Scotch Broom Remediation Effects on Soil Nitrogen Levels

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Abstract

This is a preliminary study exploring the effects of the removal of scotch broom, an invasive species, on soil nitrogen levels in Western Washington prairies. A comparison of three different removal techniques was completed based on the extractable nitrate and ammonium concentrations in treatment plots. The use of a traditional rotary mower to remove invasive scotch broom was found to be the most efficient way of reducing soil nitrogen concentrations. Reduced soil nitrogen promotes the growth of native prairie species.

Introduction

Cytisus Scoparius, commonly known as Scotch broom or Scot's broom, is a legume that grows abundantly on prairie lands in Western Washington. Scotch broom is classified as a Class B Noxious Weed in Washington State. Control of the species is underway by various organizations in an effort to restore native prairie land. Removal of scotch broom is difficult since the life span of the plant is about 10 years and the seeds can survive for 50 years in the soil. Various removal techniques are being used, including burning, mowing and cutting.

As a legume, scotch broom fixes nitrogen from the air by symbiotic microorganisms on its roots (Barber 1995). This nitrogen can become available to other plants when the scotch broom dies. Nitrogen exists in soils as organic nitrogen from decomposing organic matter, which is mineralized into inorganic forms of nitrogen: ammonium, nitrate and small amounts of nitrite. Ammonium is oxidized to nitrate by microorganisms in the soil, primarily *Nitrosomonas* and *Nitrobacter*. Nitrate is then converted to nitrous oxide by anaerobic bacteria and released into the atmosphere; this process is called denitrification (Barber 1995).

It is in the interest of prairie restoration groups that the nitrogen levels in the soil are low, since many native prairie species prefer nutrient poor soils (Haubensak et al. 2004). This study explores various mow and cutting type's efficiency in reducing the nitrogen levels in soil.

Soil nitrogen levels were determined for locations where three different removal techniques were employed. The removal techniques used were brush cutting, mowing, and flail mowing. Brush cutting is when the scotch broom plant is cut off near the base by hand and the branches are carried off of the removal area. Mowing refers to the use of a traditional rotary mower, which indiscriminately removes vegetation. Flail cutting/mowing is the use of a flail mower, which also removes vegetation indiscriminately and mulches some of the vegetation with the soil. Flail cutting creates exposed areas of soil; such sites provide places for scotch broom seeds to take root. An area of scotch broom close to the treatment sites was used as the control group.

The scotch broom removal took place in the late winter of 2006 on the Mima Prairie in Washington. The treatment plots were completed in rows, with a mowed buffer zone to the north. An alternating pattern of brush cutting, mowing, and flail cutting rows continues to the south and stretches over several hundred meters. To the east of this plot there is a dirt road that separates the removal area from the control area, where tall scotch broom extends across the prairie.

A comparison of the extractable nitrogen levels in the soils of the various plots was done to determine if there is any distinguishable difference between removal techniques. The null hypothesis is that the presence or removal of scotch broom does not alter the nitrogen concentrations of the soil. This was assumed to be true.

Methods

Sampling

Sampling took place on two dates, April 4 and 10, 2007. Soil samples were collected using a soil corer. Sampling locations were chosen semi-randomly within treatment areas. A random sample was selected close to the scotch broom control area and another random sample was selected further west, away from the control area. The samples taken from the control area were collected along the length of the treatment plots and 30 meters east of the remediation site.

A composite soil sample was generated by collecting core samples a meter north and a meter south of the sampling area from 10 centimeters below the surface, due to the rockiness of the soil. These soil cores were then mixed in a resealable plastic bag and stored in a cooler during transport to the laboratory.

Soil pH

Soil pH was measured as soon as possible prior to freezing the samples. In the laboratory, approximately 15 grams of soil was mixed with 15 mL deionized water and the pH was measured with an Orion pH meter and a Beckman pH probe.

Sample Preparation

The samples were frozen for 1-6 days and removed from the freezer on April 11, 2007 to begin air-drying in the lab and were dry on April 16, 2007. The samples were then disaggregated with a mortar and pestle, sieved through a 2mm sieve and split with a soil splitter. Soil splitting created samples for each analysis with a similar range of grain sizes.

Nitrogen Extraction

The extraction method was adapted from Western States Laboratory, Plant, Soil and Water Analysis Manual (Miller 2003). Soil Samples were weighed out 5.0 $\pm$ 0.05g on an analytical balance and the exact mass of the sample was recorded. The samples were then placed into 50mL Erlenmeyer flasks and 25.0mL of 2 N potassium chloride (KCl) extracting solution was added. The samples were shaken on a New Brunswick reciprocating shaker at a speed setting of 50 for one hour. Extract and soil was gravity filtered through Whatman no. 42 filter paper and washed with deionized water into a 100mL volumetric flask. Extract was diluted to 100mL with deionized water and then stored in polypropylene bottles and refrigerated in the dark for no more than one week. Analyses were completed within one and four days after extraction.

Cadmium Reduction Nitrate Analysis

Standard Methods for the Examination of Water and Wastewater 4500- NO_3^- E. Cadmium Reduction Method was used to determine nitrate concentration in the soil extracts. Nitrate concentrations are calculated as micrograms nitrogen per gram soil. Dr. Stroh prepared the cadmium column and the column efficiency was determined to be between 81-91% using spike recoveries.

Phenate Ammonium Analysis

Ammonium concentrations were determined as outlined by Standard Methods for the Examination of Water and Wastewater 4500- NH_3 D. Phenate Method. Ammonium concentrations were calculated as micrograms nitrogen per gram soil.

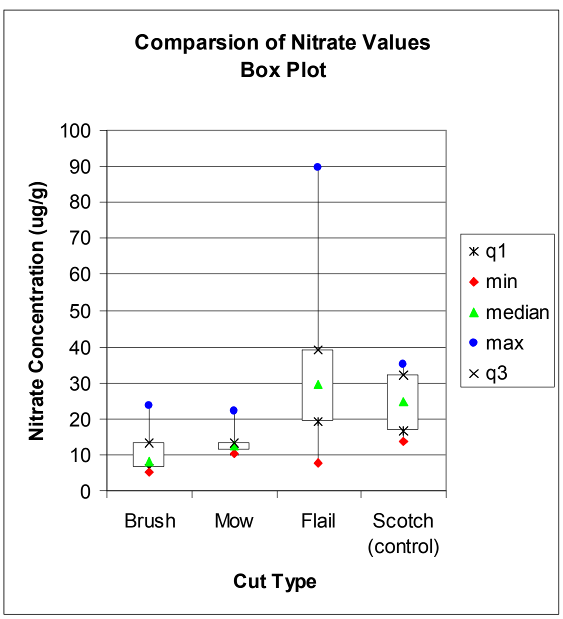
Results

The results of both analyses show a wide range of nitrate and ammonium concentrations amongst treatment plots (Appendix 1: Tables 2 & 3). Within brush cut plots the average extractable nitrate is 10.6 µg NO_3^--N / g soil. While on average ammonium concentrations are slightly higher at 14.6 µg NH_4^+-N / g soil. Mowed plots are the opposite with higher average nitrate concentrations at 13.0 µg NO_3^--N / g soil and a lower average ammonium concentration of 9.2 µg NH_4^+-N / g soil (Table 1). The average nitrate concentration of mowed plots is skewed by plot 5 sample B, a suspected outlier based on a 1.5 x Inter Quartile Range test. A new calculated average of 12.2 µg NO_3^--N / g soil excluding the outlier does not alter the observed trend.

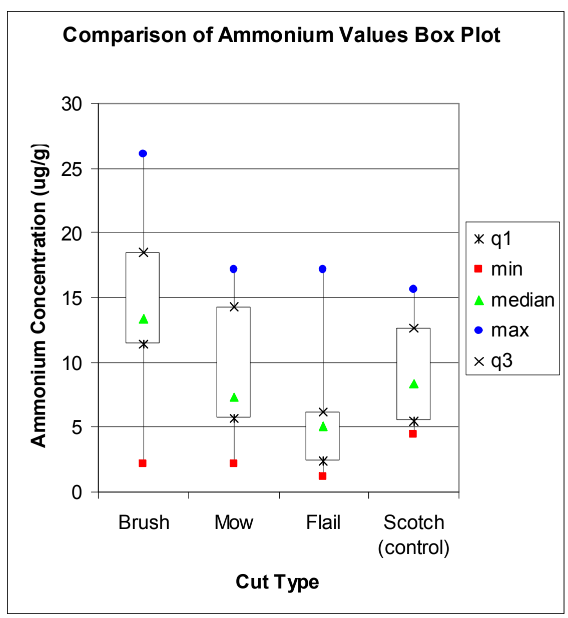
Table 1 Average concentrations for pH, Extractable Nitrate, Extractable Ammonium and Total Extractable Nitrogen.

Removal Technique	Average Values Soil pH	Extractable Nitrate ug/g NO_3^--N	Extractable Ammonium ug/g NH_4^+-N	Total Extractable Nitrogen ug/g NO_3^--N & NH_4^+-N
Brush Cut	5.1	10.6	14.6	25.2
Flail Mower	5.0	36.0	6.5	42.5
Rotary Mower	5.0	13.0	9.2	22.2
No Removal	4.9	24.4	10.6	35.0

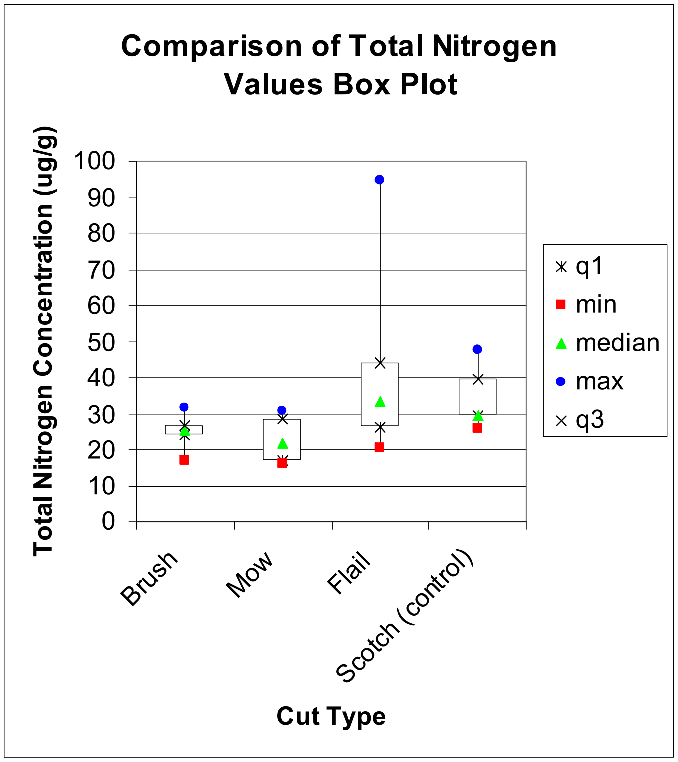
However, flail cut areas show a greater range of nitrate concentrations with a higher average nitrate at 36.0 µg NO_3^--N / g soil (Table 1 & Box Plot 1). The average nitrate concentration for flail cut areas exceeds the control region. This is due to the presence of an outlier, from flail cut plot 3 sample B, removal of this outlier generates an average of 24.3 µg NO_3^--N / g soil. Such a nitrate concentration is nearly equal to that of the control area at 24.4 µg NO_3^--N / g soil. The average ammonium concentration is 6.5 µg NH_4^+-N / g soil. Flail cut plots 1 samples A and B and plot 2 sample A, ammonium concentrations are also suspected outliers. The skew of the data can be seen in Box Plot 2.



Box Plot 1 Comparison of Nitrate Values



Box Plot 2 Comparison of Ammonium Values



Box Plot 3 Comparison of Total Extractable Nitrogen Concentrations

Even with the removal of outliers from the calculated average concentrations of nitrate and ammonium within treatment areas, the trends shown in Box Plots 1, 2, and 3 are consistent. Brush cut areas have low nitrate levels with high ammonium concentrations. Mowed plots have lower nitrate than all other plot areas. Flail cut areas have high concentrations of nitrate and the lowest ammonium concentrations.

Statistical analysis with the use of ANOVA F tests found that the means of all plot areas are unequal. Thus the null hypothesis that the presence or removal of scotch broom does not affect the soil nitrogen was false. Other ANOVA F tests were completed to see if the means of ammonium and nitrate concentrations were equal for all removal techniques and F Values greater than the F Critical Values were determined. Therefore, the means of all removal techniques are not equal and they do not affect soil nitrogen in the same way.

Discussion

The results show that scotch broom removal alters nitrogen levels in soil. Brush cutting tends to generate less nitrate and greater concentrations of ammonium than the other removal techniques and the control area. This high concentration of ammonium is due to the initial decomposition of legumes which release large amounts of organic nitrogen and ammonium (Barber 1995). Brush cutting leaves the root system of the scotch broom intact and as it decomposes creates a spike in ammonium levels in the soil. Flail cut plots show high concentrations of nitrate and the lowest ammonium concentrations out of all removal techniques. Since the flail cut areas have plant matter mulched into the soil this may increase the rate of decomposition and in turn the mineralization of nitrogen. The low concentration of ammonium may be due to the fact that the ammonium increase from decayed scotch broom has almost entirely oxidized to nitrate. In the mowed plots either they have undergone denitrification and decreased the level of nitrogen in the soil. Or the process of decay and mineralization has yet to take place.

According to the determined concentrations of extractable nitrate and ammonium in the remediation area soils, there may be one removal technique that is preferable to the rest. Traditional rotary mowing is quicker than brush cutting by hand and it is less damaging to the prairie than a flail mower. Mowing also promotes lower nitrate concentrations and reasonably low ammonium concentrations. Removal of scotch broom by mowing is a more efficient means of decreasing nitrogen concentrations in soil. Such decreases in soil nitrogen will provide a more desired environment for native prairie species in Western Washington.

As a preliminary study, this research does not give conclusive evidence as to how scotch broom removal fully influences the concentration of nitrogen in soil. For example, the organic nitrogen levels in the plot areas may alter the calculated total nitrogen levels and provide a pool of potentially mineralized nitrogen. Such data may change the conclusions gained from this study. Continued analysis of soil nitrogen levels on the Mima Prairie and within the sample location will offer more definite conclusions. Future studies will provide a reliable determination of the best removal technique for invasive scotch broom.

Tables and Figures

Table 1 Tabulated results for pH and Extractable Nitrate.

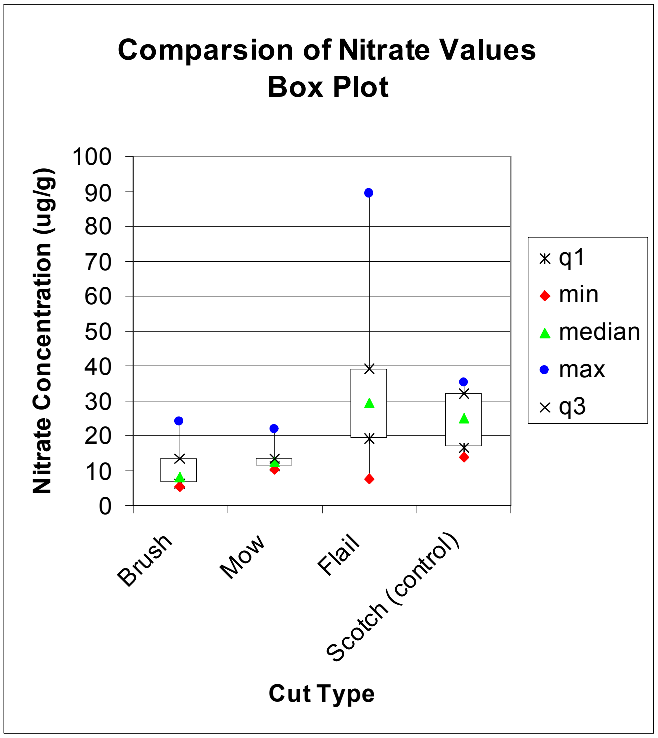
Sample	Soil pH	Extractable Nitrate ug/g NO_3^--N	% dif between duplicates
Brush Cut 1A	5.1	5.3	
Brush Cut 1B	5.4	5.6	
Brush Cut 2A	5.4	8.7	
Brush Cut 2B *	4.7	6.3	
Brush Cut 3A	4.9	13.8	
duplicate extraction & analysis		17.1	10.64%
Brush Cut 3B	5.2	12.0	
Brush Cut 4A	4.9	7.2	
duplicate analysis		6.5	5.31%
Brush Cut 4B *	5.4	23.8	
Average	5.1	10.6	
Standard Deviation	0.3	6.1	
Relative Standard Deviation (%)	5.3	57.2	
Percent Error of Analysis		± 8.0%	
Mow 1A	4.8	10.3	
Mow 1B	5.5	11.1	
Mow 2A	4.9	12.6	
Mow 2B	4.7	13.3	
Mow 3A	5.0	11.4	
duplicate extraction & analysis		10.3	5.11%
Mow 3B	4.9	10.8	
Mow 4A	4.9	15.2	
Mow 4B	4.9	12.5	
duplicate analysis		13.4	3.60%
Mow 5A	5.1	13.2	
Mow 5B *	5.1	22.0	
Average	5.0	13.0	
Standard Deviation	0.2	3.2	
Relative Standard Deviation (%)	4.4	24.5	
Percent Error of Analysis		± 7.2%	
Flail Cut 1A *	4.7	7.6	
Flail Cut 1B *	5	11.9	
Flail Cut 2A *	4.9	39.3	
Flail Cut 2B	5.1	19.0	
Flail Cut 3A	5.1	19.5	
Flail Cut 3B	5	89.5	
duplicate analysis		76.9	7.56%
Flail Cut 4A	5.1	38.0	
Flail Cut 4B	5.2	23.9	
duplicate extraction & analysis		34.8	18.58%
Average	5.0	36.0	
Standard Deviation	0.2	27.2	
Relative Standard Deviation (%)	3.1	75.4	
Percent Error of Analysis		± 8.0%	
Control Area			
Scotch Broom 1	4.7	13.6	
Scotch Broom 2	4.9	13.9	
Scotch Broom 3	5.2	34.9	

duplicate analysis		34.4	0.67%
Scotch Broom 4	4.9	25.0	
duplicate extraction & analysis		24.6	0.84%
Average	4.9	24.4	
Standard Deviation	0.2	9.3	
Relative Standard Deviation (%)	4.2	38.3	
Percent Error of Analysis		± 7.2%	
Deionized Water Method Blanks			
Method Blank 1 (4/4/07)	------	4.4	
Method Blank 2 (4/10/07)	5.9	5.4	
Average		4.9	
Standard Deviation		0.7	
Relative Standard Deviation (%)		14.1	
Percent Error of Analysis		± 7.2%	
* = scotch broom seedling near sampling site			

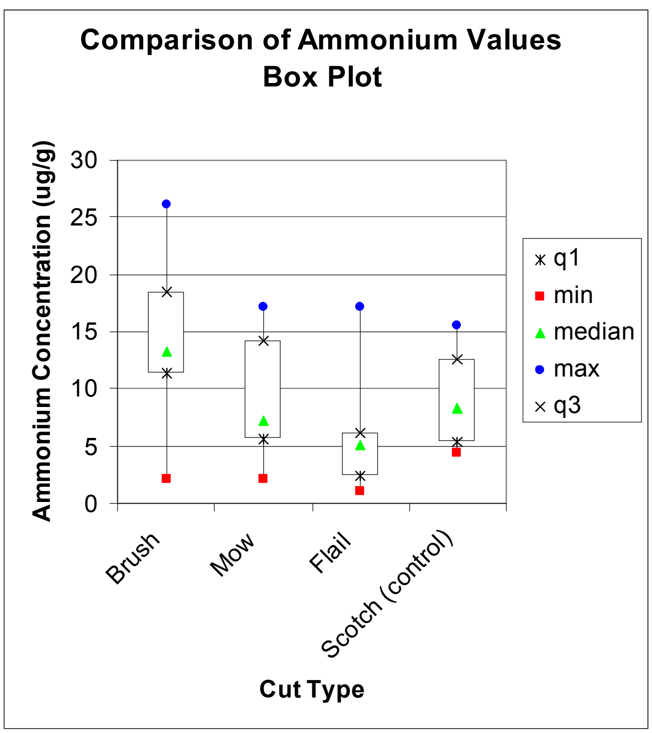
Table 2 Tabulated Results for Extractable Ammonium and Total Extractable N.

	Extractable Ammonium		**Total Extractable Nitrogen**
Sample	ug/g NH_4^+-N	% dif between duplicates	ug/g NO_3^--N & NH_4^+-N
Brush Cut 1A	20.5		25.7
Brush Cut 1B	26.1		31.6
Brush Cut 2A	18.5		27.2
Brush Cut 2B *	18.4		24.7
Brush Cut 3A	11.2		25.1
duplicate extraction & analysis	14.3	12.27%	31.5
Brush Cut 3B	12.0		24.0
Brush Cut 4A	12.3		19.5
duplicate analysis	10.6	7.38%	17.1
Brush Cut 4B *	2.2		26.0
Average	14.6		25.2
Standard Deviation	6.6		4.5
Relative Standard Deviation (%)	45.0		18.0
Percent Error of Analysis	± 7.9%		
Mow 1A	7.3		17.6
Mow 1B	5.7		16.8
Mow 2A	4.4		17.0
Mow 2B	8.8		22.1
Mow 3A	5.6		17.0
duplicate extraction & analysis	5.5	0.71%	15.8
Mow 3B	15.9		26.7
Mow 4A	13.8		29.0
Mow 4B	15.6		28.1
duplicate analysis	17.2	5.12%	30.7
Mow 5A	7.9		21.1
Mow 5B *	2.2		24.1
Average	9.2		22.2
Standard Deviation	5.1		5.4
Relative Standard Deviation (%)	55.8		24.5
Percent Error of Analysis	± 7.9%		

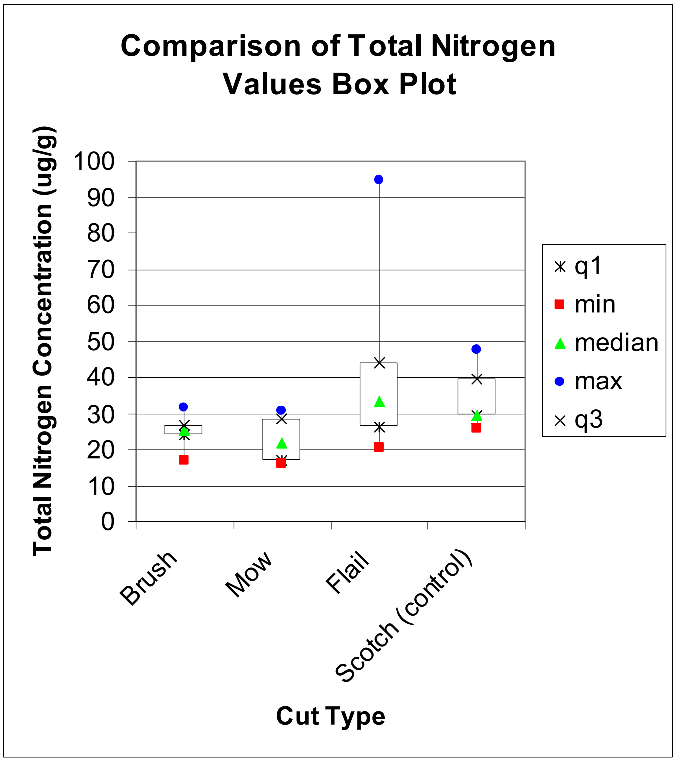
Flail Cut 1A *	16.5			24.1
Flail Cut 1B *	17.2			29.1
Flail Cut 2A *	2.1			41.4
Flail Cut 2B	5.6			24.6
Flail Cut 3A	1.1			20.5
Flail Cut 3B	5.0			94.5
duplicate analysis	6.2	10.18%		83.1
Flail Cut 4A	6.0			44.0
Flail Cut 4B	2.3			26.2
duplicate extraction & analysis	2.8	9.54%		37.6
Average	6.5			42.5
Standard Deviation	5.7			25.8
Relative Standard Deviation (%)	88.8			60.6
Percent Error of Analysis	± 7.9%			
Scotch Broom 1	12.2			25.8
Scotch Broom 2	15.6			29.5
Scotch Broom 3	12.7			47.6
duplicate analysis	8.3	21.25%		42.7
Scotch Broom 4	4.4			29.5
duplicate extraction & analysis	4.5	0.12%		29.1
Average	10.6			35.0
Standard Deviation	4.6			8.9
Relative Standard Deviation (%)	43.5			25.3
Percent Error of Analysis	± 7.9%			
			Total extractable N for Method Blanks calculated from Extractable Nitrate Values	
Method Blank 1 (4/4/07)	0.0	negative concentrations		4.4
Method Blank 2 (4/10/07)	0.0			5.4
Average	0.0			4.9
Standard Deviation	0.0			0.7
Relative Standard Deviation (%)				14.1
Percent Error of Analysis	± 7.9%			
* = scotch broom seedling near sampling site				



Box Plot 1 Comparison of Nitrate Values for each plot type.



Box Plot 2 Comparison of Ammonium Values for each plot type.



Box Plot 3 Comparison of Total Extractable Nitrogen Values for each plot type.

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