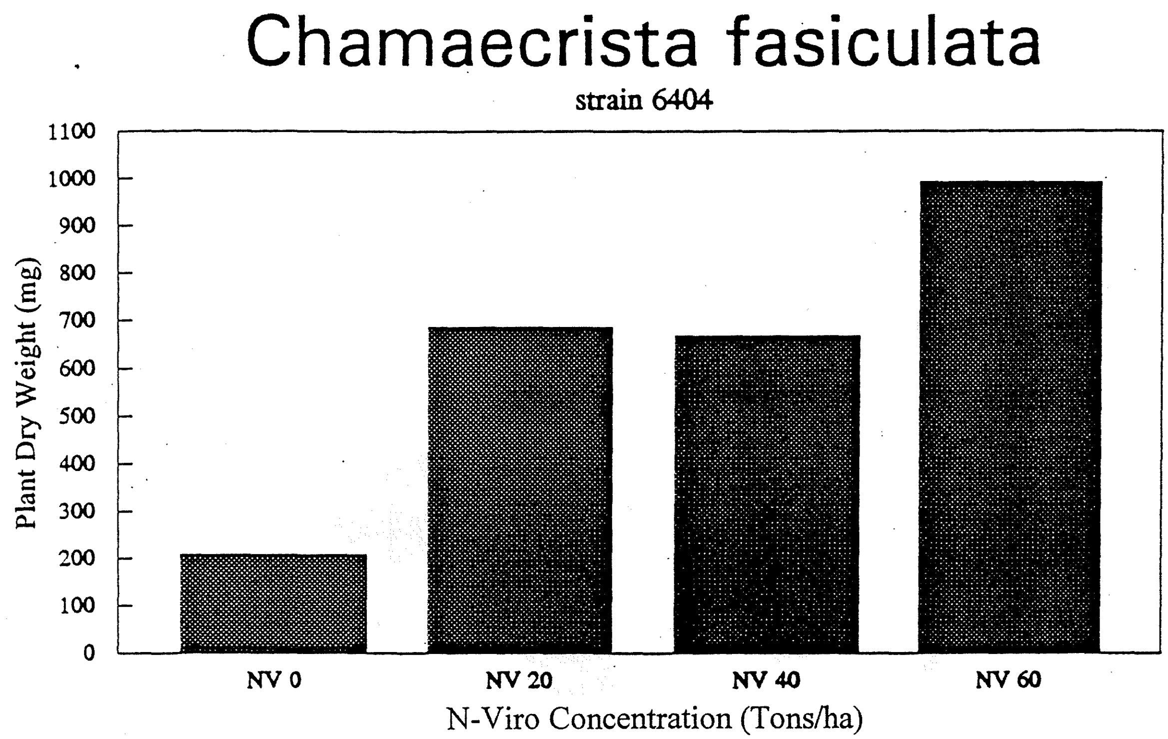
Figure2

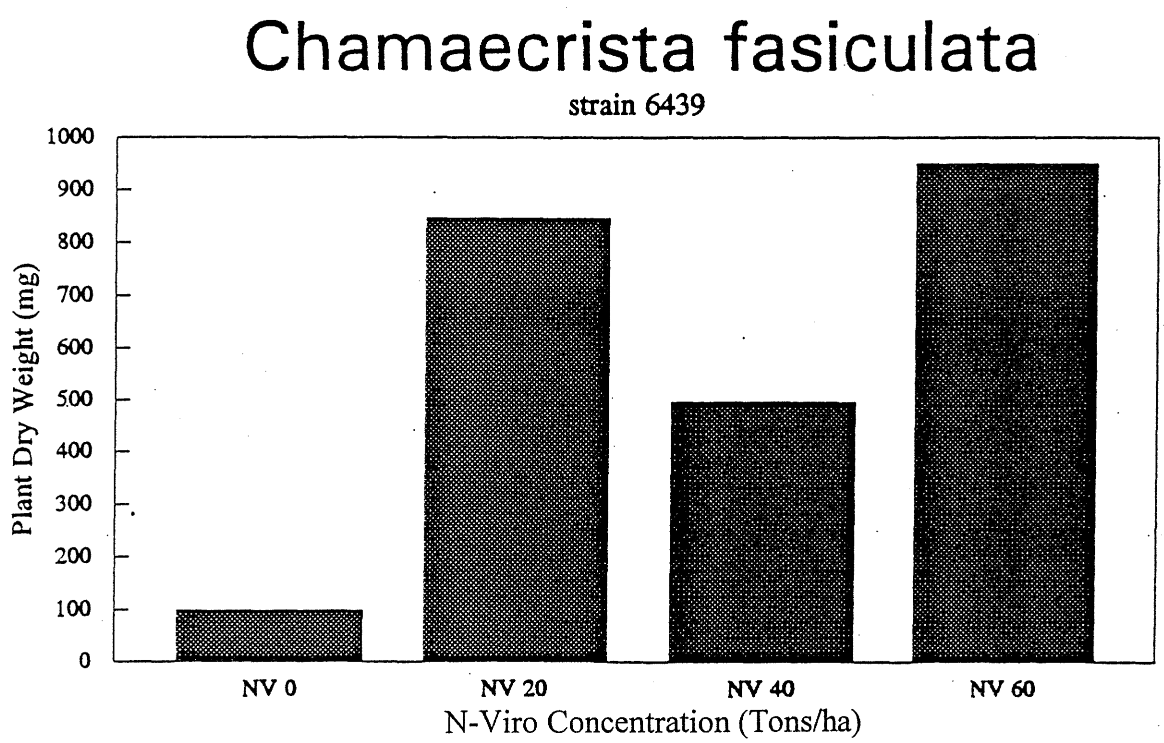


Box plot representatations of the 1996 percent cover and biomass data from the demonstration plots.

Graph 1

	Cham 6404		Cham 6439
NV 0	207.25	NV 0	99.25
NV 20	685.5	NV 20	846.25
NV 40	667.25	NV 40	496.75
NV 60	991.25	NV 60	948.5





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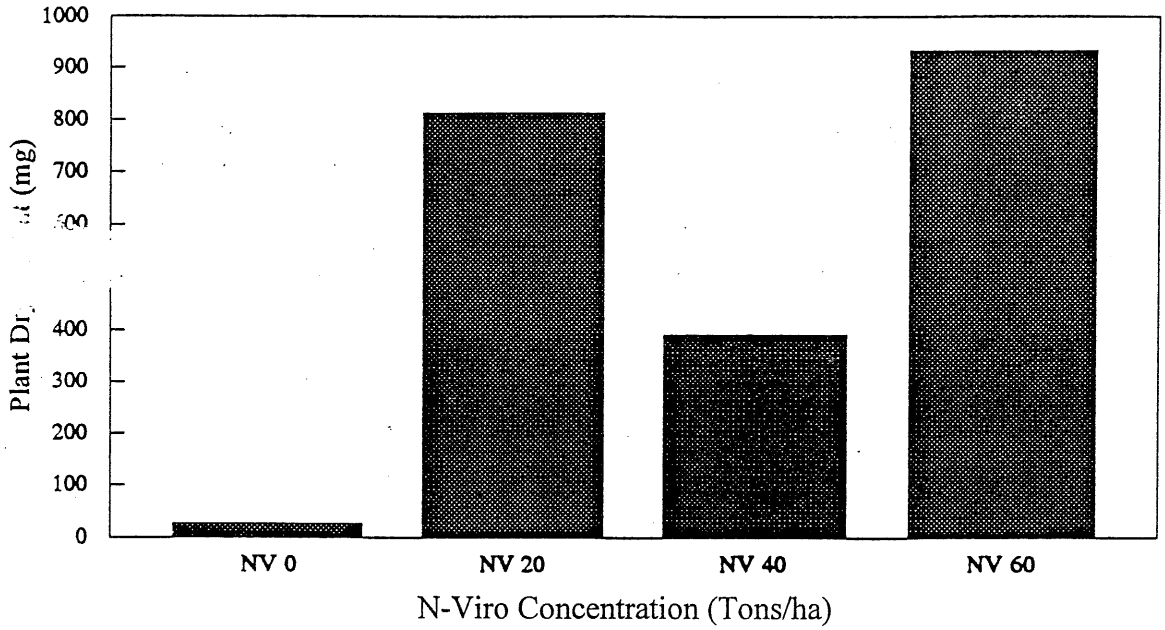
Graph 2

	Desm 6404		Desm 6439
NV 0	27	NV 0	16
NV 20	813.5	NV 20	727.75
NV 40	391.5	NV 40	333.5
NV 60	934	NV 60	467.5

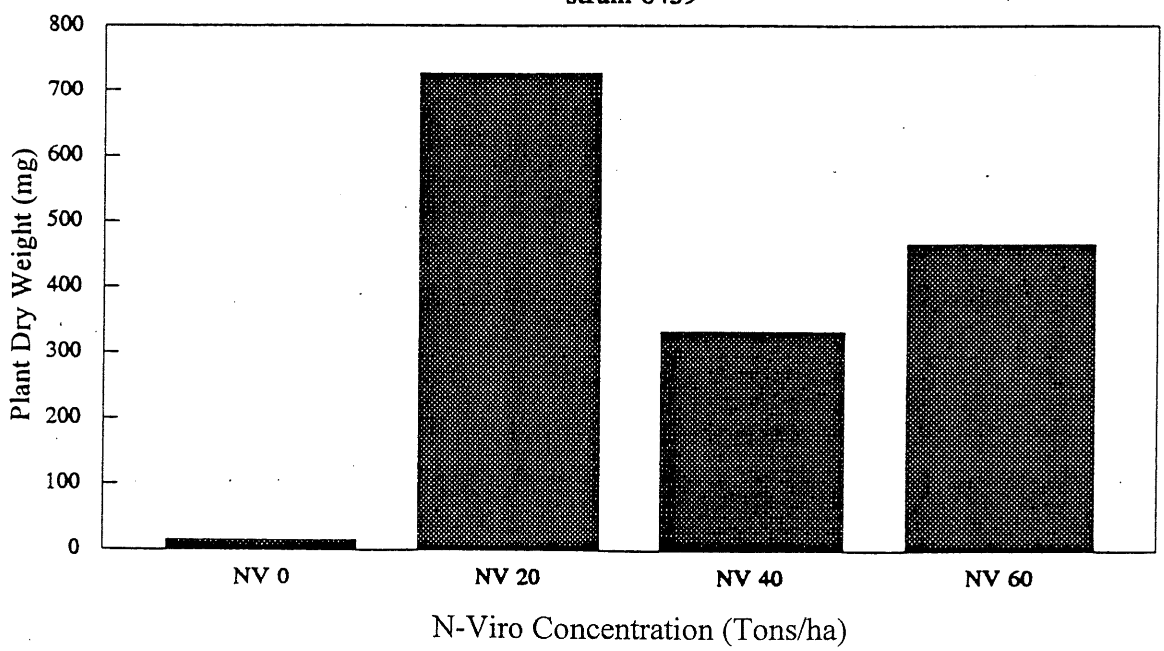
Desmodium canadense

strain 6404



Desmodium canadense

strain 6439



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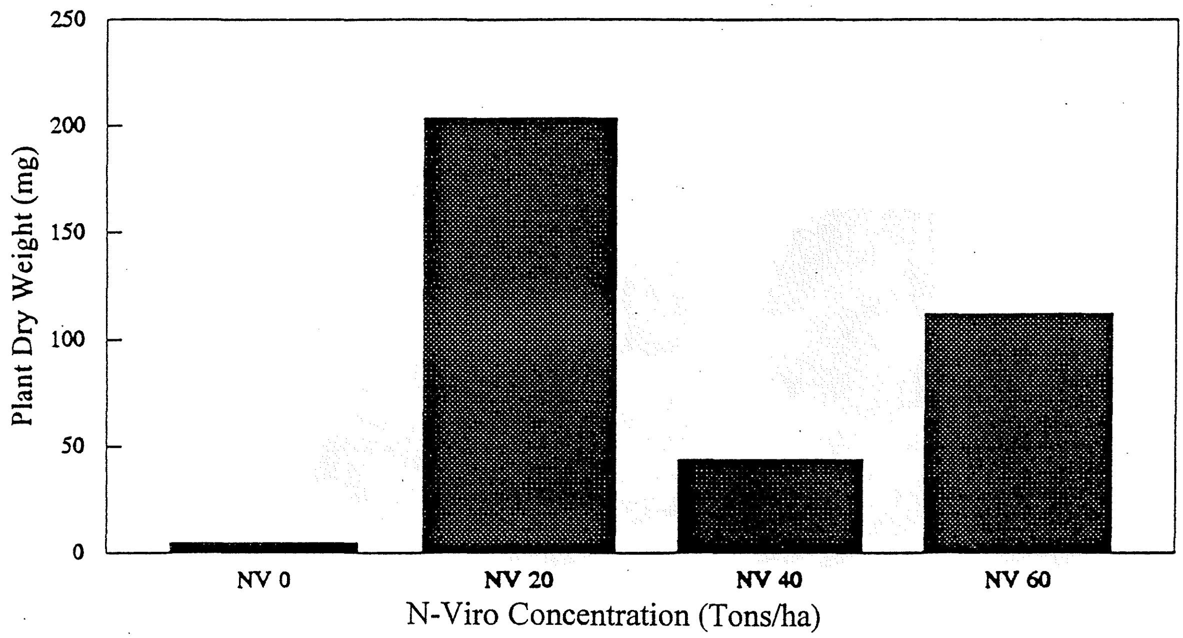
Graph 3

	Lesp 6404
NV 0	4.75
NV 20	203.5
NV 40	44.25
NV 60	112

	Lesp 6439
NV 0	3.75
NV 20	50
NV 40	52.75
NV 60	6

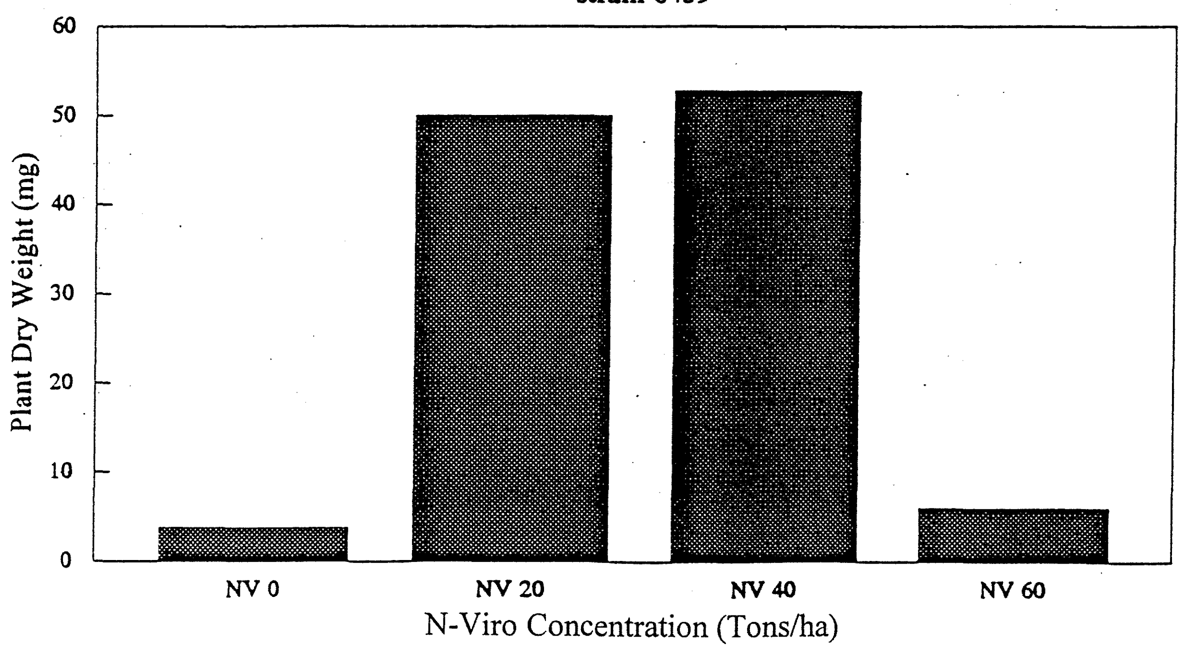
Lespedeza capitata

strain 6404



Lespedeza capitata

strain 6439



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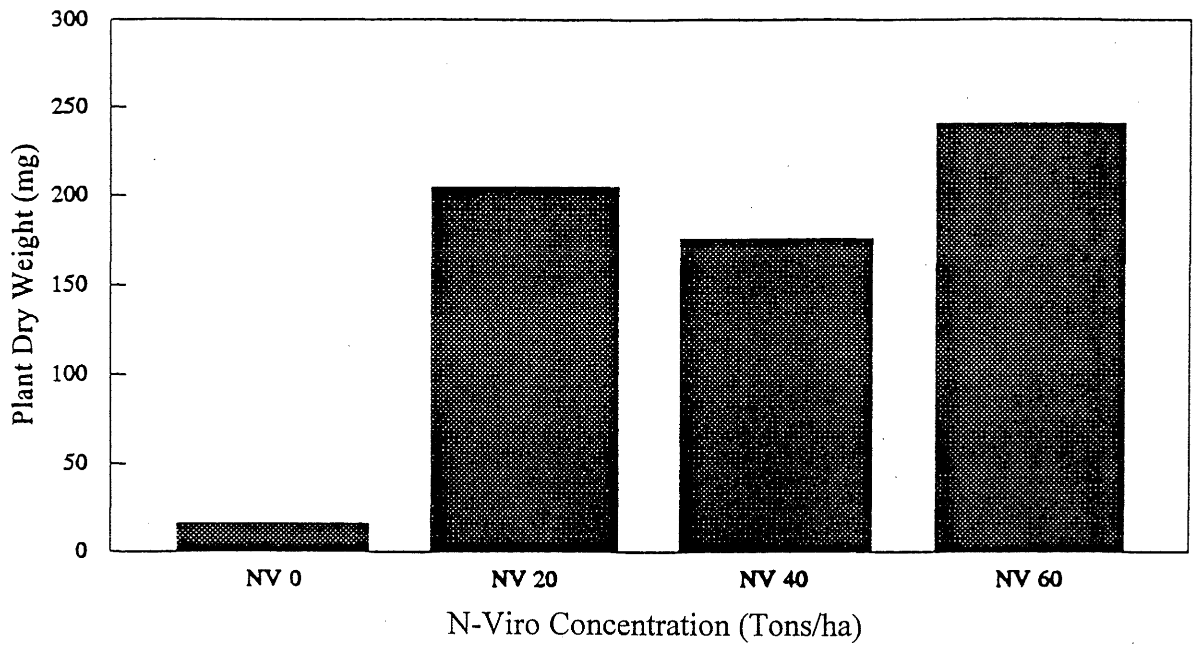
Graph 4

	Glyc
NV 0	16.25
NV 20	204.5
NV 40	176
NV 60	240.75

	Astrag
NV 0	66.5
NV 20	549
NV 40	955.5
NV 60	1080

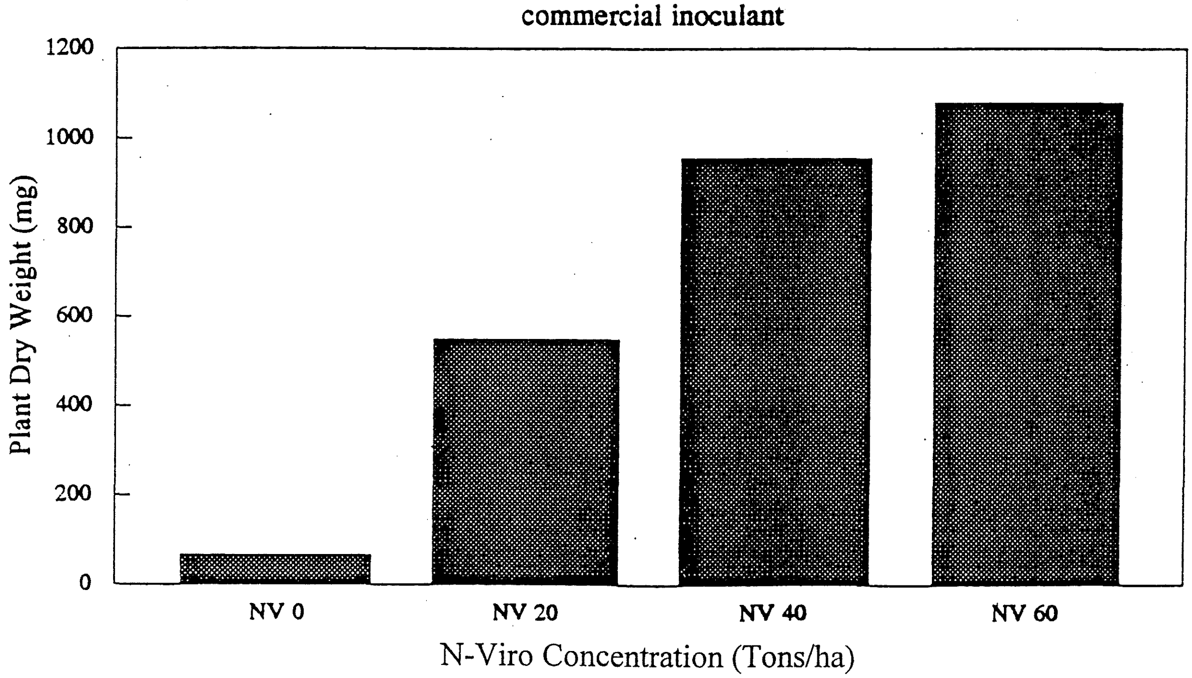
Glycyrrhiza lepidota

commercial inoculant



Astragalus canadensis

commercial inoculant

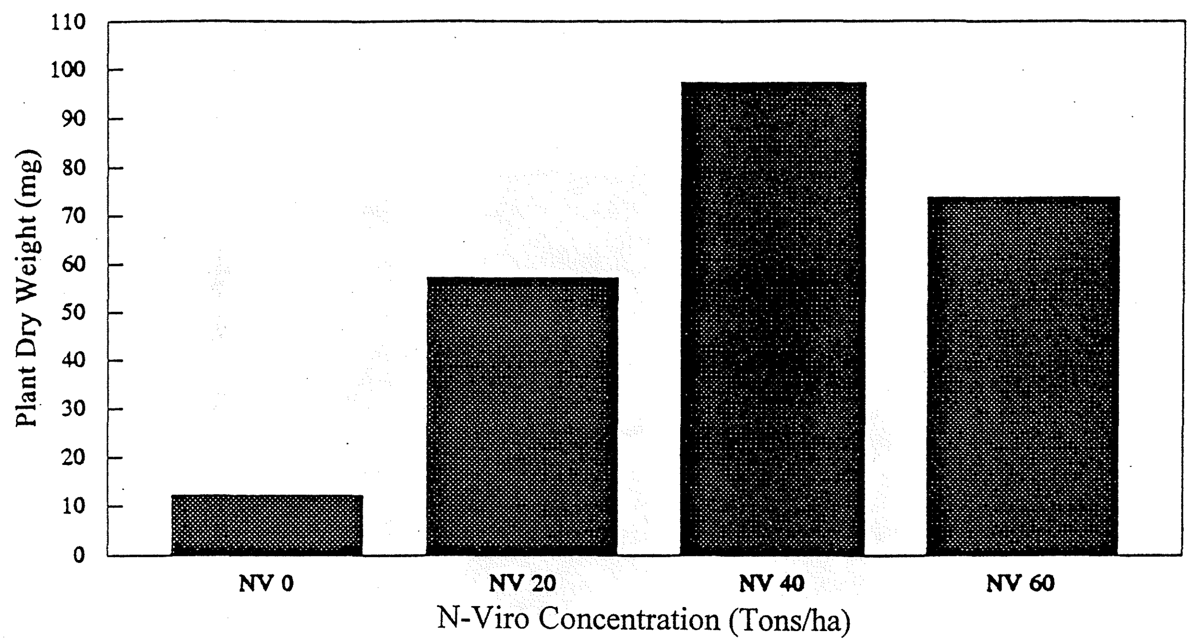


Graph 5

	amorpha		Petal
NV 0	12.25	NV 0	77.25
NV 20	57.25	NV 20	316.25
NV 40	97.25	NV 40	597.75
NV 60	73.75	NV 60	497

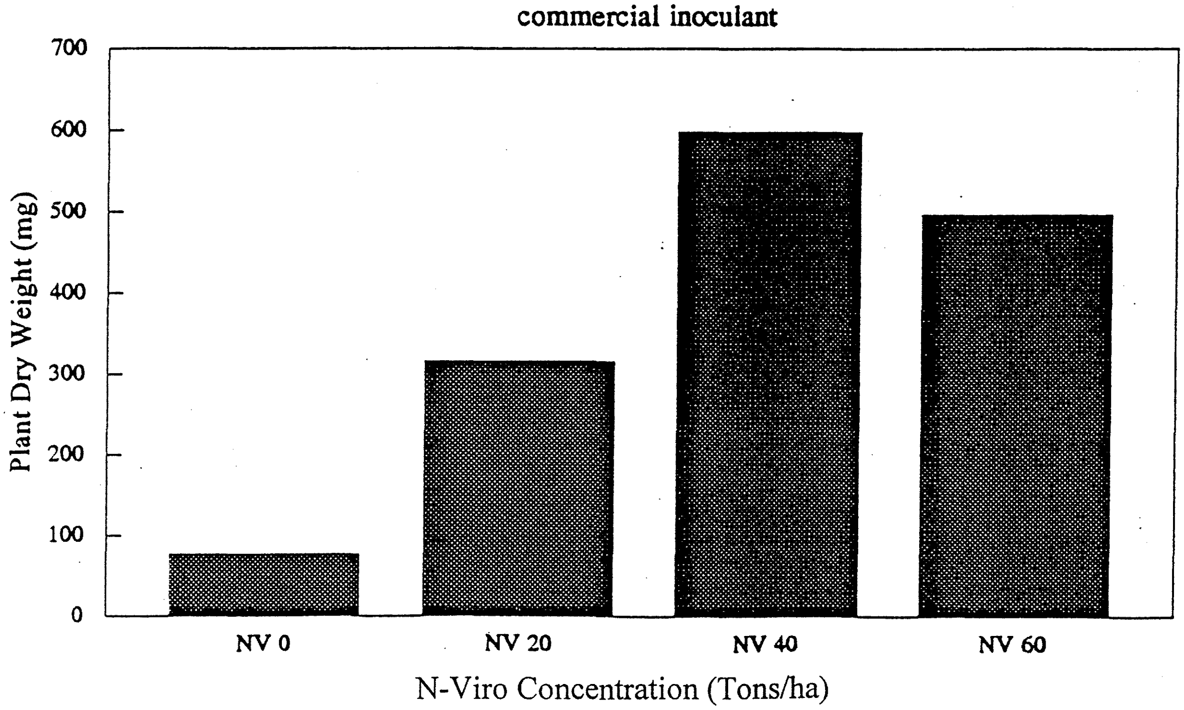
Amorpha canescans

commercial inoculant



Petalostemum perpureum (or Dalea perpurea)

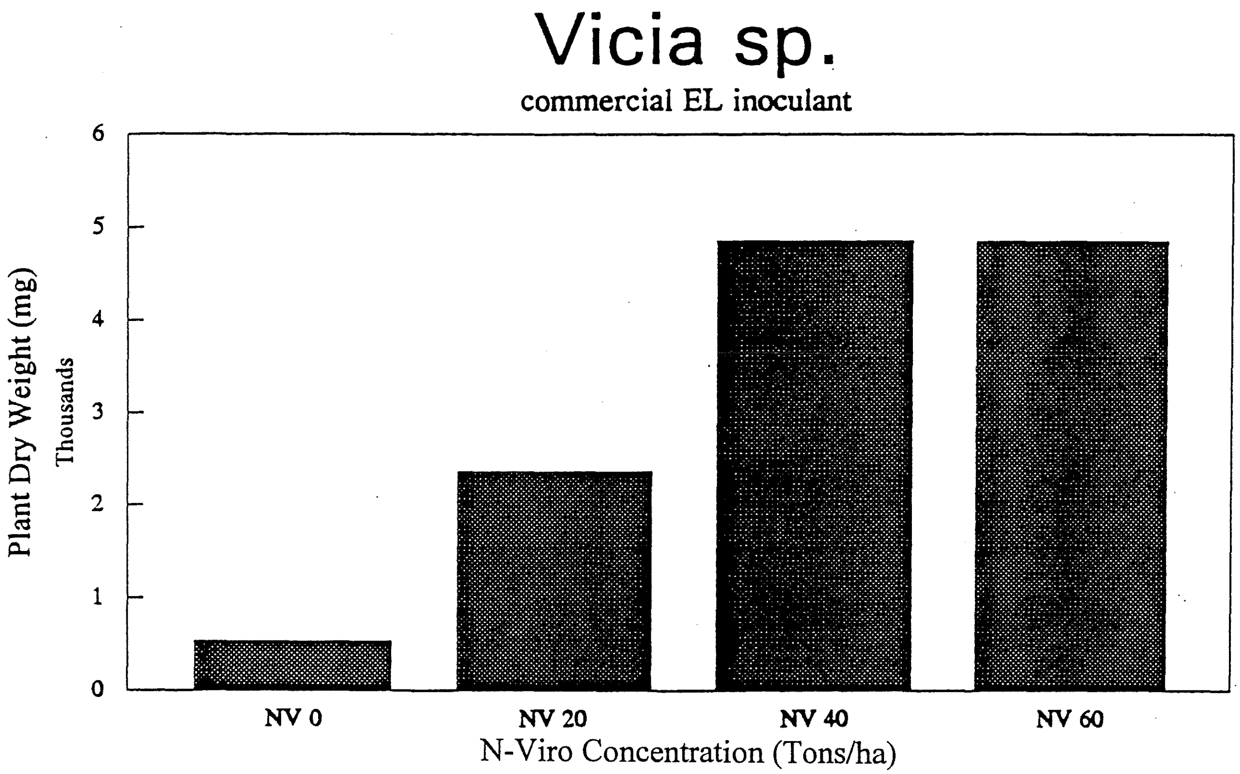
commercial inoculant



c:\

Graph 6

	Vicia sp.
NV 0	534.25
NV 20	2362.5
NV 40	4851
NV 60	4847.5



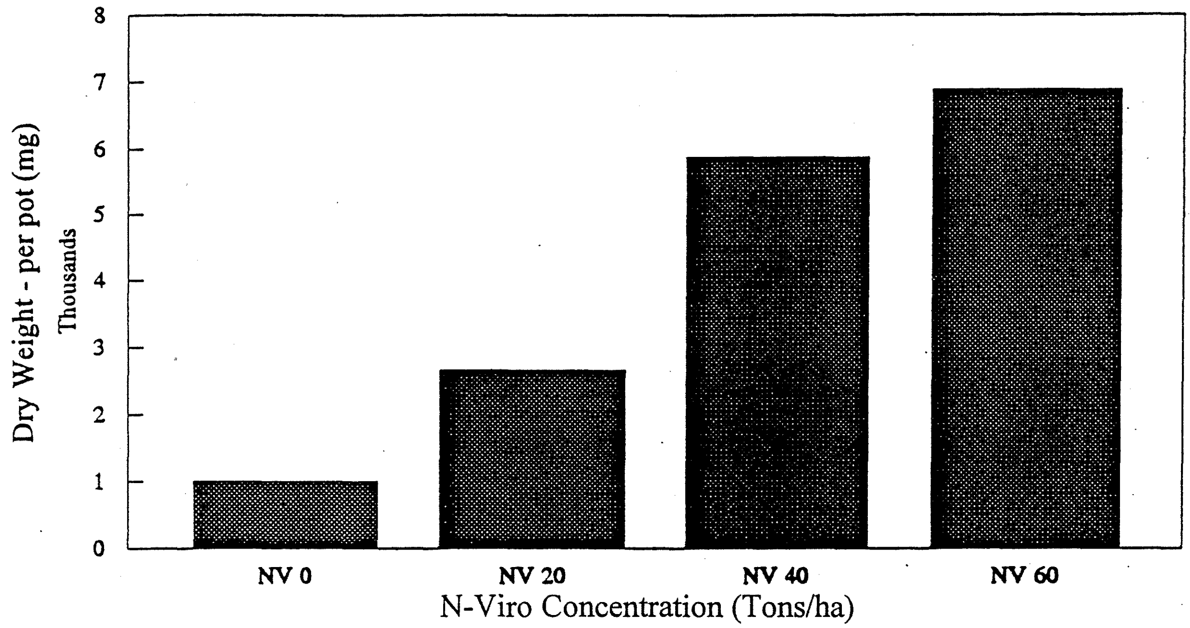
c:\

Graph 7

	Andropogon		Sorghastram
NV 0	995	NV 0	322
NV 20	2662.5	NV 20	1417.5
NV 40	5873	NV 40	1950
NV 60	6885	NV 60	2747.5

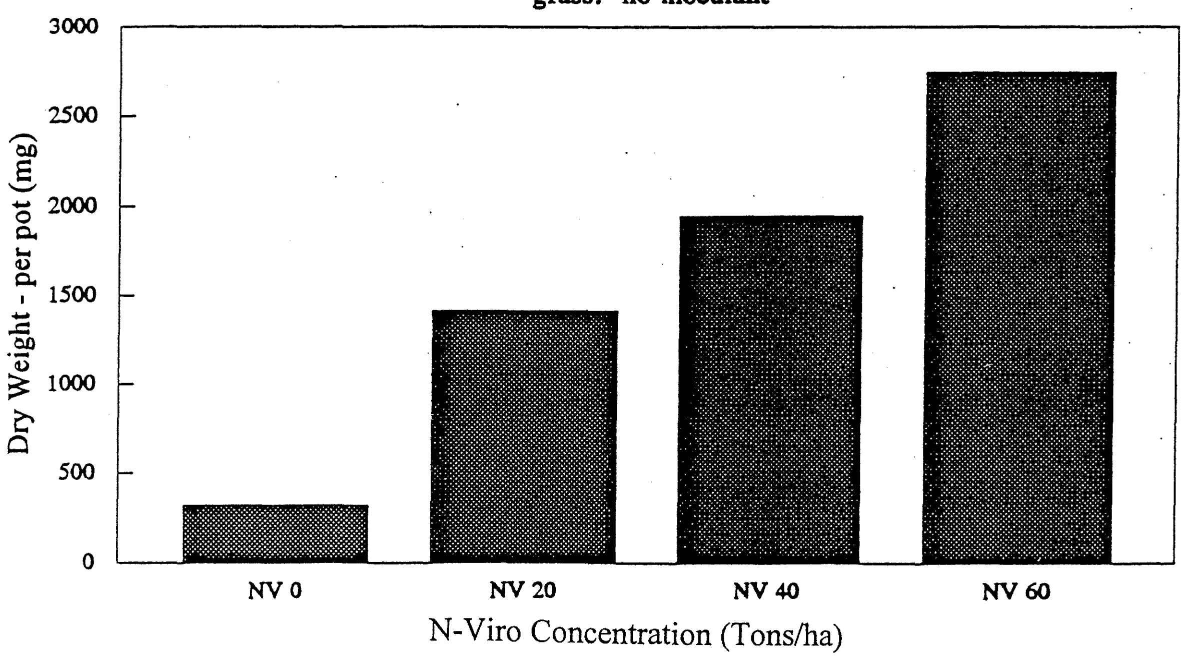
Andropogon gerardi

grass: no inoculant



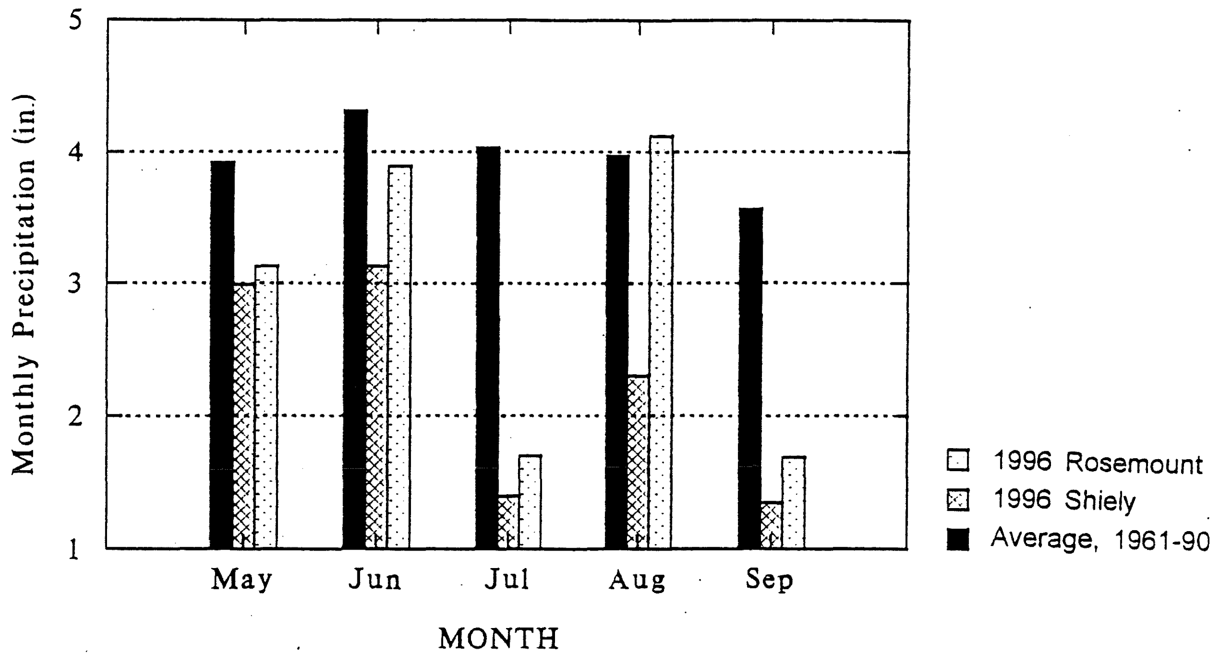
Sorghastrum nutans

grass: no inoculant



c:\

Graph 8



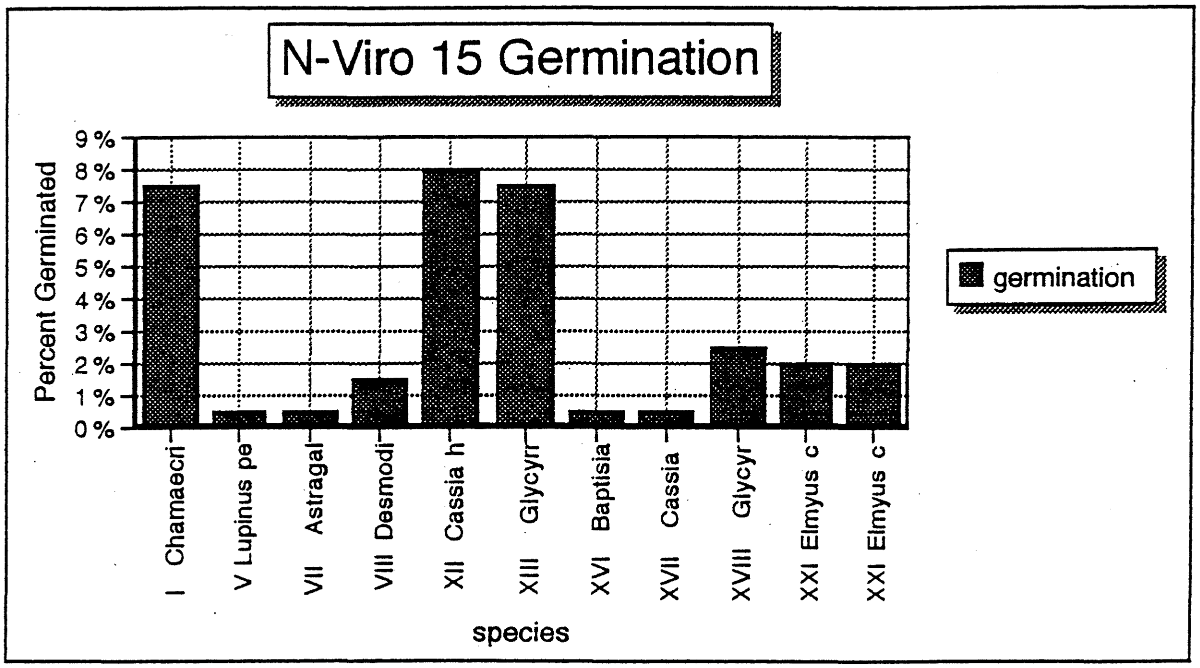
Bar chart of monthly 1996 precipitation recorded at Shiely Co.'s Nelson Mine, compared with both 1996 values and average historical (1961-90) values from the nearby Rosemount weather monitoring station. (2.07 of the 2.99 inches recorded for May fell prior to completion of the demonstration plots.)

Source: Department of Natural Resources

Graph 9

N-Viro 15: 29 Days

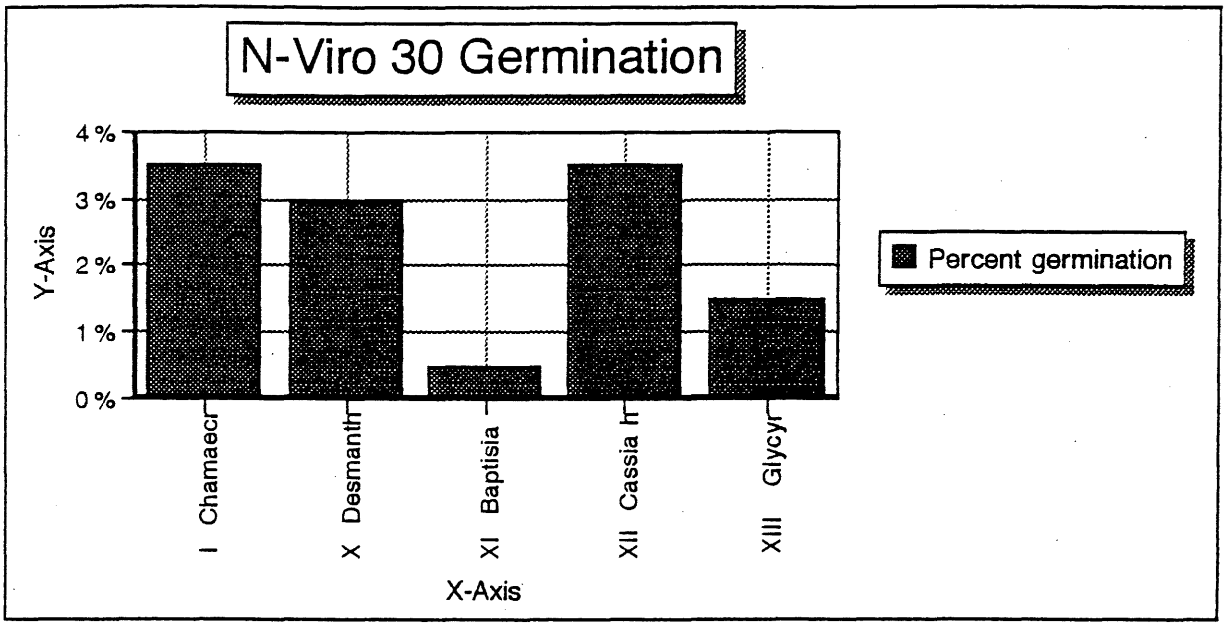
I Chamaecrista fasiculata	8%	15
V Lupinus perenne	1%	1
VII Astragalus canadensis	1%	1
VIII Desmodium canadense	2%	3
XII Cassia hebecarpa	8%	16
XIII Glycyrrhiza lepidota	8%	15
XVI Baptisia australis*	1%	1
XVII Cassia hebecarpa *	1%	1
XVIII Glycyrrhiza lepidota*	3%	5
XXI Elmyus canadensis	2%	4
XXI Elmyus canadensis	2%	4



Graph 10

N-Viro 30

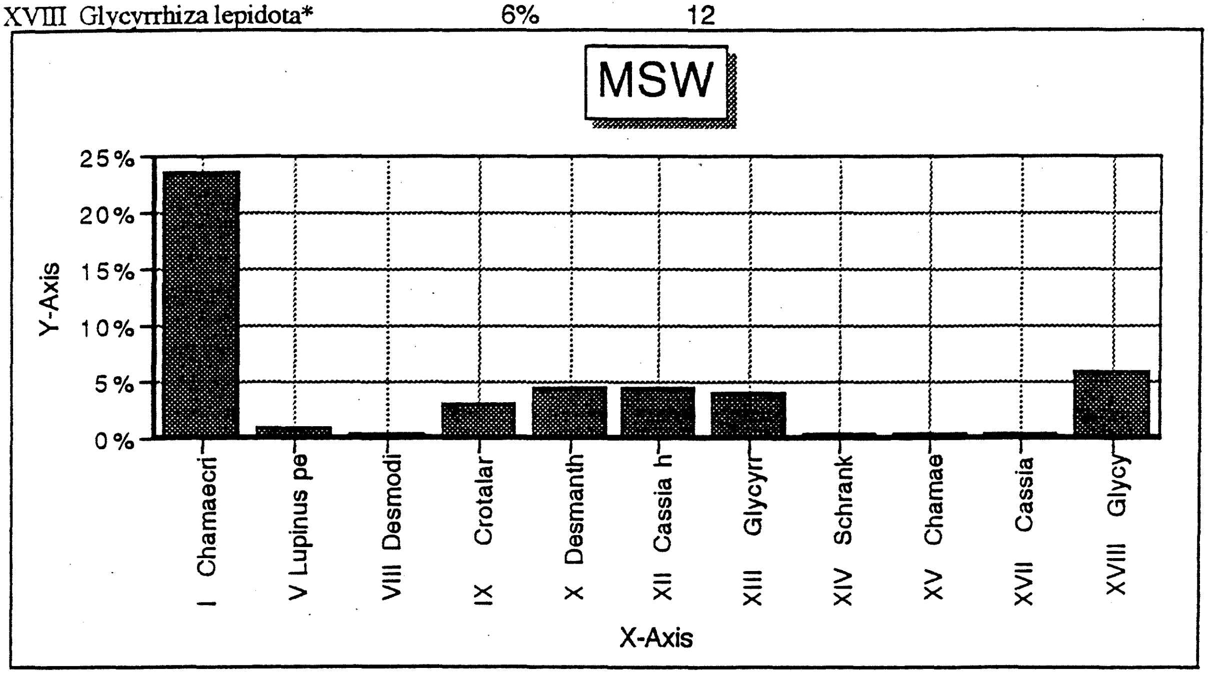
N-Viro 30 Germination	Percent germination	
I Chamaecrista fasiculata	4%	7
X Desmanthus illinoensis	3%	6
XI Baptisia australis	1%	1
XII Cassia hebecarpa	4%	7
XIII Glycyrrhiza lepidota	2%	3



Graph 11

MSW

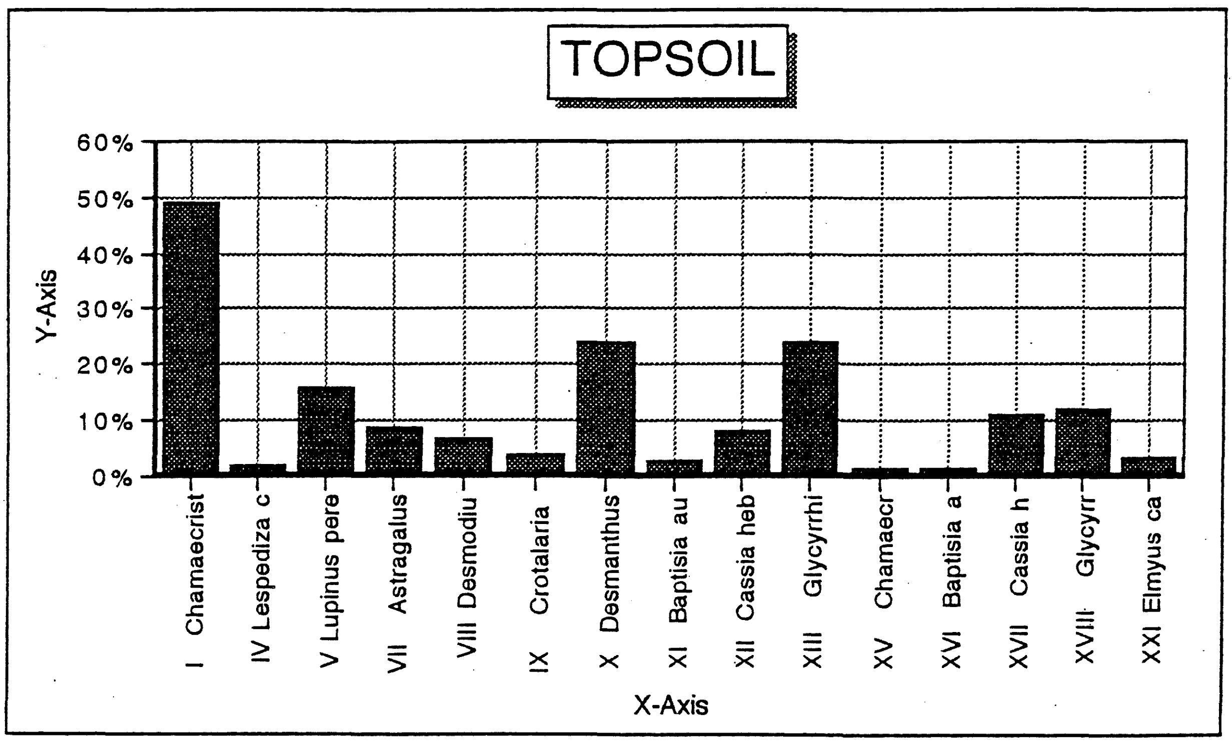
I Chamaecrista fasiculata	24%	47
V Lupinus perenne	1%	2
VIII Desmodium canadense	1%	1
IX Crotalaria sagittalis	3%	6
X Desmanthus illinoensis	5%	9
XII Cassia hebecarpa	5%	9
XIII Glycyrrhiza lepidota	4%	8
XIV Schrankia uncinata	1%	1
XV Chamaecrista fasciculata*	1%	1
XVII Cassia hebecarpa *	1%	1
XVIII Glycyrrhiza lepidota*	6%	12



Graph 12

TOPSOIL

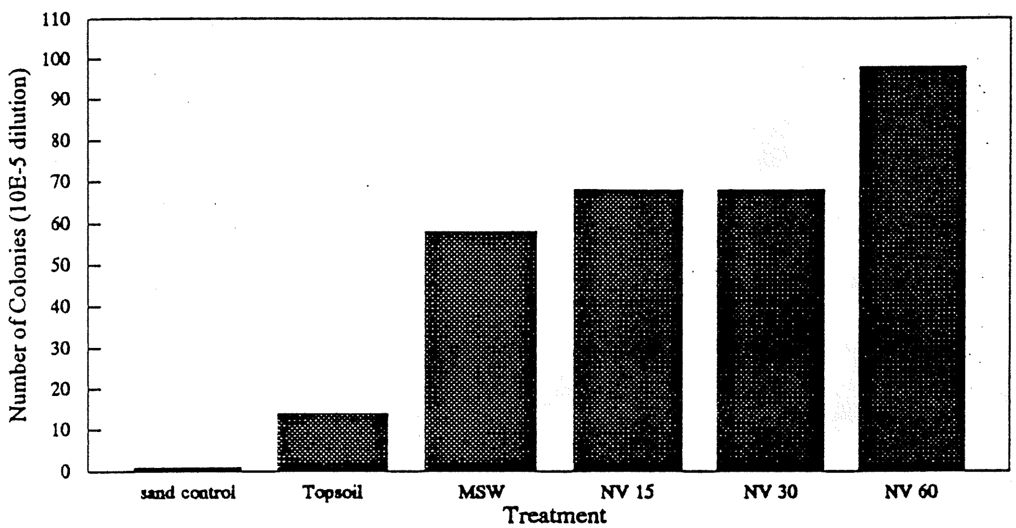
I Chamaecrista fasiculata	49%	98
IV Lespediza capitata	2%	4
V Lupinus perenne	16%	32
VII Astragalus canadensis	9%	17
VIII Desmodium canadense	7%	13
IX Crotalaria sagittalis	4%	8
X Desmanthus illinoensis	24%	48
XI Baptisia australis	3%	6
XII Cassia hebecarpa	8%	16
XIII Glycyrrhiza lepidota	24%	48
XV Chamaecrista fasciculata*	2%	3
XVI Baptisia australis*	2%	3
XVII Cassia hebecarpa *	11%	22
XVIII Glycyrrhiza lepidota*	12%	24
XXI Elmyus canadensis	4%	7



Graph 13a

sand control	0.96
Topsoil	14
MSW	58
NV 15	68
NV 30	68
NV 60	98

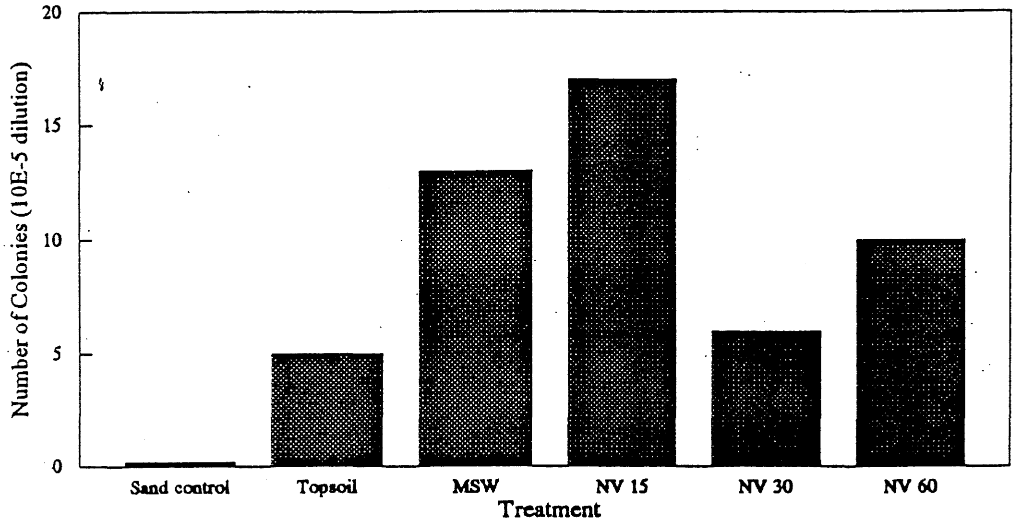
MPN Count: BYMA media



Graph 13b

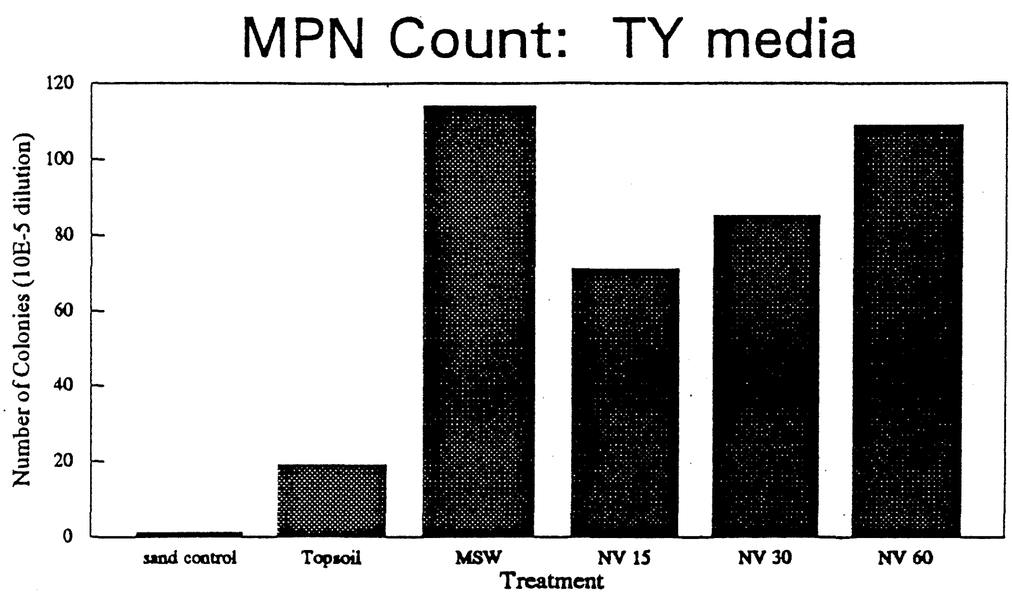
Sand control	0.2
Topsoil	5
MSW	13
NV 15	17
NV 30	6
NV 60	10

MPN Count: PDA media

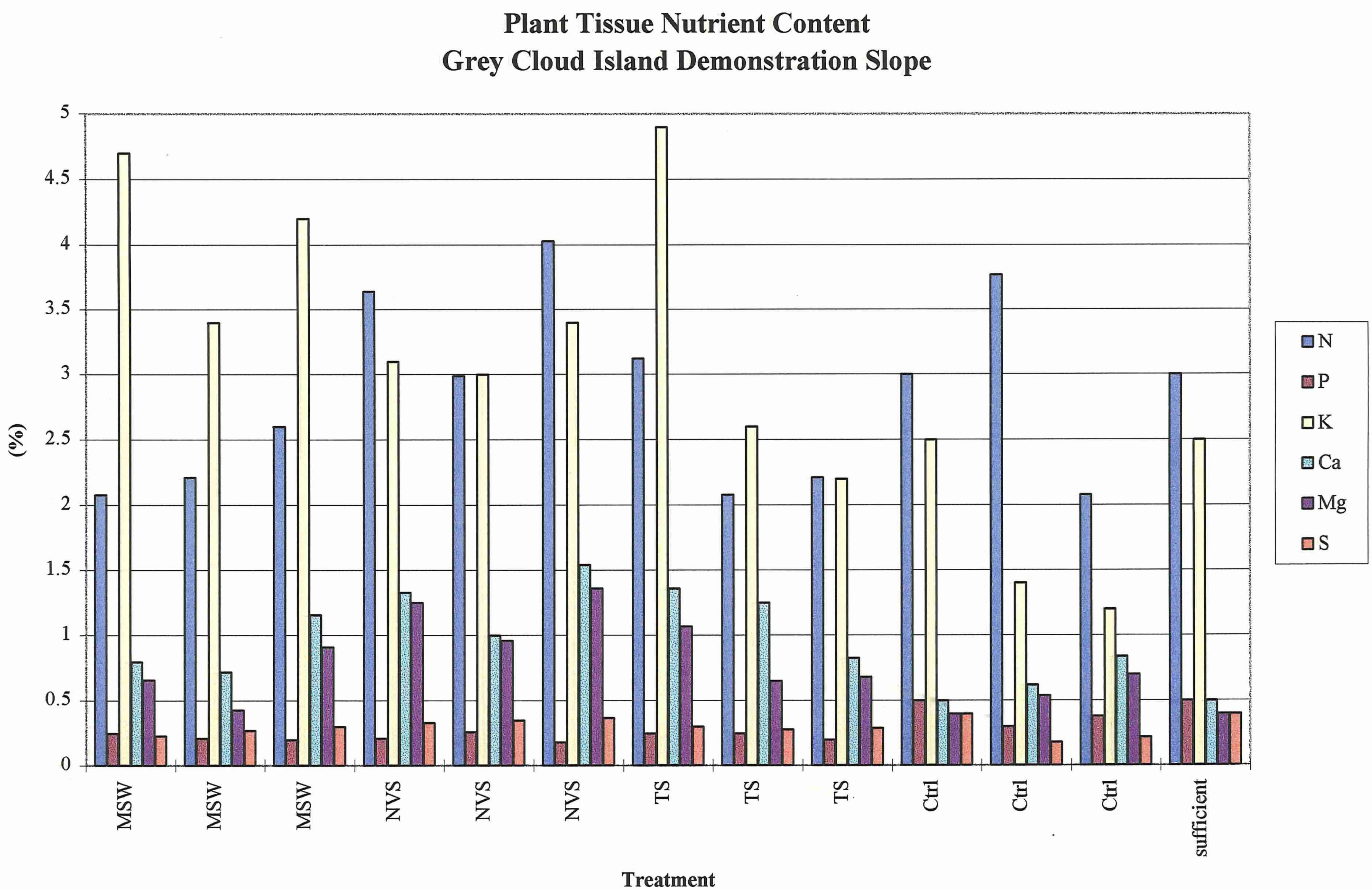


Graph 13c

sand control	1.1
Topsoil	19
MSW	114
NV 15	71
NV 30	85
NV 60	109

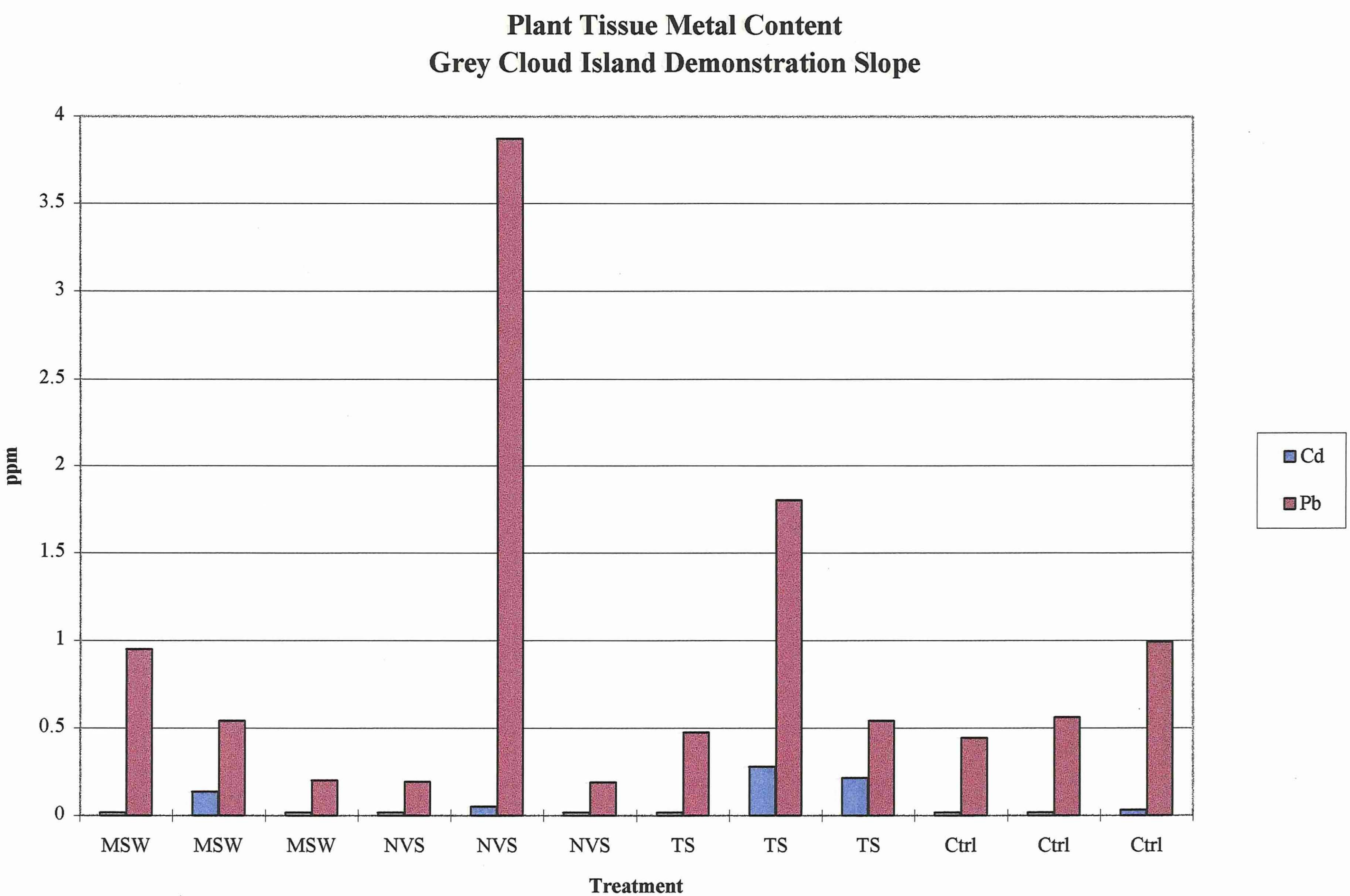


Graph 14



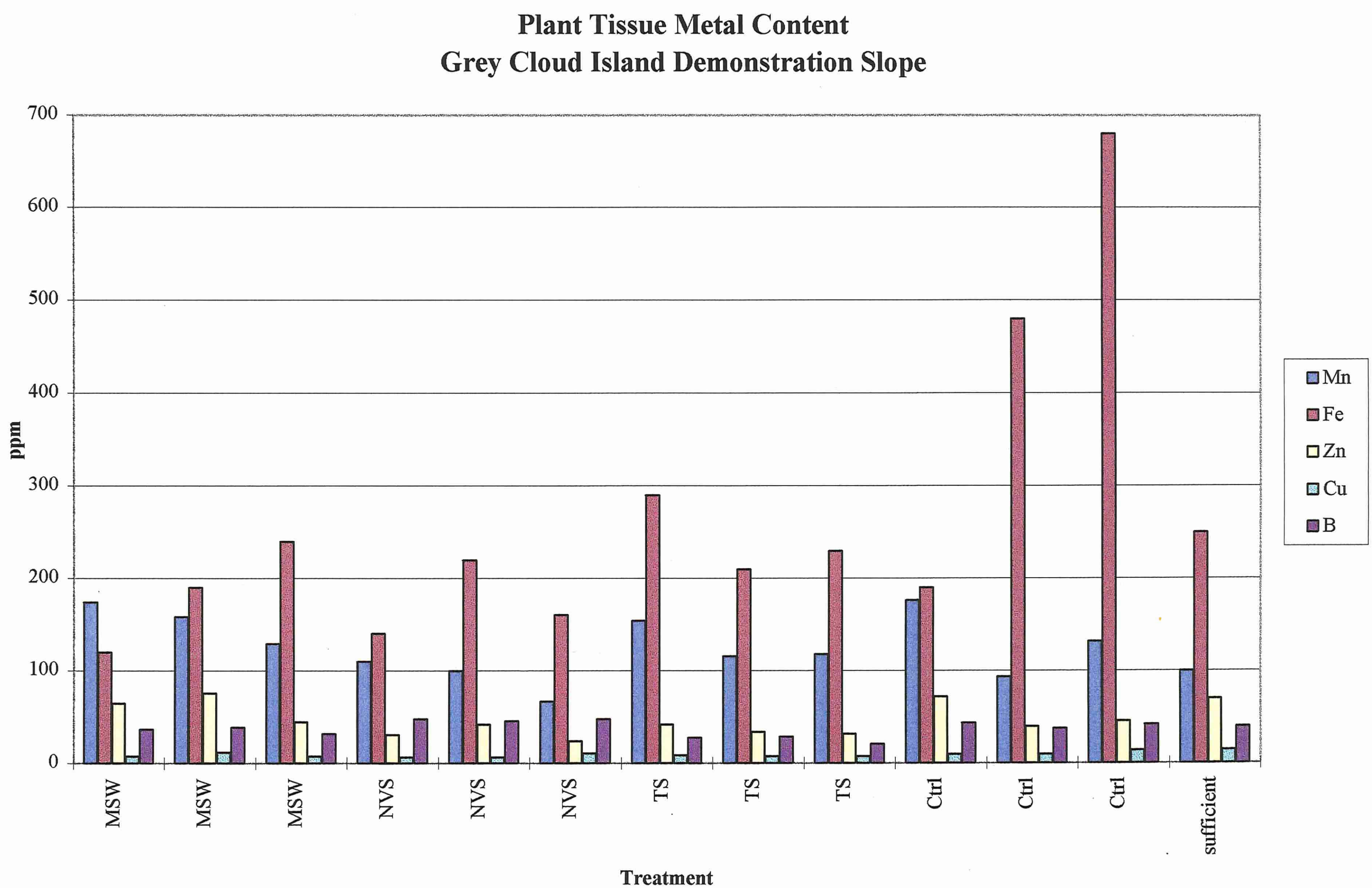
Plant Tissue Nutrient Content
Grey Cloud Island Demonstration Slope
(%)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
MSW
MSW
MSW
NVS
NVS
NVS
TS
TS
TS
Ctrl
Ctrl
Ctrl
sufficient
Treatment
N
P
K
Ca
Mg
S

Graph 15



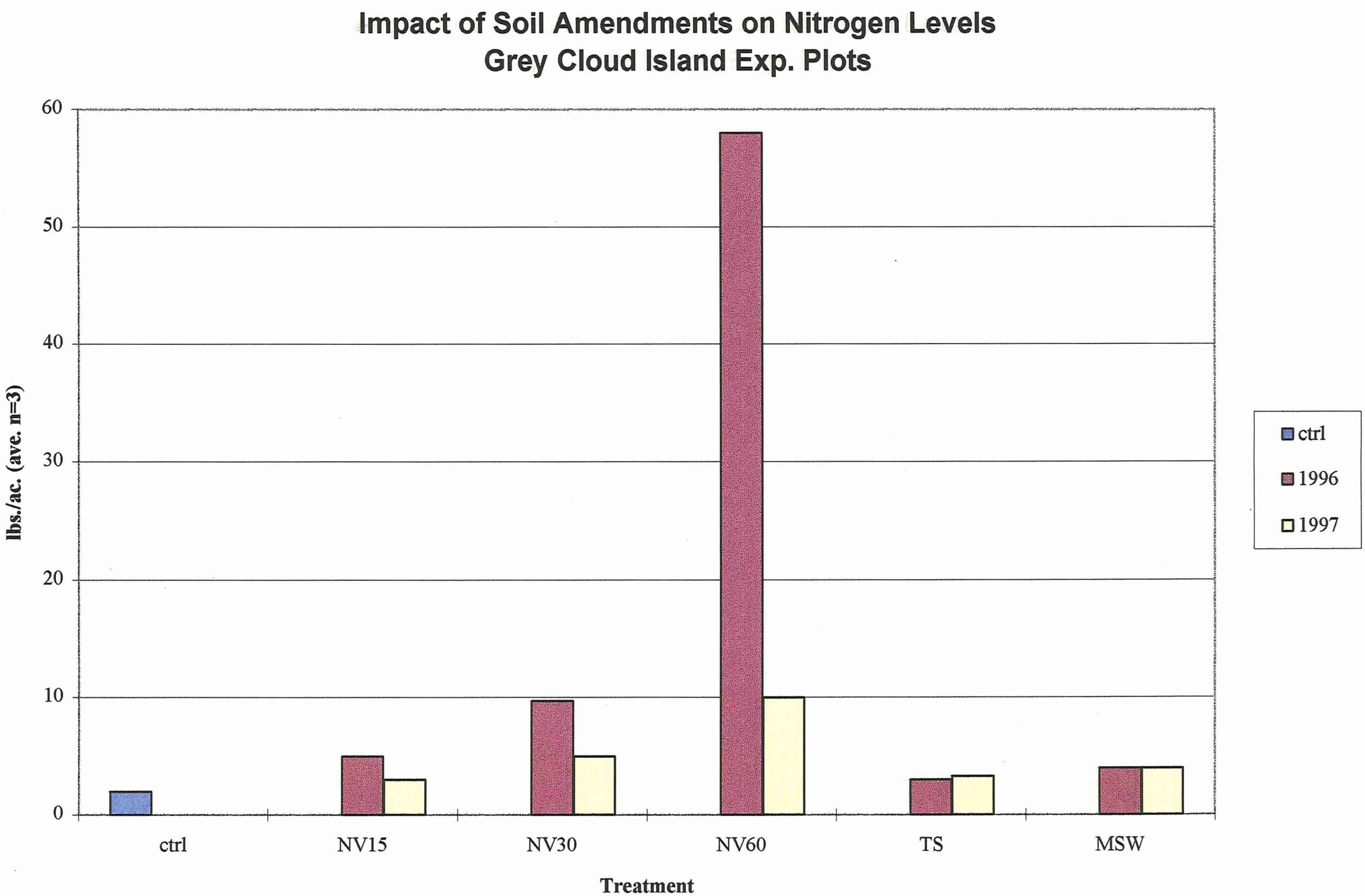
Plant Tissue Metal Content
Grey Cloud Island Demonstration Slope
ppm
4
3.5
3
2.5
2
1.5
1
0.5
0
MSW
MSW
MSW
NVS
NVS
NVS
TS
TS
TS
Ctrl
Ctrl
Ctrl
Treatment
Cd
Pb

Graph 16

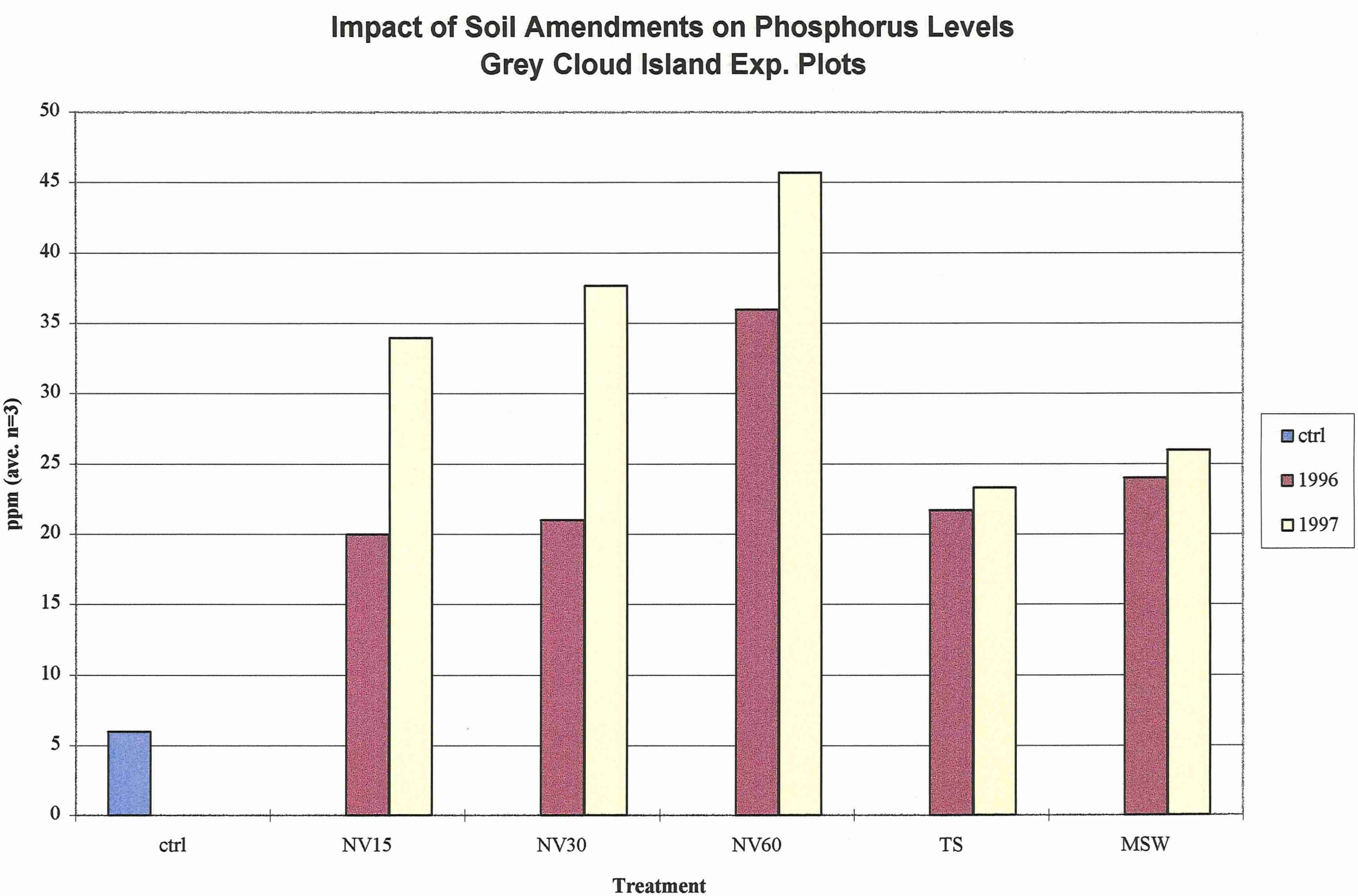


Plant Tissue Metal Content
Grey Cloud Island Demonstration Slope
700
600
500
400
300
200
100
0
ppm
MSW
MSW
MSW
NVS
NVS
NVS
TS
TS
TS
Ctrl
Ctrl
Ctrl
sufficient
Treatment
Mn
Fe
Zn
Cu
B

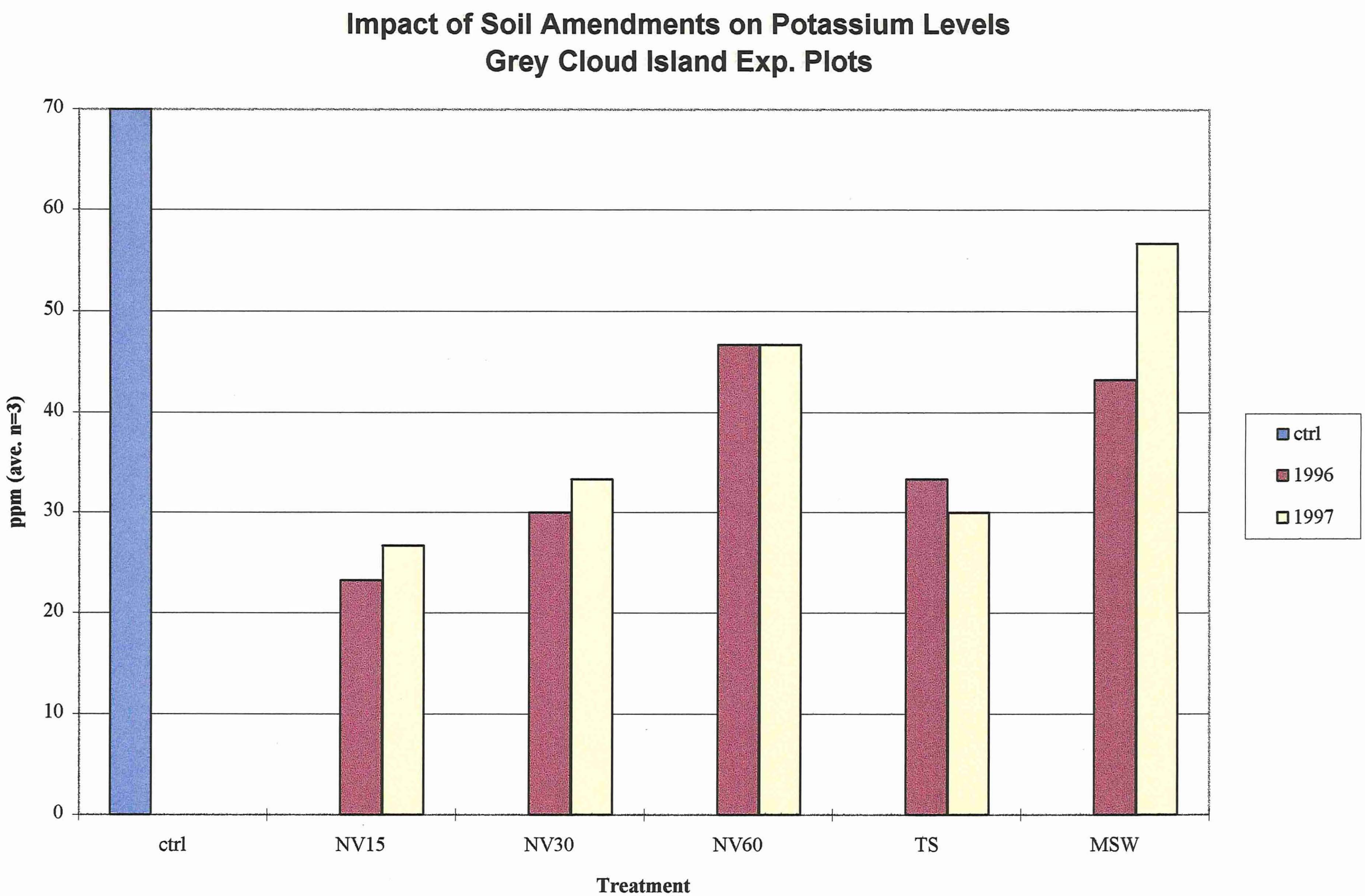
Graph 17


Impact of Soil Amendments on Nitrogen Levels
Grey Cloud Island Exp. Plots
60
50
40
30
20
10
0
lbs./ac. (ave. n=3)
ctrl
NV15
NV30
NV60
TS
MSW
Treatment
ctrl
1996
1997

Graph 18

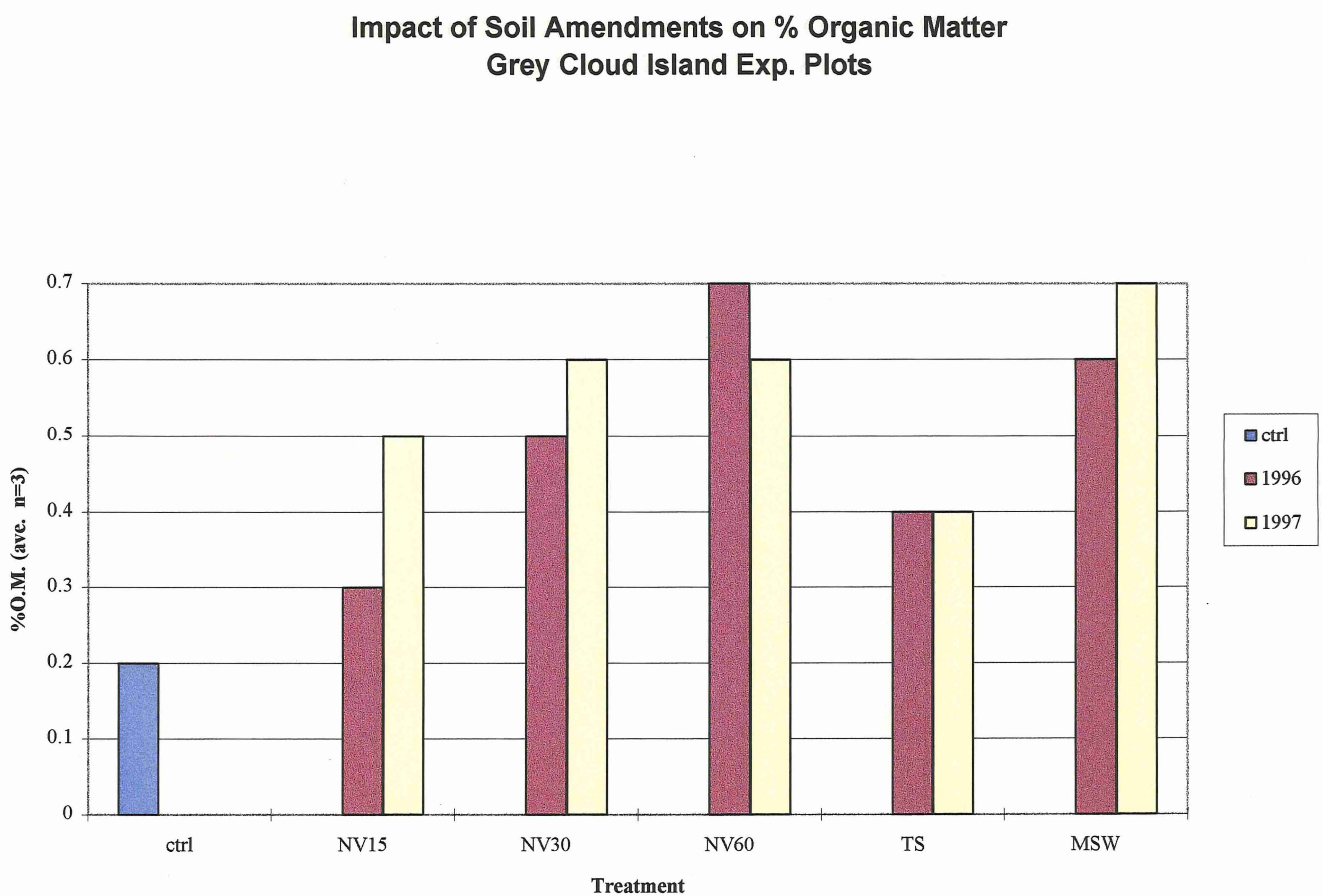

Impact of Soil Amendments on Phosphorus Levels
Grey Cloud Island Exp. Plots
ppm (ave. n=3)
0
5
10
15
20
25
30
35
40
45
50
ctrl
NV15
NV30
NV60
TS
MSW
Treatment
ctrl
1996
1997

Graph 19



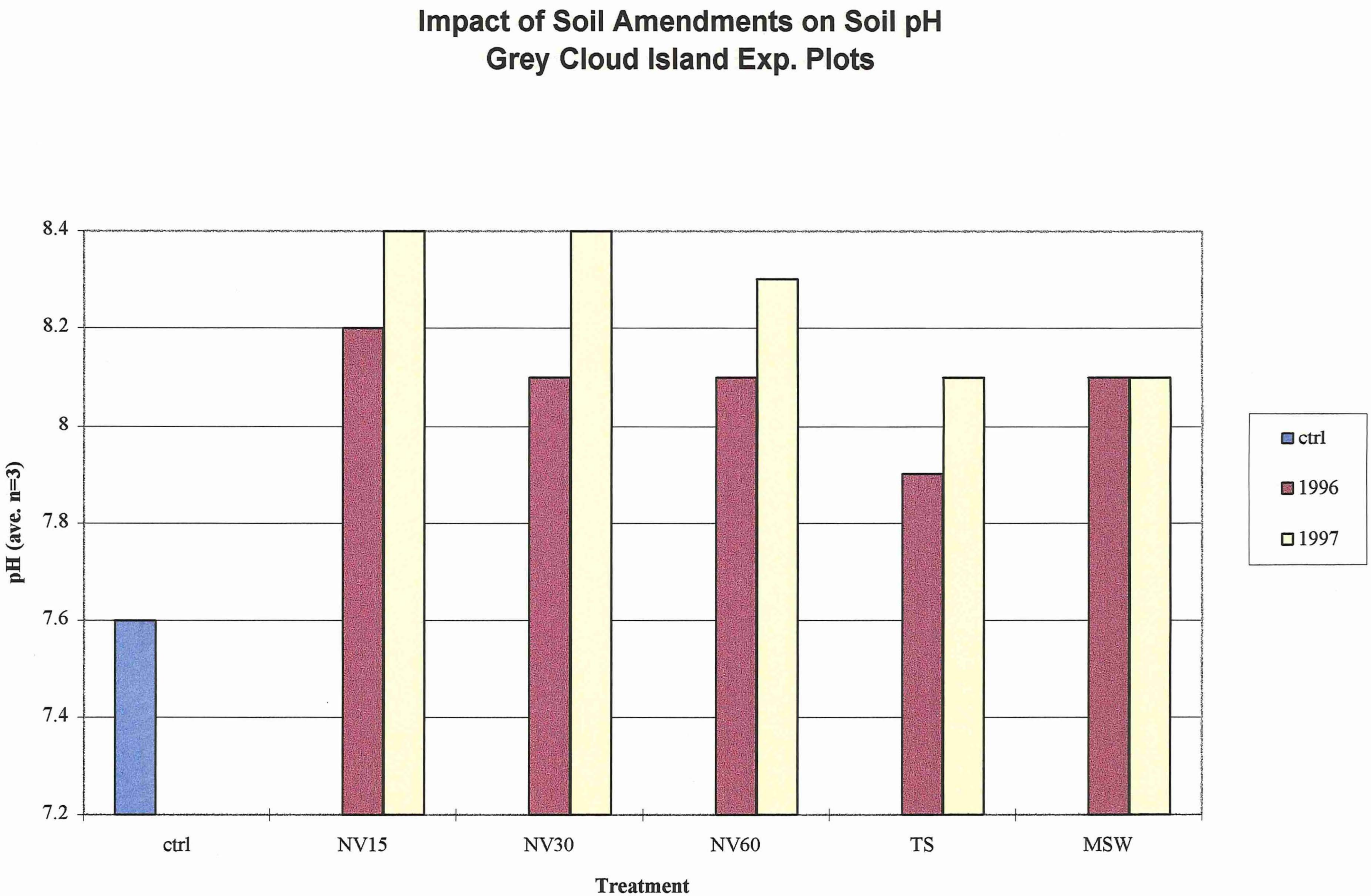
Impact of Soil Amendments on Potassium Levels
Grey Cloud Island Exp. Plots
ppm (ave. n=3)
70
60
50
40
30
20
10
0
ctrl
NV15
NV30
NV60
TS
MSW
Treatment
ctrl
1996
1997

Graph 20



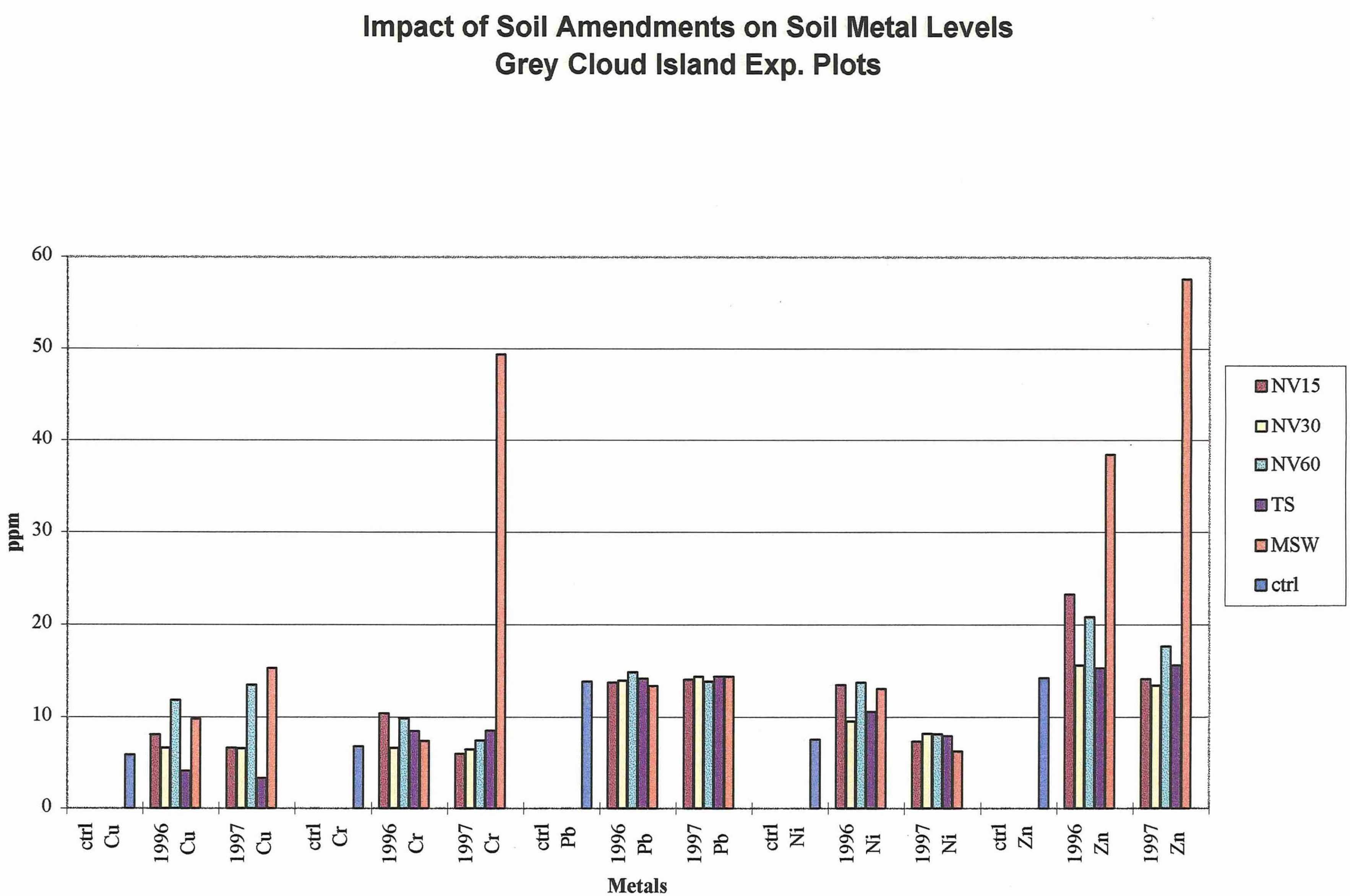
Impact of Soil Amendments on % Organic Matter
Grey Cloud Island Exp. Plots
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
%O.M. (ave. n=3)
ctrl
NV15
NV30
NV60
TS
MSW
Treatment
ctrl
1996
1997

Graph 21



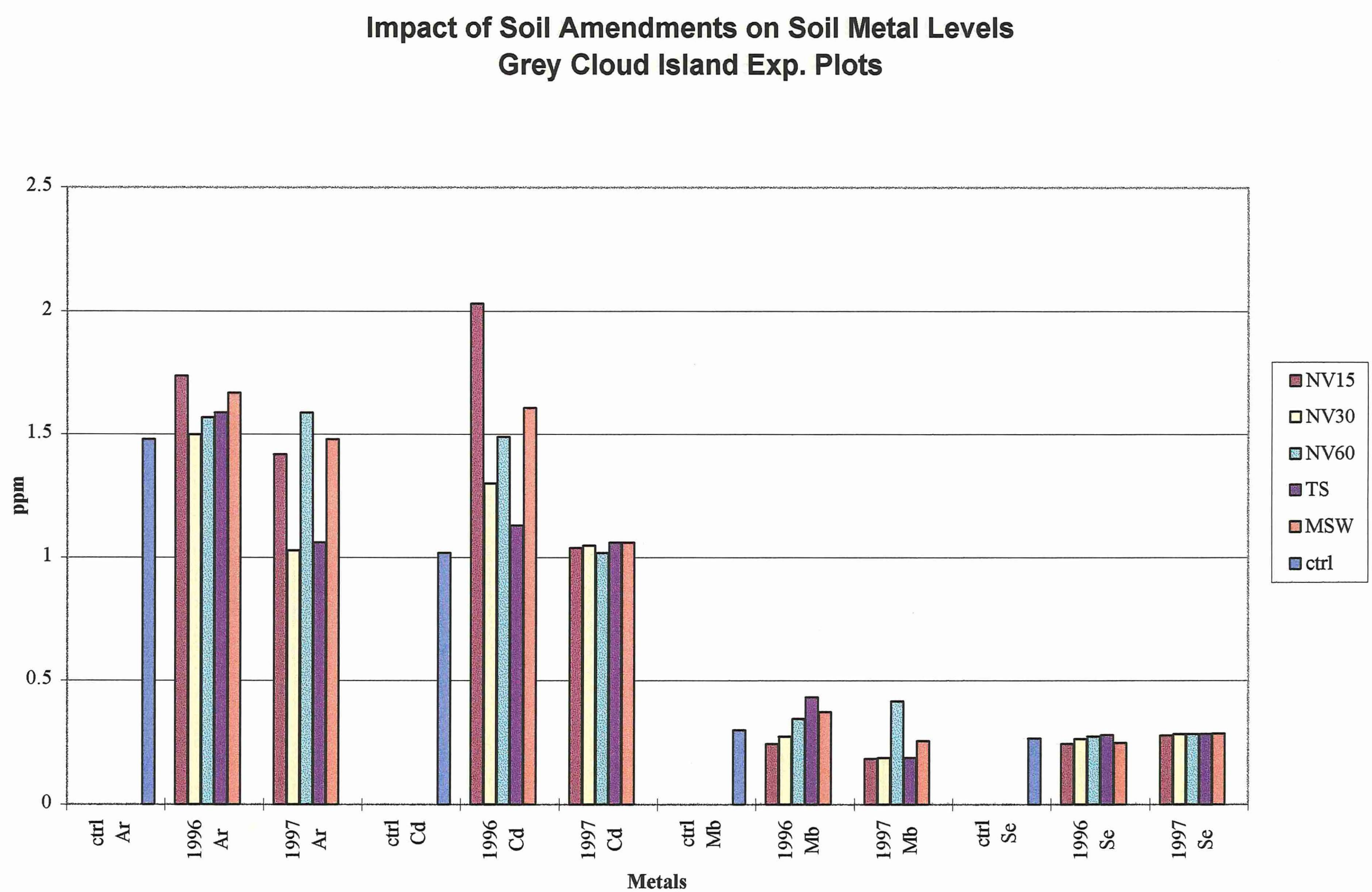
Impact of Soil Amendments on Soil pH
Grey Cloud Island Exp. Plots
8.4
8.2
8
7.8
7.6
7.4
7.2
pH (ave. n=3)
ctrl
NV15
NV30
NV60
TS
MSW
Treatment
ctrl
1996
1997

Graph 22



Impact of Soil Amendments on Soil Metal Levels
Grey Cloud Island Exp. Plots
ppm
60
50
40
30
20
10
0
ctrl Cu
1996 Cu
1997 Cu
ctrl Cr
1996 Cr
1997 Cr
ctrl Pb
1996 Pb
1997 Pb
ctrl Ni
1996 Ni
1997 Ni
ctrl Zn
1996 Zn
1997 Zn
Metals
NV15
NV30
NV60
TS
MSW
ctrl

Graph 23



Impact of Soil Amendments on Soil Metal Levels
Grey Cloud Island Exp. Plots
ppm
2.5
2
1.5
1
0.5
0
ctrl Ar
1996 Ar
1997 Ar
ctrl Cd
1996 Cd
1997 Cd
ctrl Mb
1996 Mb
1997 Mb
ctrl Se
1996 Se
1997 Se
Metals
NV15
NV30
NV60
TS
MSW
ctrl

The Issues

- Regulatory Requirements
- Dust Control
- Odor Control
- Storage
- Transportation
- Nutrient Value
- Nutrient Needs
- Characteristics of Land
- Application Method
  - slurry, solid, other
- Record Keeping
- Liability
- Chemical Makeup
- Wetlands and Groundwater Protection
- Cost
- Tree Spacing
- Monitoring and Testing

This conference jointly sponsored by:

EVTAC MINING

EVTAC Mining Company
P.O. Box 180
Eveleth, MN 55734

Sustainability International
904 St. Paul Avenue
St. Paul, MN 55116

Partial funding for this project approved by the Minnesota Legislature, ML 1995, Chapter 220, Sec. 19, Subd. 5t, as recommended by the Legislative Commission on Minnesota Resources from the Oil Overcharge Money.

RSVP, Contact: Myrna at 218/744-7643

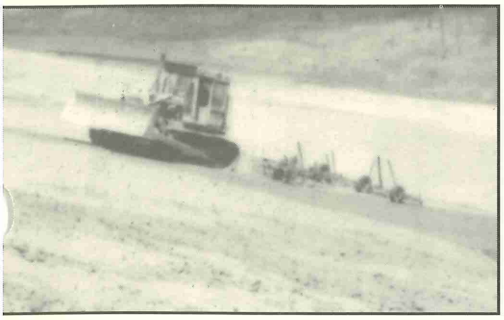
A Conference on Applying
Municipal and Paper Biosolids
for Mineland Reclamation

Earth to Earth

The Benefits - The Methods
How to Make it Safe
Regulatory Issues

April 29, 1997
Viking Room, Coates Hotel,
Virginia, Minnesota

Welcome!



Reclaimed mineland requires nutrients in order to produce vegetation. Biosolids can be a cost-effective solution.

Welcome to our conference. Paper mill and municipal biosolids contain valuable organic matter and nutrients and can help prevent erosion on sloped lands. The aim of this conference is to stimulate the paper and mining industries to begin working together with all stakeholders to find environmentally responsible procedures for applying such biosolids to reclaimed minelands and to convert these lands into forests that can serve as a renewable source of timber for the paper industry.

Chuck Williams
Vice President Public Affairs
EVTAC Mining Company

Kathy Draeger
President
Sustainability International

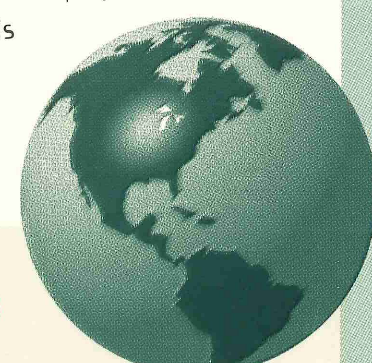
Registration 8:00 - 8:30

Attendees can check in and receive their nametags beginning at 8:00 a.m. Coffee and donuts available.

Opening Remarks 8:30 - 8:45

"The Way It Is - The Way It Can Be"
Charles Williams, EVTAC's Vice President - Internal/External Affairs, and former Minnesota Pollution Control Agency Commissioner. Chuck is a veteran of the taconite industry and a former Executive Director of the Western Lake Superior Sanitary District.

"Land Application of Biosolids - A Good Idea Whose Time Has Come"
Kathy Draeger, President, SI, and Project Manager for the LCMR project: "Recycled Biosolids Used to Reclaim Disturbed Areas." She is writing a book on behalf on the EPA and the Water Environment Research Foundation.



The Benefits
8:45 - 8:55

"A Testimony to the Beneficial Re-Use of Biosolids," Steve Stark, Metropolitan Council Environmental Services.

Trees' Needs
8:55 - 9:20

"Rapid Growth Species," Bill Bergeson, Natural Resources Research Institute.

"Nutritional Needs of Papermaking Trees," Tom Murn, Woodland Forester, Potlatch Corporation.

The Concerns
9:20 - 10:20

"What we Need to Know - The Regs, The Steps Needed to Make Biosolids Safe," A Panel of Experts:

Steve Stark: Facilitator

Brad Anderson: Environmental Engineer, EVTAC Mining Company

Kathy Draeger: President, Sustainability International

Jorja Dufresne: Soil Scientist, Minnesota Pollution Control Agency

Paul Eger: Principal Engineer, Minnesota Department of Natural Resources

Steve Johnsen: Manager - Operations and Maintenance, Western Lake Superior Sanitary District

Diane Lundin: Environmental Manager, Potlatch Corporation

Break 10:20 - 10:30

The Next Steps
10:30 - 11:15

Discussion Groups - participants are invited to join discussion groups to confer on the steps that each stakeholder needs to take and to recommend a timetable for getting a system working. Final report and discussion.

Summary Report
11:15 - 11:30

Charles Williams and Kathy Draeger

Special Video
11:30 - 11:45

Close Conference
Luncheon served in the Hotel dining room

Photo 1

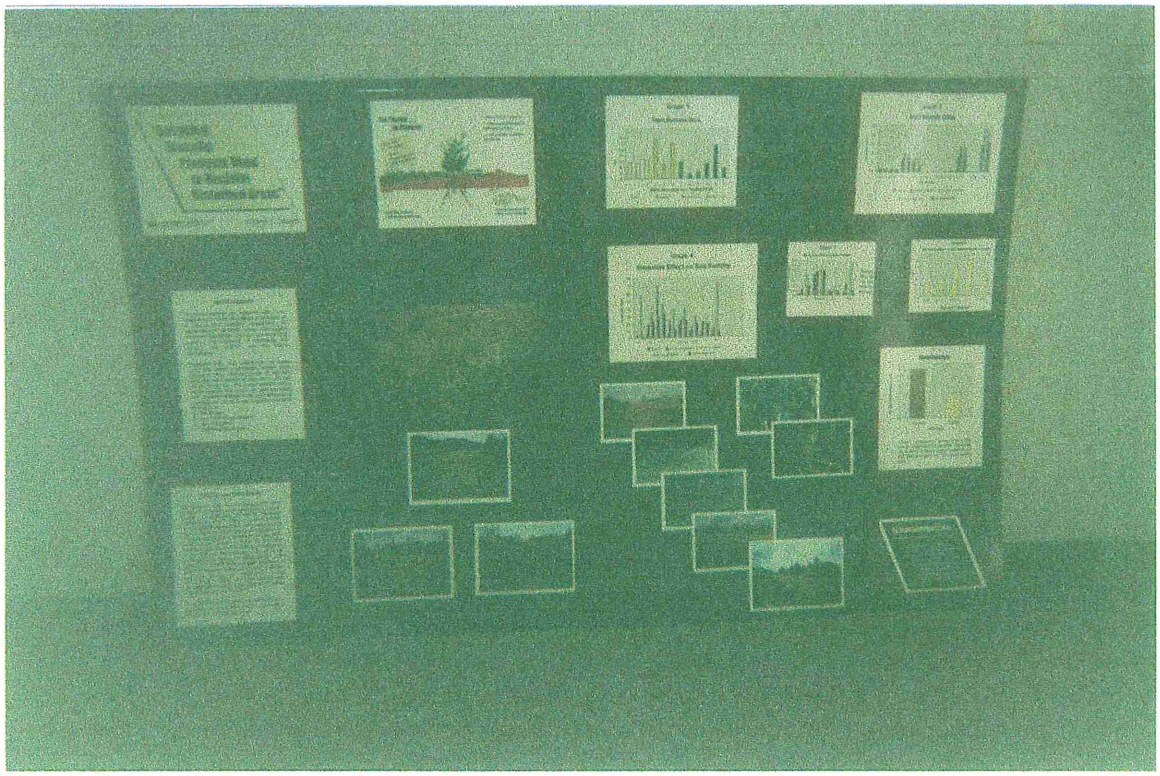


Photo 2