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Solarization effects on chemical properties of soils under kudu *(Pueraria montana)* invasion

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SOLARIZATION EFFECTS ON CHEMICAL PROPERTIES OF SOILS UNDER KUDZU *(PUERARIA MONTANA)* INVASION

A Thesis
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment
of the Requirements for the Degree
Master of Science
Forestry Resources

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by
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ABSTRACT

Solarization is an effective method for managing small areas with kudzu (*Pueraria montana*) invasions that may alter soil chemical properties. Conducted from 2005 to 2007 at the Clemson University Experimental Forest in Clemson, South Carolina on a Cecil clay loam (fine, kaolinitic, thermic Typic Kanhapludult), this study compares soil chemical properties under thermally-treated and non-treated plots at different depths invaded by Kudzu.

The experimental factors of treatment and depth were arranged in a factorial treatment design with 15 treatments arranged in a split plot design. The five thermal treatments were the whole plot factors which were arranged in a randomized complete block experiment design, and the depths (0-10, 10-20, 20-30 cm) were included as a split plot factor. A model was developed for the design, and Analysis of Variance (ANOVA) was used to determine if there were significant main effects or interactions of treatment and depth. Fischer's Least Significant Difference (LSD) test was used to determine if there were significant differences among specific pairs of means.

Plots invaded by Kudzu had significant increases in pH, nitrogen (N), phosphorus (P), calcium (Ca), manganese (Mn), copper (Cu), boron (B) and base saturation with lower carbon-to-nitrogen (C/N) ratio compared to bare soil at all sampling depths. Kudzu plots treated with translucent polyethylene sheeting showed significant increases in pH, P, potassium (K), Mn, and Cu as well as lower C/N ratio and magnesium (Mg) and sodium (Na) content compared to bare soil at all sampling depths. Plant analysis demonstrated kudzu's stem and leaf parts contain higher concentrations of Mn, B, K, P, zinc(Zn), Cu, and sulfur (S) than root tissue, with roots having higher concentrations of Mg and iron (Fe). Results show that kudzu invasion had significant effects on soil chemical properties by nutrient uplift and solarization released these nutrients from decomposing plant tissue.

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CHAPTER ONE

INTRODUCTION

Invasive species are having a negative effect on the environment and the economy in the U.S., causing over $120 billion worth of damages a year (Pimentel et al., 2005). In the Southeast, one of the more aggressive and harmful species is kudzu (*Pueraria montana*), responsible for great economic losses. In the forestry industry alone, kudzu causes a loss of $100 to $500 million per year of productive land (Forseth and Innis, 2004). Britton (2002) states that power companies spend $1.5 million a year to eliminate kudzu. It causes toppling of power lines due to the heavy weight of the vines. Railroad companies spend resources to eliminate kudzu from rails where the vines grow thick enough to derail cars (Blaustein, 2001; Britton et al., 2002).

Kudzu has already spread over three million ha in the eastern U.S. (Everest et al., 1999; Terrill et al., 2003). This rapid spread over large areas can be attributed to its physiology. Kudzu is a leguminous, perennial, twining vine with large tuberous roots that serve to store water, nitrogen, starch, and carbon (Forseth and Innis, 2004). The higher allocation of resources to the leaf area, roots, and stem elongation instead of upright support tissue allows kudzu to gain area at quicker rates, with stems growing up to 30 cm per day (Blaustein, 2001). Its ability to fix nitrogen and initiate roots at nodes where stems come in contact with soil, gives it an added ability to grow in poorly vegetated soils (Forseth and Innis, 2004; Witkamp et al., 1966). This allows kudzu to dominate native vegetation, leading to a decrease in species diversity that alters the ecosystem’s natural functions by creating a mono-species habitat (Blaustein, 2001; Forseth and Innis, 2004; Miller and Edwards, 1983).

Though many invasive species such as kudzu are negatively impacting their environment, these species may influence the environment in other ways. Ehrenfeld (2003) refers to that influence by stating that “invasive plant species frequently increase biomass and net primary production, increase N availability, alter N fixation rates, and produce litter with higher decomposition rates than co-occurring natives”. Most studies investigating kudzu focus on its elimination and its negative affects to the invaded environment. A lack of information is available on the effects of kudzu on soils except for its ability to increase soil nitrogen concentrations and remove heavy metals (Blaustein, 2001; Brown et al., 2001; Kaimi et al., 2007; Koutika et al., 2001).

Roots of kudzu can penetrate five meters deep into the soil (Miller, 2003), with the potential to affect the environment in several different ways. Overall, roots play a key role in the biological and chemical composition of soil. They aid in the transport of nutrients and water as well as the weathering of soils; they also provide organic material after decomposition.

The nutrient uplift hypothesis suggests that minerals found in the lithosphere are transported within the plant from the roots to the leaves and are released back to the upper layers of the lithosphere through decomposition and leaching of minerals in fallen leaf litter (Jobbagy and Jackson, 2004). The ability of an invasive species to provide nutrient uplift benefits to the ecosystem depends on the root depth of the invasive species compared to that of resident vegetation (Vanderhoeven et al., 2006). In order for nutrient uplift to occur, deeper roots must vertically cycle nutrients upward. The root depth determines which pools of nutrients will be accessed; those pools that are below the maximum rooting depth will not be depleted (Jobbagy and Jackson, 2001). In a study analyzing soil chemistry after the invasion of *Solidago gigantean* into its non-native habitat, roots did not grow deeper than surrounding resident vegetation, thus preventing it from adding higher nutrient concentrations in the topsoil (Vanderhoeven et al., 2006).

The first meter of depth is an area of high depletion; it also has the most root activity and competition for nutrients (Jobbagy and Jackson, 2001). Plants that are able to develop roots below 2 m have a noticeable advantage in reaching untapped nutrient pools and are referred to as ecosystem engineers (Jobbagy and Jackson, 2001; Schenk and Jackson, 2005). Kudzu's primary roots can reach depths of 1 to 5 m thus; it may have an ability to uplift nutrients deep in the soil stratum. In this way, deep-rooted plants are redistributing the mineral makeup of the lithosphere through the vertical uplift of nutrients, allowing shallow-rooted plants to benefit from having deep-rooting neighbors (Jobbagy and Jackson, 2004).

Kudzu's ability to increase nutrient status in soil and protect against soil erosion is one of the many reasons it was planted widely. Introduced in 1876 to the U.S. at the Centennial Exposition in Philadelphia, kudzu was once a praised and highly sought-after plant with uses ranging from ornamental vines to cattle feed (Miller and Edwards, 1983). In the Depression Era, the government paid farmers to plant kudzu in order to control the erosion of distressed land, with South Carolina soils being one of the most ravaged soils after the depression (Miller and Edwards, 1983; Sorrells, 1984). South Carolina soils are ideal for kudzu invasion due to long summers and low fertility soil where competitive vegetation would be absent. Over time, the uncontrolled vines began to spread too rapidly, and eradication of the vines was difficult, leading the Soil Conservation Service to list kudzu as a weed in 1970 (Miller and Edwards, 1983).

Current methods of kudzu eradication include: herbicides, grazing with ruminants, burning, and a most recent method of solarization (Harrington et al., 2003; Mount, 1994; Newton et al., 2008). Repeated applications of these methods are needed in order to deplete the nutrient storage of their large storage root system and to eradicate asexually produced growth such as rooting at stem nodes (Forseth and Innis, 2004; Mount, 1994).

Eradication of kudzu using livestock has been successful in many studies (Miller, 1996). According to Mount (1994), when grazing with angora goats, kudzu was 80-85% controlled after the second year of grazing and to prevent re-growth, 3 more years of grazing was suggested. Most grazing animals will consume kudzu with cattle being the most successful (Miller, 1996). Using fences, grazing animals can be contained in the area where kudzu is located to ensure consumption (Miller, 1996). However grazers are not recommended near water bodies due to increases in nitrogen and fecal coliform (Berka et al., 2001).

Herbicides are also used to eliminate kudzu. While herbicides are successful in defoliation, eradication of roots is difficult. In order to completely thwart the future spread of kudzu, individual roots crowns have to be treated (Miller, 1996). Several applications are required to control kudzu, ranging from 3 to 10 years (Forseth and Innis, 2004; Harrington et al., 2003). The use of herbicides in sandy soils and near bodies of water is restricted due to leaching into water which can also affect non-target plant species (Miller, 1996). Herbicides also have restricted usage near crops or trees that can be injured or killed (Miller, 1996).

While herbicides and grazing are successful at controlling kudzu, a concern over the usage of these methods near sensitive areas such as riparian areas and crops is a concern (Berka et al., 2001). An alternative, nonchemical approach for kudzu elimination was conducted in the Clemson Experimental Forest (CEF) in South Carolina by the use of solarization (Newton et al., 2008).

Solarization is a method of eradicating pathogens, nematodes, weeds, weed seed banks, and other soil pests by covering the soil with polyethylene sheeting in order to heat the soil (Culman et al., 2006; Horowitz et al., 1983; Katan, 1981; Marenco and Lustosa, 2000). While many studies have been done on the use of solarization to eradicate weeds, fungus and microbes, few studies have been done on using solarization to eliminate invasive species. Newton (2008) demonstrated that solarization was effective in eliminating kudzu with the use of polyethylene sheeting by eradicating above ground kudzu biomass as well as 97% of kudzu root crowns by the second year of treatment.

Studies have been completed on the effects of solarization on soil chemical properties with noted increases in concentrations of K, Na, Ca, and Mg (Chen and Katan, 1980).The addition of organic amendments under solarization has also been demonstrated to enhance soil fertility (Gelsomino et al., 2006). Additionally, solarization is known to cause an increase in plant growth response (Culman et al., 2006; Gelsomino et al., 2006; Grunzweig et al., 1998; Marenco and Lustosa, 2000).

Plants need major and minor nutrients to thrive and grow. Of these, hydrogen, oxygen, and carbon can be obtained from water or air; the others[1] are obtained from the weathering of rocks and soil (Brady and Weil, 2004). However, after the harvest or removal of plants, essential lithophilic minerals are taken out of the system (Crews, 2005). With the deep roots of perennial kudzu, soils might be continuously supplied necessary nutrients. Nutrients stored in uncultivated vegetation are made available to crops through decomposition (Crews, 2005).

Several studies have been conducted on the effects of solarization on soil with and with out organic amendments (Gelsomino et al., 2006; Horowitz et al., 1983). Newton (2008) demonstrated that solarization was an effective method in the elimination of kudzu. However, no studies were found that examined solarization of kudzu effects on soil chemical properties. A study on solarized kudzu could determine the soil stratum parameters under this treatment. The purpose of this study is to analyze the effects of solarization on soil under kudzu in anticipation of unique findings due to kudzu's root structure and physiology.

We hypothesized that solarized kudzu would contribute to significant increases in soil N, P, and K as well as increases in other soil chemical concentrations and properties. This research aimed to examine the effects of decomposed solarized kudzu on soil chemical properties. The objectives of this study were: (1) to determine differences

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[1] N, P, K, Ca, Mg, S, Mn, B, Zn, Cu, Ni, Cl, Mo, Co, and Fe.

among three different degrees of solarized kudzu invaded soils with non solarized kudzu invaded soils and disturbed bare soils for variations in soil chemical properties; (2) to evaluate the mineral and elemental concentrations of kudzu's leaf, stem and roots to determined kudzu's ability to access and store nutrients in tissue that are then released into soil after decomposition.

CHAPTER TWO

MATERIALS AND METHODS

Study area

The location for this study was the Clemson University Experimental Forest in Clemson, South Carolina (N 34° 41' 55.7", W 82° 52' 45.7"). The site used for the study is a 1.2 ha kudzu infestation at least 30 years old, which is bordered on the north by a 15-year-old loblolly pine plantation. Local businesses and county highways border the remaining three sides (Fig. 2.1).

This site is within the Southern Outer Piedmont ecoregion (Griffith et al., 2002). Mean temperatures for this site range from -2°C to 10°C in January and from 20°C to 32°C in July (Griffith et al., 2002). There are between 190 and 230 frost-free mean days annually, and mean annual precipitation ranges from 112 to 142 cm (Griffith et al., 2002). Detailed precipitation and temperature data for the sampling seasons are summarized in Table 2.1.

The slope for the site ranges from 6% to10% with a south-west aspect. There are several terraces across the tract. Aerial photographs dated 1938 show that this was once a home site with the terraces planted in row crops. The soil is a highly erodable Cecil clay loam (fine, kaolinitic, thermic Typic Kanhapludult) (USDA/NRCS, 2007).

A randomized complete block design (RCBD) was used for the study because we were concerned with environmental variability (Fig. 2.2). Three manipulative treatments using translucent polyethylene sheeting were installed for this study in preparation for the

2005 growing season: complete coverage during the growing season; alternating weekly coverage; and covered for one-week, uncovered for four- weeks.

Untreated control areas (live kudzu plots and disturbed bare soil) were sampled immediately outside the plots. Each treatment was replicated three times. The plots used for the manipulative treatments measured 20 feet by 100 feet (6.1m by 30.5m). Translucent polyethylene sheeting used during the 2005 growing season was not UV-resistant. The number of treatments, plot size, and study materials were amended for the 2006 growing season after analysis of the 2005 data.

The same study site was used for the 2006 growing season with the application of the complete season, one-week interval, and four-week interval treatments replicated three times each. Untreated control areas were again sampled immediately outside the plots (n=9). Each plot measured 20 feet by 30 feet (6.1m by 9.1m). UV-resistant translucent polyethylene sheeting was used in each treatment (Newton et al., 2008).

Historic Land Use Analysis

The study area is located in the Clemson Experimental Forest, which is the result of the federal land reclamation project initiated by the Roosevelt administration in the 1930s. Aerial photography associated with the project taken November 14, 1938 (PI-16-66) shows the study area as cultivated land. Kudzu was widely planted along road and railroad cuts for soil stabilization by the WPA and CCC projects. Forest and stand records indicate that the study area was completely covered in kudzu in 1960 and recommended control and planting to pine. The 1971 stand record indicates that the area was still covered in kudzu and was periodically burned by fire originating from the railroad. The 1982 stand record indicates that the kudzu was invading adjacent high quality timber stands and recommended using the area for kudzu control research.

Using the Geographic Information Systems (GIS) software ArcMap 9.2, sections of the 1938 and 1965 aerial photos were scanned and geo-referenced to a 2006 color infrared digital ortho-photography image acquired from the USDA Geospatial Gateway. The images and historical land use information available from archival documents and literature were compared to determine the land use history of the site as it changed from agricultural to kudzu (Fig. 2.1).

Plant sampling and analysis

Kudzu was harvested in July of 2007 from the study area. The parts were separated into leaf, stem, and roots. Leaves and stems of the kudzu plant were collected from the new growth of vines. Roots were collected within the first 30 cm of the soil. Five random samples were taken for each plant part in the study area and were then washed thoroughly with deionized water to remove sediment.

Samples were oven dried at 70-80° C and then ground with a Wiley mill, in a 20-mesh sieve. Using a muffle furnace, each of the 1.00g samples were ashed. Ashes were dissolved

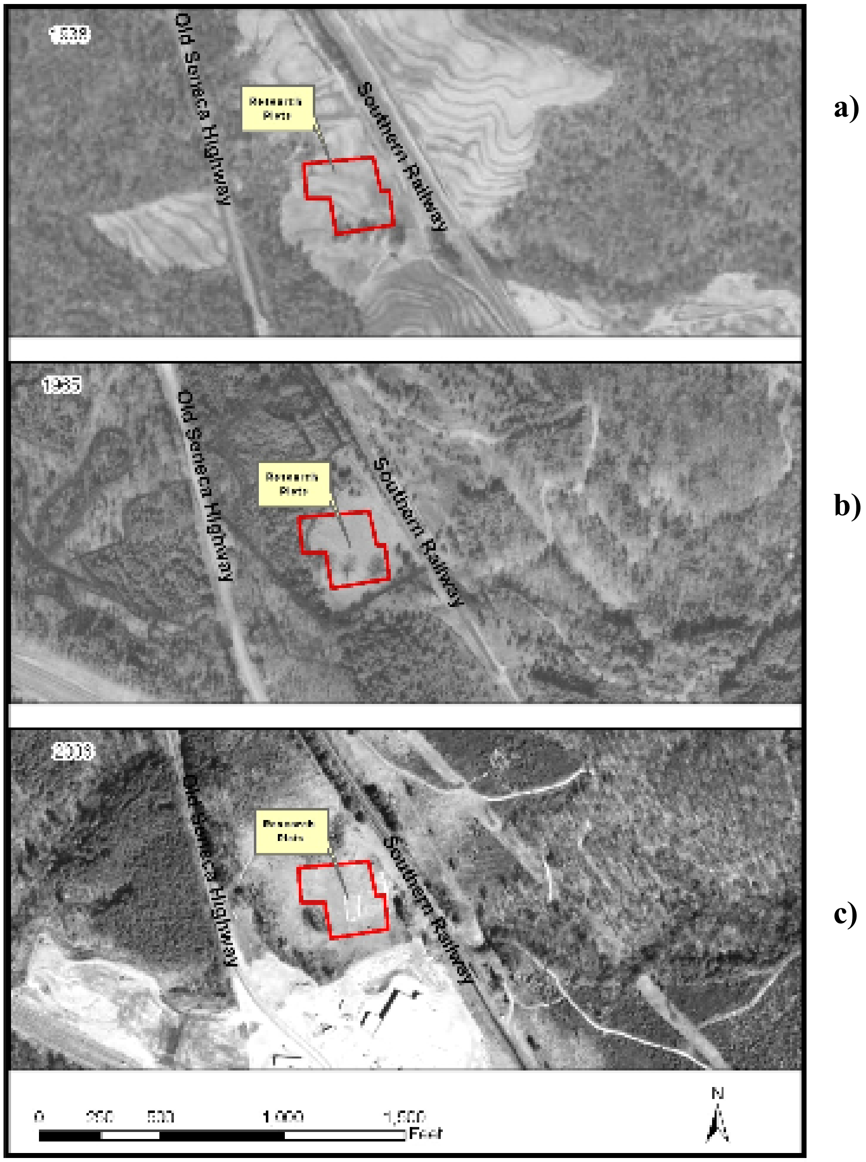

Figure 2.1 Aerial photographs of the study area from the years: a) 1938: Old field with agricultural terraces, b) 1965: Abandoned field with kudzu invasion, c) 2006: Abandoned field with continued growth of kudzu.

Table 2.1. Monthly total precipitation (mm) and monthly average temperature (°C) for Clemson University, Pickens County, SC (Data acquired from the Clemson University Weather Station: 381770 in climate division: SC-02 – Northwest).

Month	2005			2006			2007			10-yr avg.†		
	Temp.		Precip.	Temp.		Precip.	Temp.		Precip.	Temp.		Precip.
	Max.	Min.		Max.	Min.		Max.	Min.		Max.	Min.	
January	13.61	1.33	54.61	14.83	3.33	108.71	13.22	2.61	146.30	12.61	0.44	112.01
February	‡	‡	‡	12.56	1.33	50.55	12.44	0.00	100.33	13.39	1.17	103.12
March	15.83	4.22	155.96	18.33	4.83	47.50	21.44	7.56	92.20	16.56	6.33	116.33
April	21.33	8.44	86.61	25.83	10.72	103.38	22.17	7.94	27.69	22.61	9.33	94.23
May	25.17	12.28	104.65	26.22	13.39	107.70	27.89	12.50	37.59	26.61	13.89	86.87
June	28.39	18.33	245.87	31.22	17.22	249.68	32.17	18.22	84.84	30.39	18.22	129.79
July	31.22	21.06	230.38	33.06	20.28	55.37	30.89	19.06	77.47	31.94	20.33	117.60
August	31.44	20.83	98.55	33.44	20.89	66.29	36.11	21.83	43.43	32.39	20.22	90.68
September	30.94	17.44	16.76	27.17	15.94	129.54	30.67	17.39	57.15	28.56	16.44	113.03
October	24.00	11.50	71.63	22.39	9.06	113.79	25.44	12.33	40.64	23.44	10.44	77.98
November	18.94	5.67	95.50	18.28	4.44	73.91	18.83	3.78	32.00	18.78	5.17	87.38
December	11.28	-0.67	138.18	16.17	2.83	111.76	15.11	4.11	145.80	13.11	1.00	117.86
Total			1298.70			1218.18			885.44			1246.89

† Ten year average is based on data from 1998-2007. Means do not include months with missing data.

‡Indicates missing data.

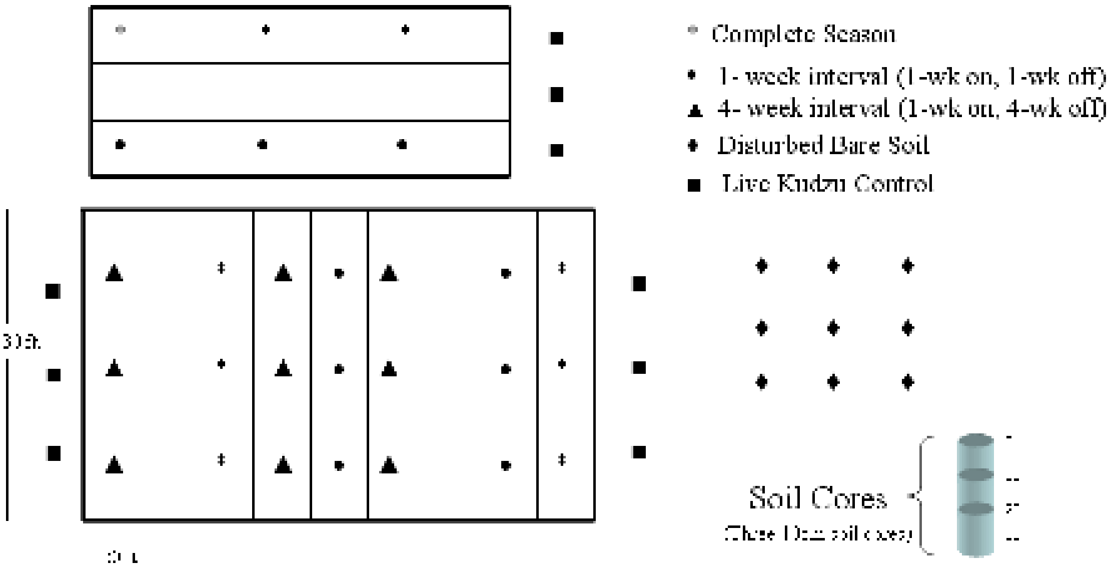

Figure 2.2 Experimental layout (modified from Newton, 2008).

by adding 10mL of 1 *M* (Molar) HCl to obtain B concentrations, 100mL H_20 to obtain Na concentrations, and 10mL of 6 *M* HCl to obtain P, K, Ca, Mg, Zn, Cu, Fe, Mn, and S concentrations. Concentrations were determined based on ICP-AES (Inductively coupled plasma - atomic emission spectroscopy). Nitrogen and carbon was analyzed using the Elementar Vario Macro.

Plant statistical analysis

The analysis of variance (ANOVA) was used to test for significant difference among the three plant parts, after the assumptions of ANOVA were assessed. When a significant F-test occurred, mean plant part values were compared using Fishers LSD Test to detect differences. All significance tests were performed with $\alpha=0.05$ and all calculations were performed using the Statistical Analysis System (SAS Institute, 2002).

Soil sampling and analysis

Soil samples were taken with an auger during June and July 2007. Plots treated with polyethelyne sheeting had three locations sampled within each replication at three depth intervals: 0 to 10cm, 10 to 20cm, and 20 to 30cm. Soil samples were taken in live kudzu control areas located immediately outside the treated plots at the three depths. Disturbed bare soil plots were located outside of the treated plots.

Laboratory soil tests were conducted to determine soil pH; organic carbon and nitrogen contents; nitrate-nitrogen; extractable phosphorus, potassium, calcium, magnesium, zinc, manganese, copper, boron, and sodium; cation exchange capacity

(CEC); acidity; and percent base saturation. An extensive description of all soil tests and quality control procedures is available via the test laboratory website (www.clemson.edu/agsrvlb/procedures2/interest.htm). After drying, the samples were crushed and homogenized by grinding and screening through a 10-mesh (2-mm) screen before analysis.

The pH of all soil samples was determined by equilibrating 20g of soil with 20mL of deionized water for a minimum of one hour and then measuring the pH with a calibrated AS-3000 dual pH analyzer. Extractable nitrate-nitrogen (NO_3-N) was quantified using an aluminum sulfate solution and subsequent determination of nitrate with an ion specific electrode. The nitrate extracting solution was prepared by dissolving 173.2g $Al_2(SO_4)_3 \cdot 18H_2O$, 12.8g H_3BO_3, and 0.7222g KNO_3 in 10L of deionized water with the final pH adjusted to 3.0 with NaOH. Twenty grams of each soil sample were equilibrated with 40mL of the nitrate extracting solution for a minimum of one hour before filtering the extracts and measuring for NO_3-N concentrations using a calibrated specific nitrate ion electrode. Mineral analyses of 9 minerals (P, K, Ca, Mg, Na, Zn, Mn, Cu, B) were determined using a Mehlich No. 1 extraction solution and element quantification by inductively coupled plasma atomic emission spectroscopy (ICP-AES) (Jones, 2001). Total carbon (C) and nitrogen (N), equivalent to organic C and N for these particular soil samples, were measured in 200mg samples using a combustion analyzer (Elementar Vario Macro, Mt. Laurel, NJ) (Moore et al., 2002).

Soil statistical analysis

Thermal treatments were conducted using translucent polyethylene sheeting, and samples were obtained at various depths. The thermal treatment and depth factors were arranged in a factorial treatment design, resulting in 15 treatments. These treatments were arranged in a split-plot design. The five treatments defined the whole-plot treatment in the split-plot and were applied in a RCBD. The sampling depths defined the sub-plot treatment factor in the split-plot design. The whole-plot treatments were replicated three times (except for the controls, which were only replicated once), and the sub-plot treatment was replicated three times. A statistical model for the design was developed that included terms for the main effect of thermal treatment, the main effect of sampling depth, and the interaction of thermal treatment and depth. The ANOVA was used to test the significance of the terms in the model, after the assumptions of ANOVA were assessed. When a significant F-test occurred, mean soil values were compared using Fishers LSD Test to detect differences among treatments and depths. All significance tests were performed with $\alpha=0.05$ and all calculations were performed using the Statistical Analysis System (SAS Institute, 2002).

CHAPTER THREE

RESULTS AND DISCUSSION

Weather Data

Air temperatures for the summer months (June-August) all showed temperatures warmer by a few degrees than the 10-year average with the exception of July which was lower than the 10-year average (Table 2.1). The average monthly precipitation in 2007 was 73.79 cm which is 30 cm below the ten year average (1997- 2007) (Table 2.1).

Historical Land Use

Based on aerial photos taken in the years of 1938, 1965, and 2006 it was assessed that land cover in the study area has been transformed since 1938. The aerial photograph taken in 1938 depicts a study site with agricultural terraces. Old fields such as this were farmed this way to alleviate erosion of soils (Figure 2.1). According to Sorrels (1984), years of cotton production on the land contributed to poor productivity which eventually led to its abandonment. In the 1940's, kudzu was being planted on the banks of streams in South Carolina to prevent soil erosion (Sorrels, 1984). In 1968 kudzu growth continues. In 2006 kudzu can be seen at the edge of a wooded area (Figure 2.1). As aerial photographs demonstrate, kudzu has been in this study area for nearly 70 years.

Plant Chemical Composition

In order to gain an understanding of kudzu nutrient allocation in different plant parts, a chemical analysis of plant parts was conducted. Parts analyzed were root, stem, and leaf tissue. The plant analysis results indicate the distribution of chemical concentrations within the kudzu plant. The data in Table 3.1 allows a visual interpretation of kudzu uptake of metals and nutrients from the soil that are then released through solarization as the plant degrades. Calcium concentrations among leaf, stem, and underground parts showed no significant difference (Table 3.1). However, these results are not consistent with one study of kudzu conducted in Tuskegee, Alabama where Ca concentrations where significantly higher in the leaf parts than in the tuber (Corley et al., 1997). Perhaps varying conditions such as soil, harvest time, and weather play a role in the amount of Ca kudzu uptakes and should be further investigated. Concentrations of N, S, Cu, and Mn were significantly greater in leaf and stem parts than in below ground parts (Table 3.1).

Concentrations of Fe and Mg were significantly higher in below ground tissue than above ground tissue with Fe concentrations being two-fold than the stem and ten-fold than the leaf for below ground matter (Table 3.1). This trend in Fe concentrations is similar to a concentration trend found in a study done by Corley, 1997. However, in the Corley study, concentrations of Mg were significantly higher in leaf than in tuber (Corley et al., 1997). The P, Zn, and K concentrations were found to be significantly higher in the stem tissue than in the leaf and underground tissues (Table 3.1).

Soil Chemical Composition

Soil pH

Soil pH is important for many reasons. It alone can determine which nutrients and toxins will be available for uptake as well as determining which plant species and microorganisms such as fungi and bacteria will be present (Brady and Weil, 2004). In this study, levels of soil pH ranged from 5.7 to 4.8 among treatments and depths (Figure 3.1). Soil pH showed significant differences ($p<0.0001$) among the five treatments (Table 3.2). Soil pH under the complete season treatment and disturbed bare soil showed no significant differences (Figure 3.1). Soil pH was significantly higher for the one-week interval, four- week interval, and live kudzu control than disturbed bare soil and complete season treatments, with the live kudzu control having the highest soil pH of 5.7 to 5.6 at all depths (Figure 3.1).

Other studies have reported similar results of increased soil pH under solarized soils with organic amendments (Gelsomino et al., 2006). Although this study and other studies have shown increases in pH under decomposing material, the accumulation of organic matter also tends to acidify the soil which may explain why the complete season solarized treatment had the lowest pH. We believe this to be true due to the longer treatment time given for the complete season treatment. The increase in decomposition time allows more time for organic matter to decompose thus increasing the release of H^+ ions in the soil, where as the other treatments were given shorter decomposition times and therefore, may exhibit fewer H^+ ions being released in the soil (Brady and Weil, 2004). Across all treatments soil pH showed no significant changes based on depth

(Table 3.2). Higher pH levels found in the live kudzu treatment may be due to the fact that Ca concentrations were significantly higher which is known to increase pH levels in soils (Reich et al., 2005).

Table 3.1. Mean mineral value of kudzu in July 2007. Means with similar horizontal letters are not significantly different based on Fisher's protected LSD (α=0.05).

	July 2007		
Parameters	Leaf	Stem	Root
Mg (%)	0.30 (0.003) a	0.242 (0.007) a	0.426 (0.05) b
K (%)	2.32 (0.02) a	3.32 (0.07) b	0.878 (0.06) c
S (%)	0.17 (0.002) a	0.15 (0.004) a	0.108 (0.02) b
C (%)	44.74 (0.14) a	41.89 (0.62) b	44.18 (0.93) a
N (%)	3.14 (0.03) a	2.94 (0.02) b	1.32 (0.10) c
C/N	14.26 (0.16) a	14.24 (0.22) a	33.4 (2.24) b
P (%)	0.23 (0.004) a	0.286 (0.005) b	0.034 (0.05) c
Ca (%)	0.456 (0.01) a	0.458 (0.007) a	0.664 (0.13) a
B (ppm)	34.2 (1.62) a	24.00 (0.44) b	21.2 (2.80) b
Fe (ppm)	114.4 (3.85) a	417.8 (32.32) a	2036.2 (896.24) b
Zn (ppm)	25.8 (0.37) a	37.6 (0.51) b	24.4 (1.60) a
Cu (ppm)	10.6 (0.24) a	11.2 (0.37) a	7.6 (1.07) b
Mn (ppm)	131.6 (2.08) a	128.2 (3.15) a	80 (10.21) b

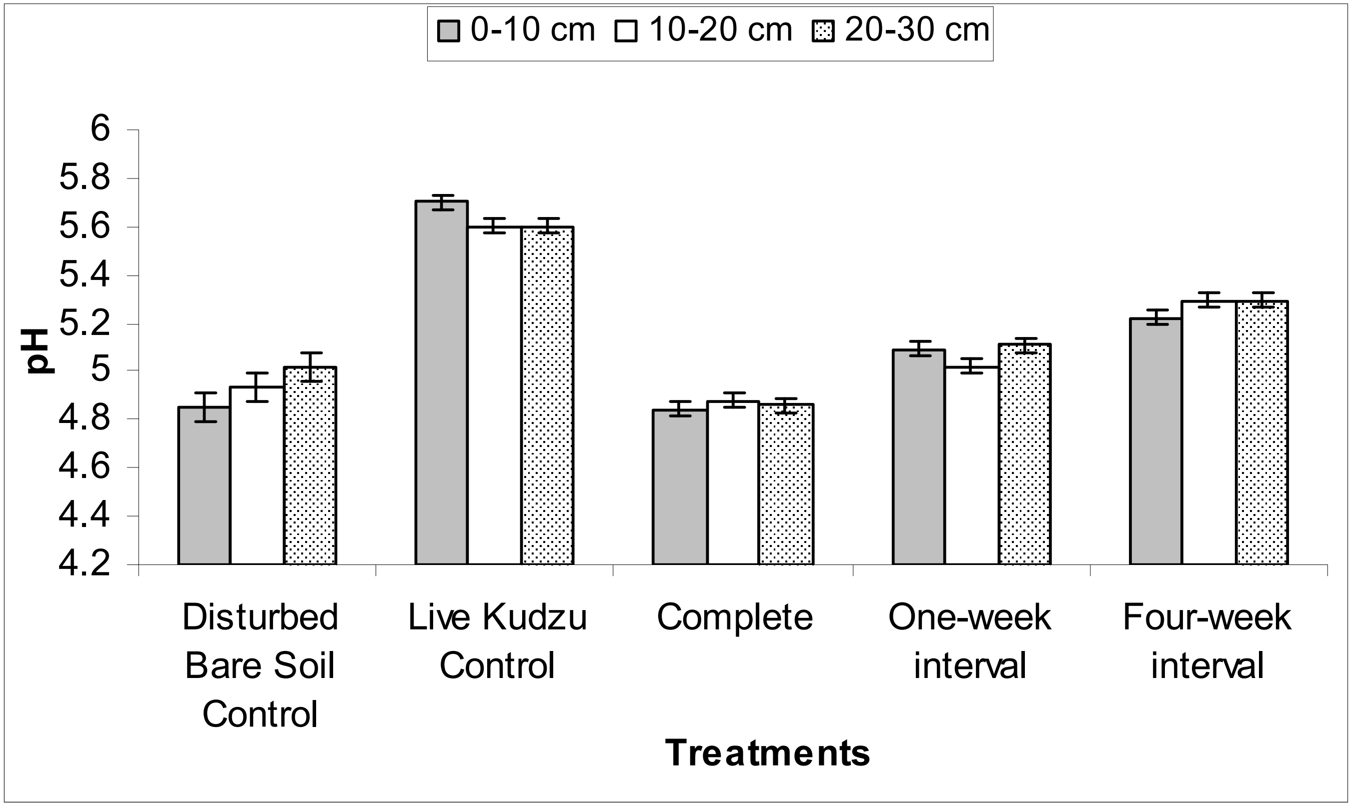

Figure 3.1. Soil pH comparisons (mean values and standard errors) among treatments and depths.

Table 3.2. Analysis of variance for the effects of treatment and depth on soil chemical properties (Summer 2007) (Continued).

Effect	df	pH	C	N	C:N	NO_3-N	P	K	Ca	Mg	Zn
Treatment	4	225.45 (<0.0001)	5.70 (0.0048)	8.48 (0.0007)	14.92 (<0.0001)	76.84 (<0.0001)	18.28 (<0.0001)	30.73 (<0.0001)	29.10 (<0.0001)	8.61 (0.0007)	1.52 (0.2447)
Rep(Trt)	8	115.67 (<0.0001)	5.52 (0.0019)	4.16 (0.0074)	16.85 (<0.0001)	5.91 (0.0013)	8.94 (0.0001)	14.47 (<0.0001)	27.79 (<0.0001)	10.44 (<0.0001)	3.16 (0.0240)
Depth	2	1.18 (0.3329)	41.51 (<0.0001)	21.41 (<0.0001)	22.09 (<0.0001)	14.88 (<0.0002)	28.25 (<0.0001)	1.22 (0.3206)	10.77 (0.0011)	3.39 (0.0591)	4.48 (0.0286)
Treatment × Depth	8	2.02 (0.1094)	2.13 (0.0946)	0.85 (0.5744)	3.28 (0.0207)	1.56 (0.2141)	0.67 (0.7098)	1.85 (0.1406)	3.12 (0.0251)	1.45 (0.2521)	0.66 (0.7211)

Table 3.2. (Continued from pg. #) Analysis of variance for the effects of treatment and depth on soil chemical properties.

Effect	df	Mn	Cu	B	Na	Ca b.s.†	Mg b.s.	K b.s.	Na b.s.	Tot. b.s.	ECEC‡	Acidity
Trt	4	36.13 (<0.0001)	7.38 (0.0014)	9.14 (0.0005)	18.10 (<0.0001)	36.06 (<0.0001)	9.26 (0.0005)	23.81 (<0.0001)	0.92 (0.4748)	21.99 (<0.0001)	3.96 (0.0202)	7.54 (0.0013)
Rep (Trt)	8	28.81 (<0.0001)	2.81 (0.0375)	7.17 (0.0004)	6.84 (0.0006)	37.46 (<0.0001)	8.71 (0.0001)	6.78 (0.0006)	1.00 (0.4726)	41.18 (<0.0001)	7.92 (0.0002)	23.05 (<0.0001)
Depth	2	2.13 (0.1512)	0.41 (0.6698)	7.69 (0.0046)	3.13 (0.0714)	10.34 (0.0013)	4.92 (0.0216)	0.97 (0.3995)	1.00 (0.3897)	4.99 (0.0207)	4.76 (0.0238)	0.34 (0.7172)
Trt × Depth	8	0.59 (0.7718)	0.53 (0.8179)	1.85 (0.1397)	0.61 (0.7582)	2.45 (0.0603)	0.82 (0.5963)	1.53 (0.2240)	0.81 (0.6057)	2.64 (0.0470)	1.77 (0.1578)	1.24 (0.3408)

† b.s. is base saturation.
‡ ECEC is Effective Cation Exchange Capacity.

Nitrogen

Nitrogen is a fundamental part of plant growth. It is integral for the formation of amino acids which develop into protein, nucleic acids, and is essential for root growth and development (Brady and Weil, 2004). Like pH it is also essential for the uptake of other nutrients. Nitrogen content showed significant differences among the five treatments ($p<0.0007$) and also by depth ($p<0.0001$) (Table 3.2). Disturbed bare soil had N concentrations statistically lower than complete season, one- week interval, and the live kudzu control treatments at the 0-10cm depth (Figure 3.2). Disturbed bare soil had the statistically lowest concentrations of N at depth 20-30cm among all treatments (Figure 3.2).

This increase of N in solarized soils is consistent with organic amended soils that were also solarized in a study done in Italy (Gelsomino et al., 2006). Nitrogen concentrations decreased as depth increased across all treatments (Figure 3.2). Due to kudzu's ability to fix nitrogen, increased N concentrations in the soil invaded by kudzu (Figure 3.2), are consistent with its ability to fix N, increasing N concentrations in soil (Forseth and Innis, 2004). In Belgium the invasive species *Rosa rugosa* also increased concentrations of N in the soil as compared with un-invaded soils (Vanderhoeven et al., 2005). Nitrogen may also increase under solarized soils as a result of the partial killing of N-storing microbial biomass during the solarization process (Scopa and Dumontet, 2007). According to Scopa and Dumontet (2007), mean microbial biomass decreased by 20% under solarized soils, versus non-solarized soils.

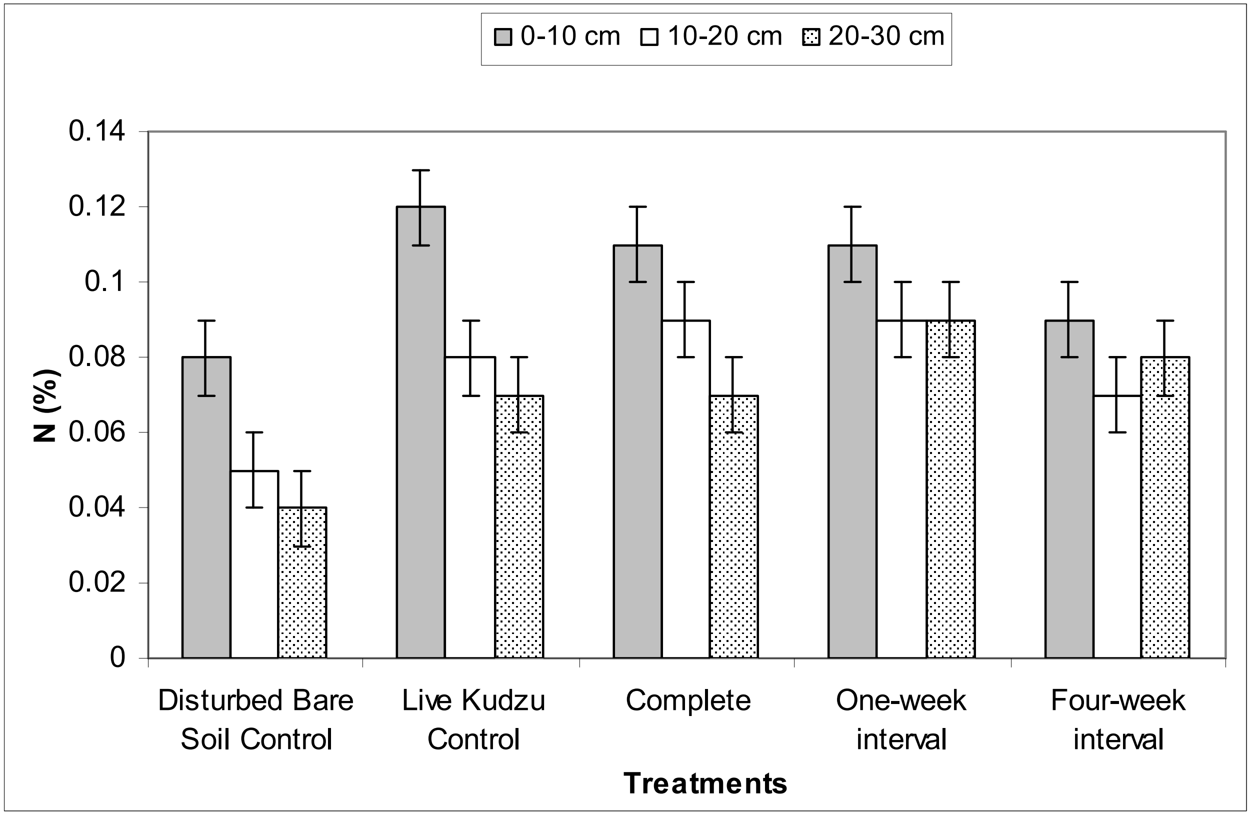

Figure 3.2. Nitrogen concentrations (%) comparisons (mean values and standard errors) among treatments and depths.

Carbon

Carbon forms many essential components in plant tissue such as carbohydrates, proteins, fats, waxes, and lignin (Brady and Weil, 2004). Carbon percentages showed significant differences among the five treatments and significant differences by depth (Table 3.2). Soils under one-week interval and four-week interval treatments had significantly higher percentages of C in depths 10-20 and 20-30cm than disturbed bare soil and for depth 20-30cm than all other treatments (Figure 3.3).

This increase in C for the one-week and the four-week interval treatments is consistent with C increases seen in a study where organic amendments were also solarized (Gelsomino et al., 2006). There were significant decreases in C as depth increased for all treatments with the exception of the four-week interval (Figure 3.3).

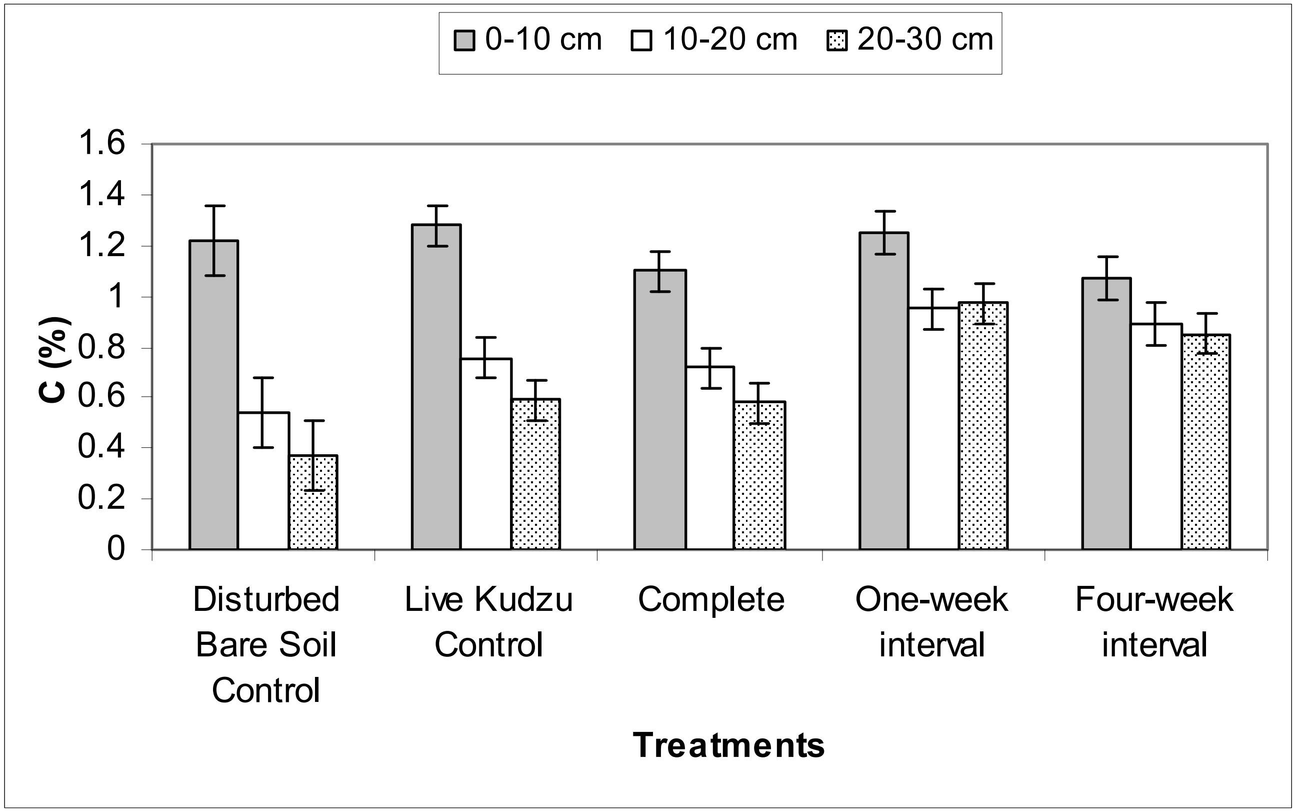

Figure 3.3. Carbon concentrations (%) comparisons (mean values and standard errors) among treatments and depths.

Carbon-to-Nitrogen Ratio

The ratio of carbon-to-nitrogen is important to plants because it determines if nitrogen will be available for uptake. If the ratio is lower, then nitrogen will be available to plants, however if the ratio is too high, the nitrogen is immobilized and not available for plant uptake (Brady and Weil, 2004). Ideal carbon to nitrogen ratios will fall under 20:1 (Brady and Weil, 2004). Following similar trends seen in N and C content in soil, the C/N ratios also showed significant decreases as depth increased (Table 3.2).

Disturbed bare soil, live kudzu control, and the complete season treatments all showed significant decreases in C/N between 0-10 and 20-30 cm (Figure 3.4). For depth 0-10 cm, disturbed bare soil had the highest C/N among all treatments with a mean of 15.47:1 (Figure 3.4). This decrease in C/N in solarized and live kudzu control soils is also seen in organic amended solarized soils in a study conducted in Italy (Gelsomino et al., 2006) (Figure 3.4). The higher C/N ratio observed in disturbed bare soil may be attributed to the fact that lower concentrations of nitrogen are present due to the absence of kudzu, a nitrogen fixing plant.

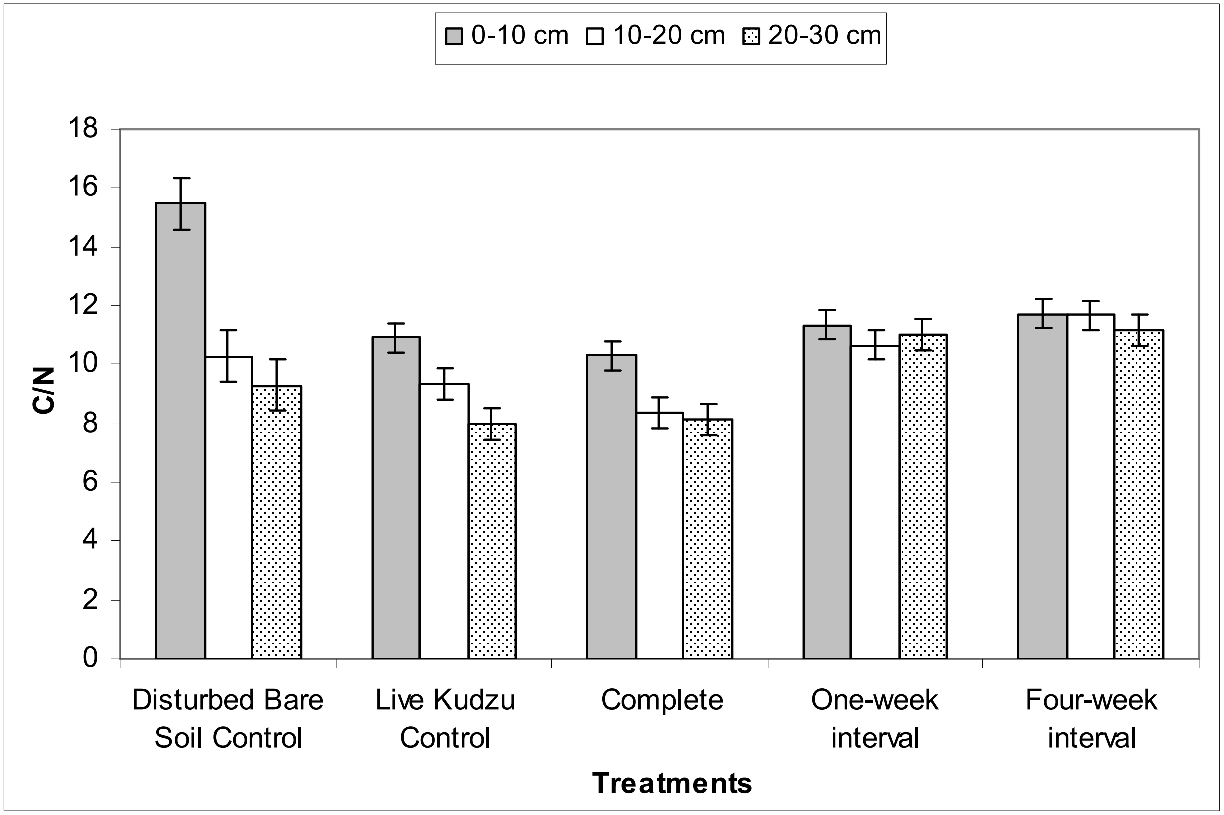

Figure 3.4. Carbon-to-nitrogen (C/N) ratio comparisons (mean values and standard errors) among treatments and depths.

Nitrates

Nitrates (NO_3-N) are another form of N that plants can receive their N requirements from. Nitrate showed significant decreases as depth increased and showed significant differences among treatments (Table 3.2 and Figure 3.5). Nitrate was highest in complete season at all depths with live kudzu control having the lowest concentrations at all depths (Figure 3.5). One- week and four- week interval treatments showed no significant difference between the two treatments at all depths (Figure 3.5). Disturbed bare soil had the second highest concentration at 0-10cm depth of 16.11 ppm behind complete season which was 22.66 ppm (Figure 3.5). The higher concentrations of NO_3-N found under solarized soils were also found in a study conducted in California where soils that were solarized had significant increases in NO_3-N in solarized soils as compared to non-solarized soils (Stapleton et al., 1985).

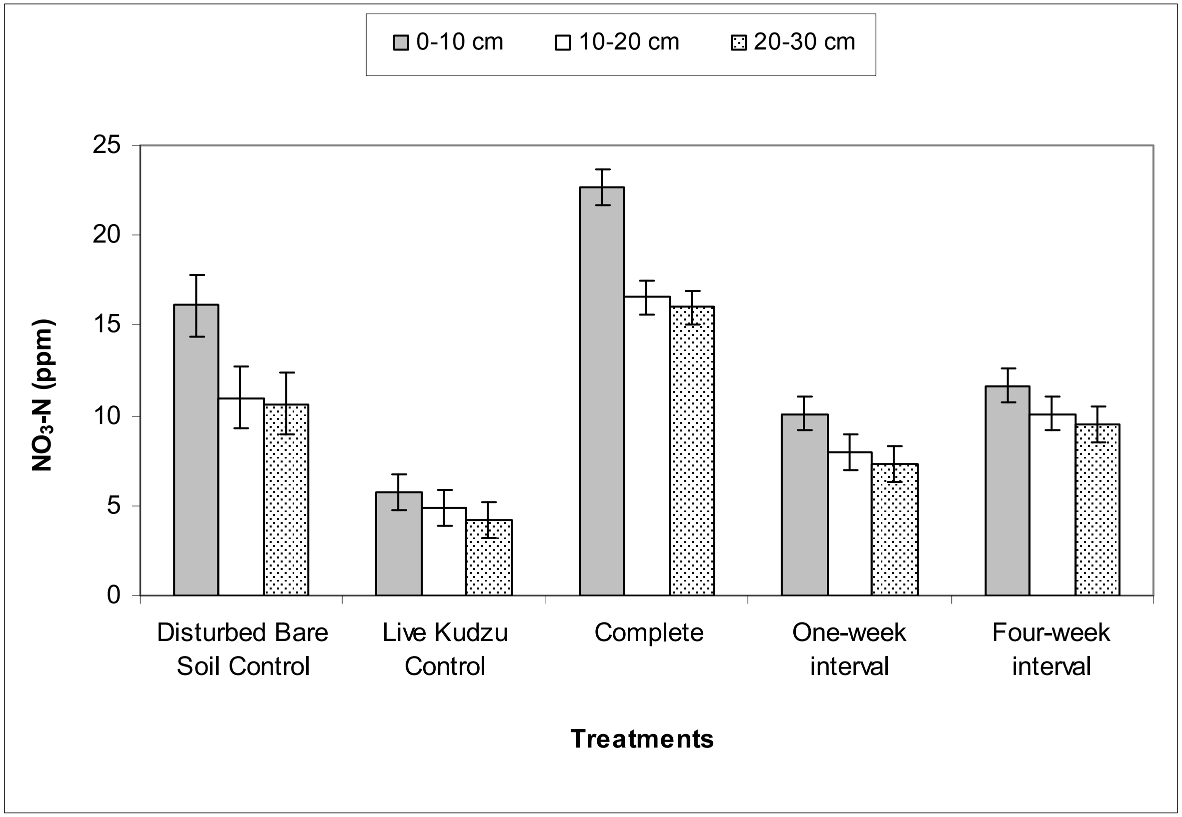

Figure 3.5. Nitrate (NO_3-N, ppm) comparisons (mean values and standard errors) among treatments and depths.

Phosphorus

Phosphorus plays an essential role in adenosine triphosphate (ATP) and the development of deoxyribonucleic acid (DNA) and phospholipids in a plant (Brady and Weil, 2004). Root growth, flowering, fruiting, nitrogen fixation as well as many other aspects of plant growth are dependent on or enhanced by the use of P (Brady and Weil, 2004). This study showed significant differences among the five treatments as well as depth (Table 3.2). Disturbed bare soil had the lowest concentrations of P at all depths with concentrations decreasing with depth (Figure 3.6). As depth increased concentrations of P decreased across all treatments (Figure 3.6). Though not significantly different, the one-week and four-week solarized plots showed the greatest concentrations of P among all treatments (Figures 3.6).

The study by Gelsomino, et al. (2006) also found P increases in soils with organic amendments. The study found a 3-fold increases in P in the soils under organic amended soil, with no difference between the solarized organic amended soils and non solarized organic amended soils (Gelsomino et al., 2006). This is consistent with this study where there were no statistical difference between live kudzu control and the solarized soils at many depths. Due to the results it appears that the presence of kudzu alone causes increases in P concentrations in soils. This increase in concentration of P with the invasive species kudzu has also been recorded in another invasive species *Solidago gigantea* in Belguim. Here the P concentrations were higher in *S. gigantea* invaded soils than in un-invaded soils (Vanderhoeven et al., 2005).

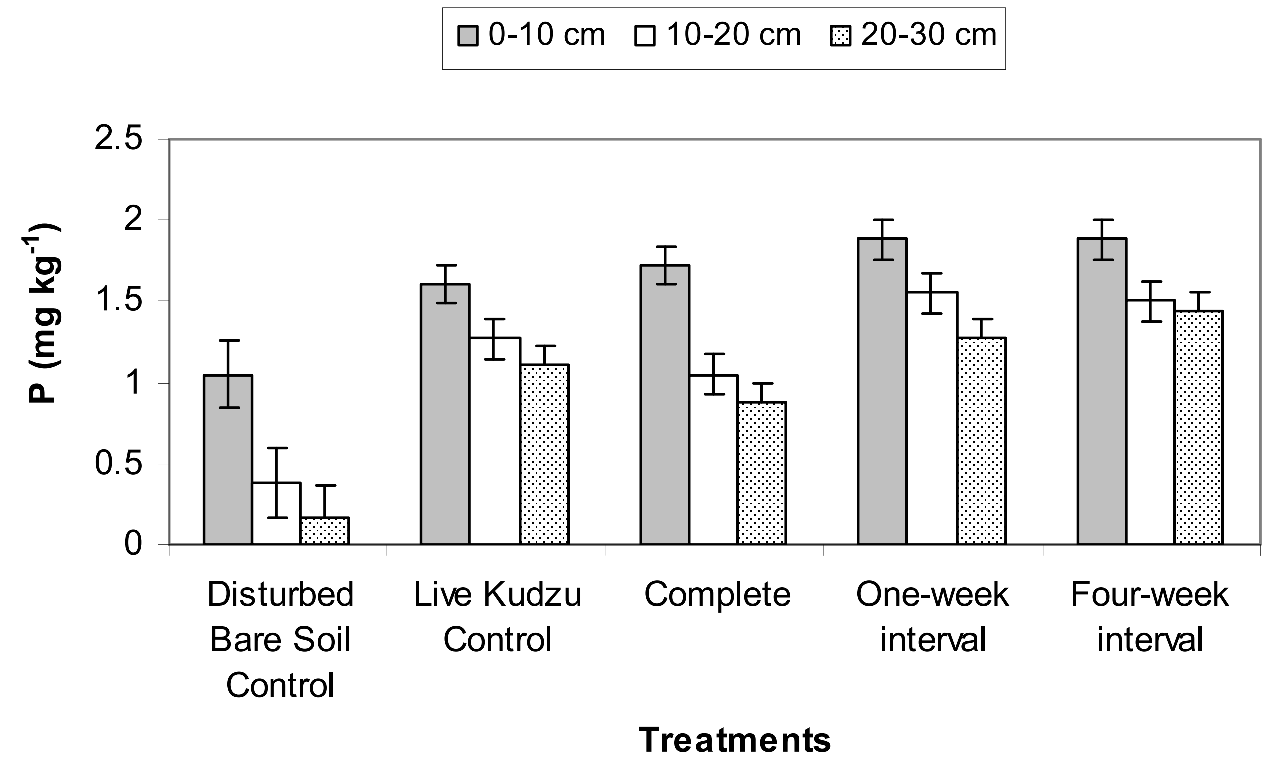

Figure 3.6. Phosphorus (mg kg^{-1}) comparisons (mean values and standard errors) among treatments and depths.

Potassium

The activation of over 80 enzymes is dependent on the presence of K (Brady and Weil, 2004). It plays a vital role in helping plants deal with environmental stresses such as drought and disease while enhancing flower and fruit quality (Brady and Weil, 2004). Disturbed bare soil and kudzu live controls had the lowest concentrations of K (Figure 3.7). Concentrations of K were higher in the solarized treatments: complete, one- week interval and four- week interval, at all depths (Figure 3.7). The disturbed bare soil was the only treatment that had significant decreasing concentrations of K with the increase of depth (Table 3.2). Greater concentrations of K in solarized soils than in live kudzu plots may be explained by the fact that higher concentrations of K are found in the plant analysis.

This increase showing that kudzu's above ground parts (leaves and stems) had significantly higher concentrations of K (Table 3.1). According to Brady and Weil (2004), plants take up large amounts of K, up to 5 to 10 times more than their uptake of phosphorus. Higher concentrations in solarized soils of K may be explained by the release of K from decomposing plant tissue during solarization. Plots invaded by invasive species in a study from Belgium showed K concentrations that were 32% higher than un-invaded soils (Vanderhoeven et al., 2005). This study showed K concentrations in solarized soil were on average 24% to 44% higher than concentrations found in disturbed bare soil and the live kudzu stand.

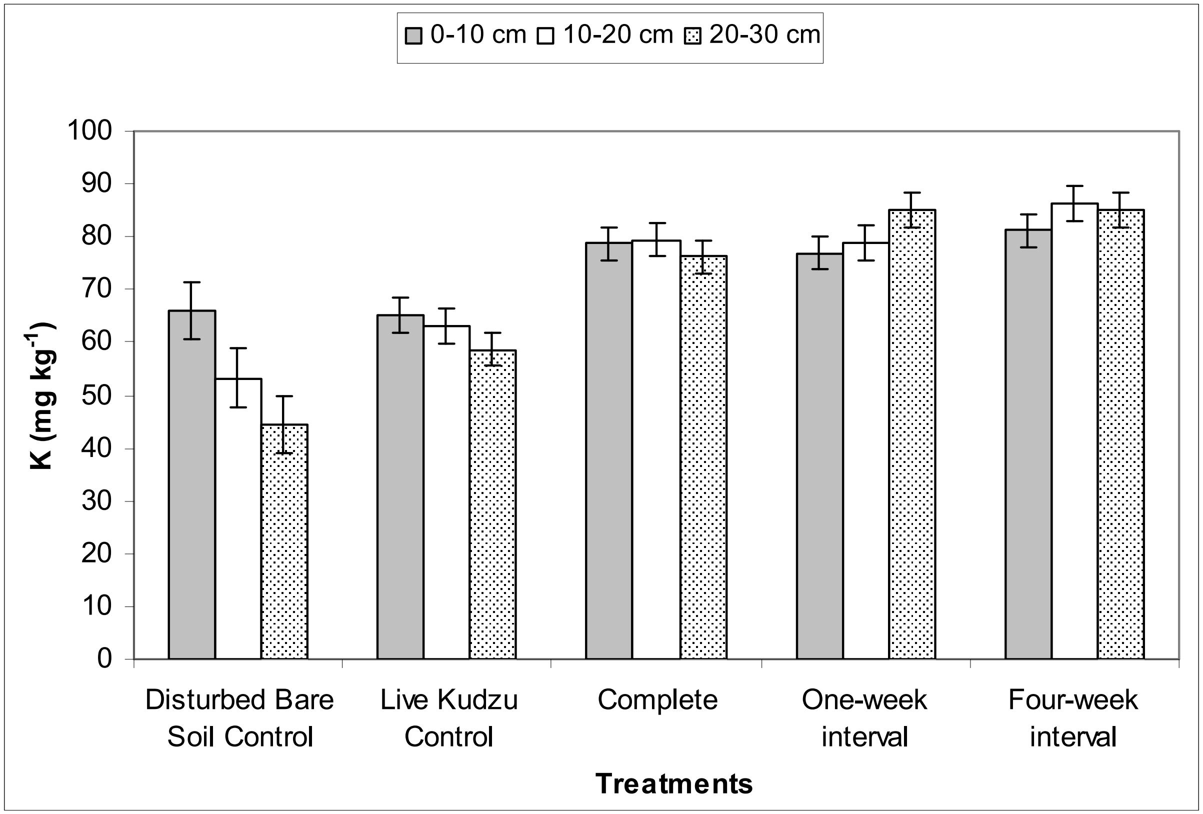

Figure 3.7. Potassium (mg kg^{-1}) comparisons (mean values and standard errors) among treatments and depths.

Calcium

Low concentrations of Ca can negatively affect the plant meristematic zones: root, stem, and leaf system, thus inhibiting plant growth (Brady and Weil, 2004). Live kudzu control had the significantly highest concentrations of Ca, with a 140% increase than disturbed bare soil at all depths (Figure 3.8). Though not significantly, the solarized treatments had greater concentration of Ca at all depths than disturbed bare soils. We believe that lower concentrations of Ca are found under the solarized plots due to the higher levels of decomposing plant matter.

With the increase of decomposing plant matter under solarized soils, the amount of organic acids being released into the soil increases (Brady and Weil, 2004). A more acidic environment increases the leaching of Ca because solubility of iron and aluminum increases, thus competing with base cations such as Ca for the binding sites on the exchange complex (Dijkstra and Smits, 2002).

Perhaps due to kudzu's deep roots, it is able to tap into leached Ca levels in the soil which is then cycled upward into the plant. Higher levels of Ca in soils under live kudzu than in disturbed bare soil suggest this Ca uplift theory. Not only is kudzu increasing levels of Ca in the soil but records of the invasive species *Prunus serotina* in Belguim also increased Ca concentrations by 42% (Vanderhoeven et al., 2005). Though not significant at all depths, solarization seems to increase levels of Ca leaving it to still be a viable option in increasing Ca concentrations in soil.

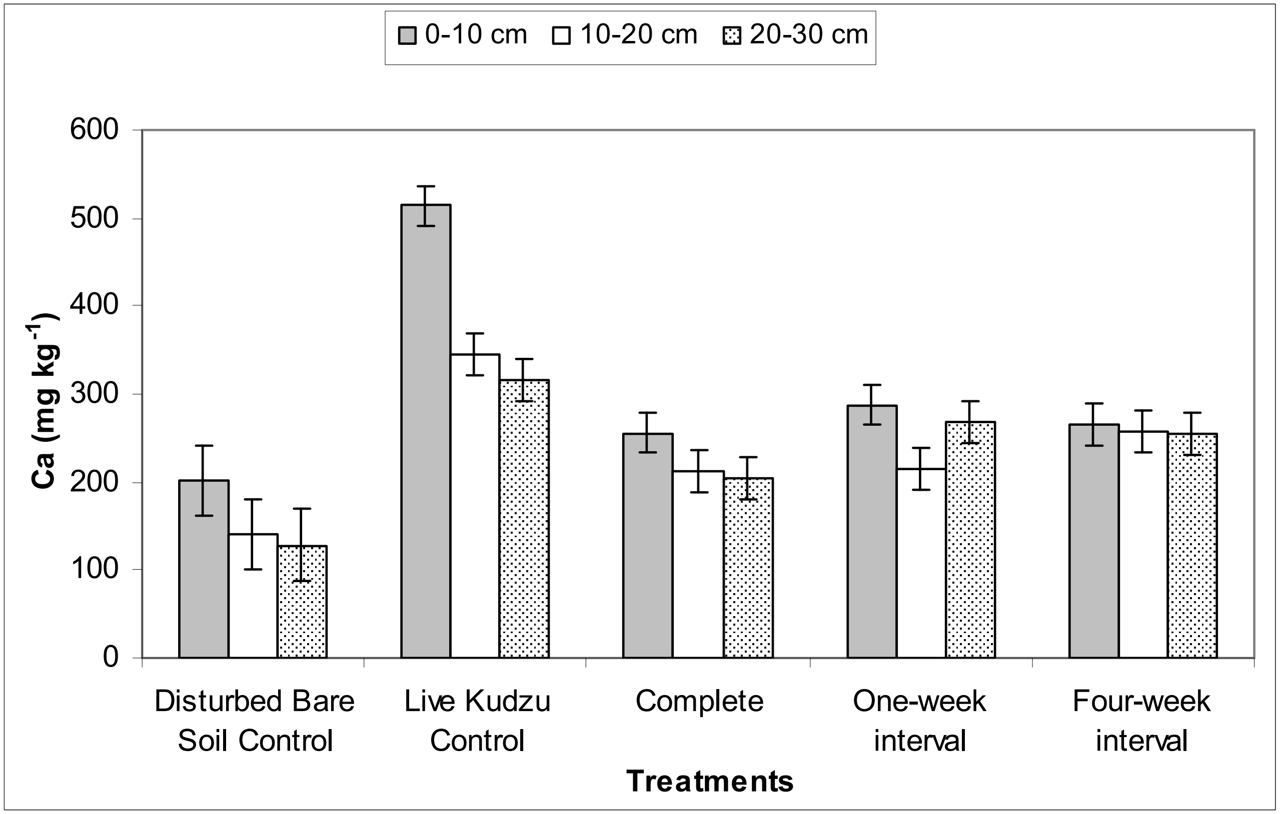

Figure 3.8. Calcium (mg kg^{-1}) comparisons (mean values and standard errors) among treatments and depths.

Magnesium

Synthesis of oils and proteins are reliant on sufficient concentrations of Mg (Brady and Weil, 2004). Magnesium also plays a major part in the process of photosynthesis due to it being a component part of the chlorophyll molecule (Brady and Weil, 2004). Disturbed bare soil had the highest concentration of Mg at all depths (Figure 3.9). There were no significant differences among solarized soils and live kudzu soils suggesting that large amount of this nutrient are not stored in plant tissue (Figure 3.9). Concentrations of Mg had a pattern of increases in concentration as depth increased (Table 3.2). This is apparent in one-week treatment and disturbed bare soil.

The higher concentration of Mg in disturbed bare soil is consistent with the idea that the main source of Mg is the exchangeable Mg found on the clay-humus complex (Brady and Weil, 2004). On the contrast in a study by Vanderhoeven (2005) the presence of invasive species showed significant increases in Mg concentrations in sites invaded by *Fallopia japonica* versus un-invaded sites.

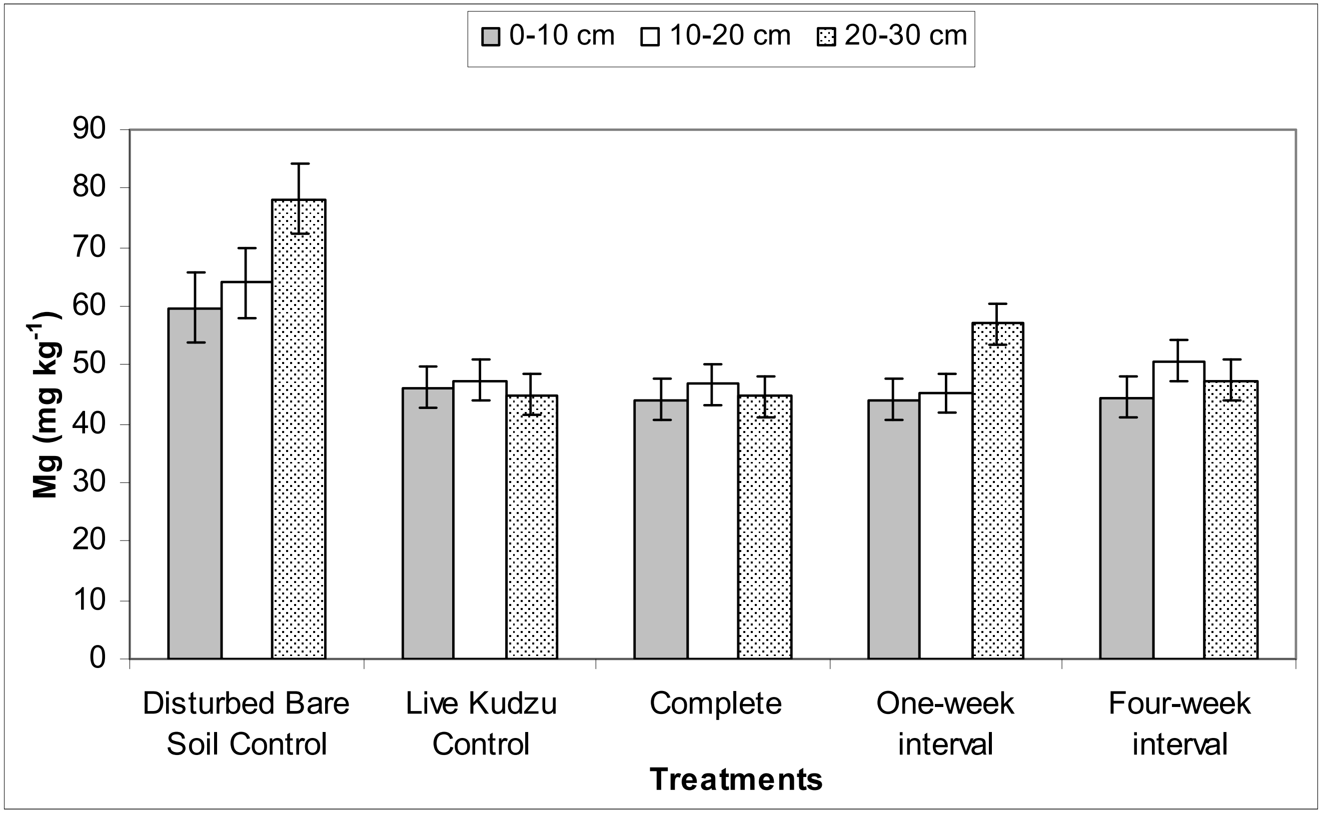

Figure 3.9 Magnesium (mg kg^{-1}) comparisons (mean values and standard errors) among treatments and depths.

Zinc

Zn is important in the promotion of seed maturation and production as well as in the promotion of growth hormones and starch production (Brady and Weil, 2004). This study showed no significant difference among treatments ($p<0.2447$) and had slight differences among the different depths ($p<0.0286$) for concentrations of Zn (Table 3.2) (Figure 3.10). This is consistent with in the study done by Stapleton (1985) where there were no significant differences between treatments. On the contrary the soil under the invasive species *Fallopia japonica* had significantly higher levels of Zn than un-invaded soils in Belgium (Vanderhoeven et al., 2005).

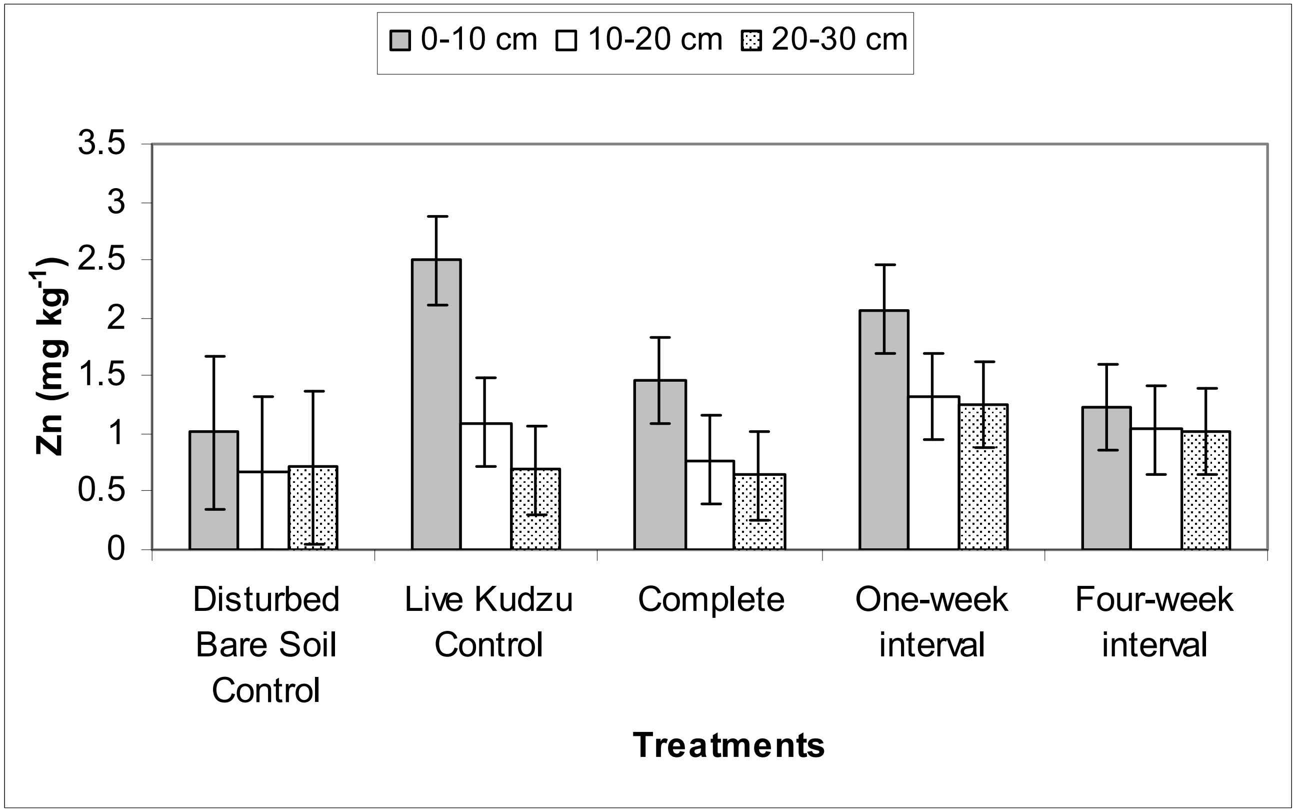

Figure 3.10. Zinc (mg kg^{-1}) comparisons (mean values and standard errors) among treatments and depths.

Manganese

Manganese is important in nitrogen assimilation, nitrogen metabolism, and in the process of photosynthesis (Brady and Weil, 2004). The results of this study showed that there was no significant difference among Mn concentrations by depth ($p<0.1512$) however there was significant difference among treatments ($p<0.0001$) (Table 3.2). Disturbed bare soil and live kudzu controls had the lowest concentrations of Mn (Figure 3.11). Though not significant from 0-10cm, increases in Mn concentrations from disturbed bare soil to live kudzu control are consistent with a study done in Belgium were Mn concentrations were 34% higher under invaded soils than under un-invaded soils (Vanderhoeven et al., 2005).

All sites showed an increase in Mn concentrations under live kudzu and solarized plots. One study found that higher concentrations of Mn were found in the soil of solarized treatments as compared to non-solarized (Seman-Varner et al., 2008). This study showed an almost two fold of Mn concentrations in live kudzu soils than in disturbed bare soil and at least a three fold of Mn from disturbed bare soil to the solarized soils. Higher concentrations of Mn were seen in solarized soils than in live kudzu plots while plant analysis showed that kudzu above ground parts (leaves and stems) had significantly higher concentrations of Mn than below ground parts (Table 3.1 and Figure 3.11). Increased uptake of metals in the leaves of kudzu has been previously noted (Brown et al., 2001). This higher concentration of Mn in the leaves may also explain the higher concentrations of Mn that are in solarized soils that were released during the process of solarization. Even though high concentrations of Mn were stored in kudzu, it is not a hyper accumulator because only species containing over 10,000 mg kg^{-1} are regarded as such (Peng et al., 2008).

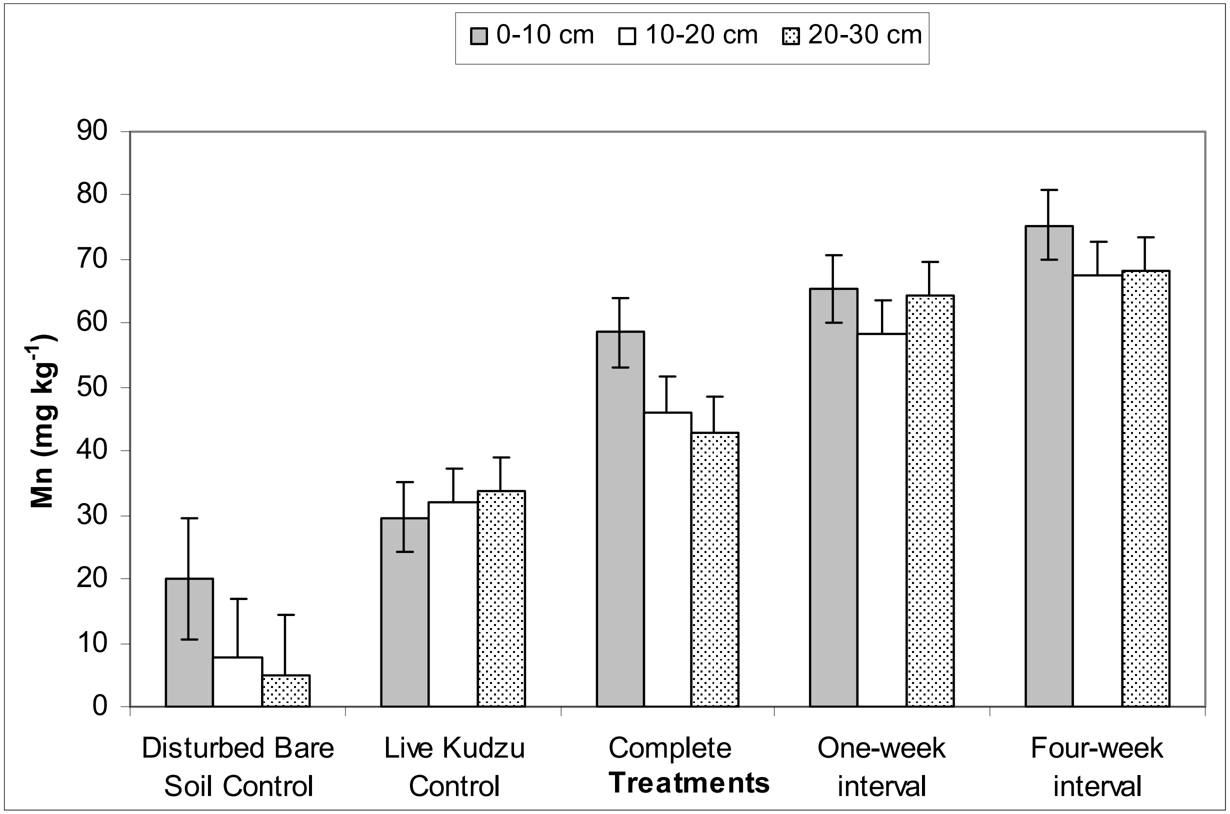

Figure 3.11. Manganese (mg kg^{-1}) comparisons (mean values and standard errors) among treatments and depths.

Copper

Copper plays an important role in photosynthesis, nitrogen fixation, and protein and carbohydrate metabolism (Brady and Weil, 2004). There was no significant difference among the depths ($p<0.6698$) (Table 3.2). Disturbed bare soil had the lowest significant concentration of Cu among the treatments (Figure 3.12). All other treatments, with the exception of disturbed bare soil, showed no significant difference between concentrations of Cu at all depths.

The invasive species *Fallopia japonica* showed an increase in concentrations of Cu in invaded soils versus un-invaded soils (Vanderhoeven et al., 2005). On the contrast, a solarization study done by (Seman-Varner et al., 2008), Cu concentrations were lower in solarized treatments compared to non-solarized treatments. Possibly kudzu has the ability to tap into Cu pools deep in the soil and circulate it into the upper depths at great concentrations.

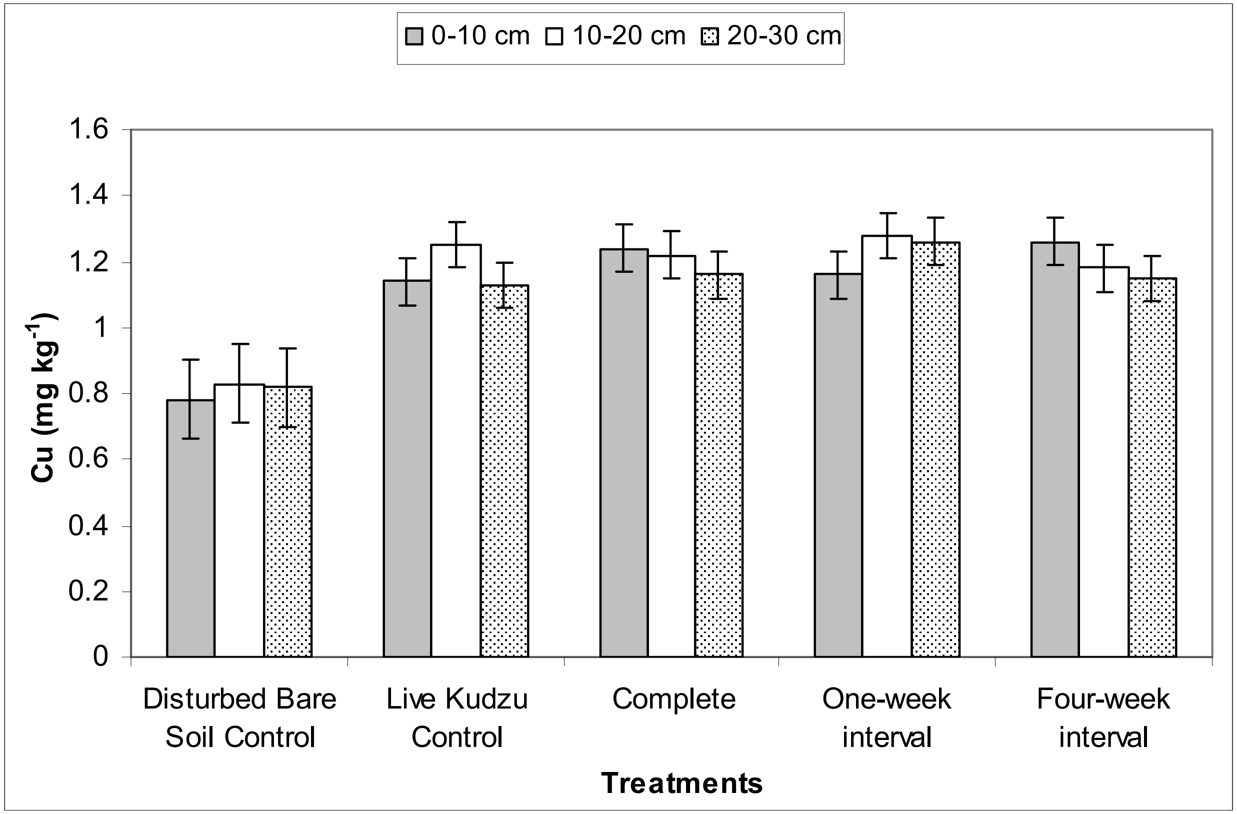

Figure 3.12. Copper (mg kg^{-1}) comparisons (mean values and standard errors) among treatments and depths.

Boron

Boron is an important micronutrient in the development and division of cells (Brady and Weil, 2004). Table 3.2 shows that B has significant changes in concentration among depth ($p<0.0046$). General trend amongst treatments showed a decrease in B concentrations as depth increased (Figure 3.13). This trend of decrease in concentration with depth may be explained by the form of B that is taken up by vegetation being a highly leachable form (Nable et al., 1997). Significant differences among treatment concentrations of B are evident in depths below 10cm, with the one-week treatment having higher concentrations than all other treatments from 20-30cm (Figure 3.13).

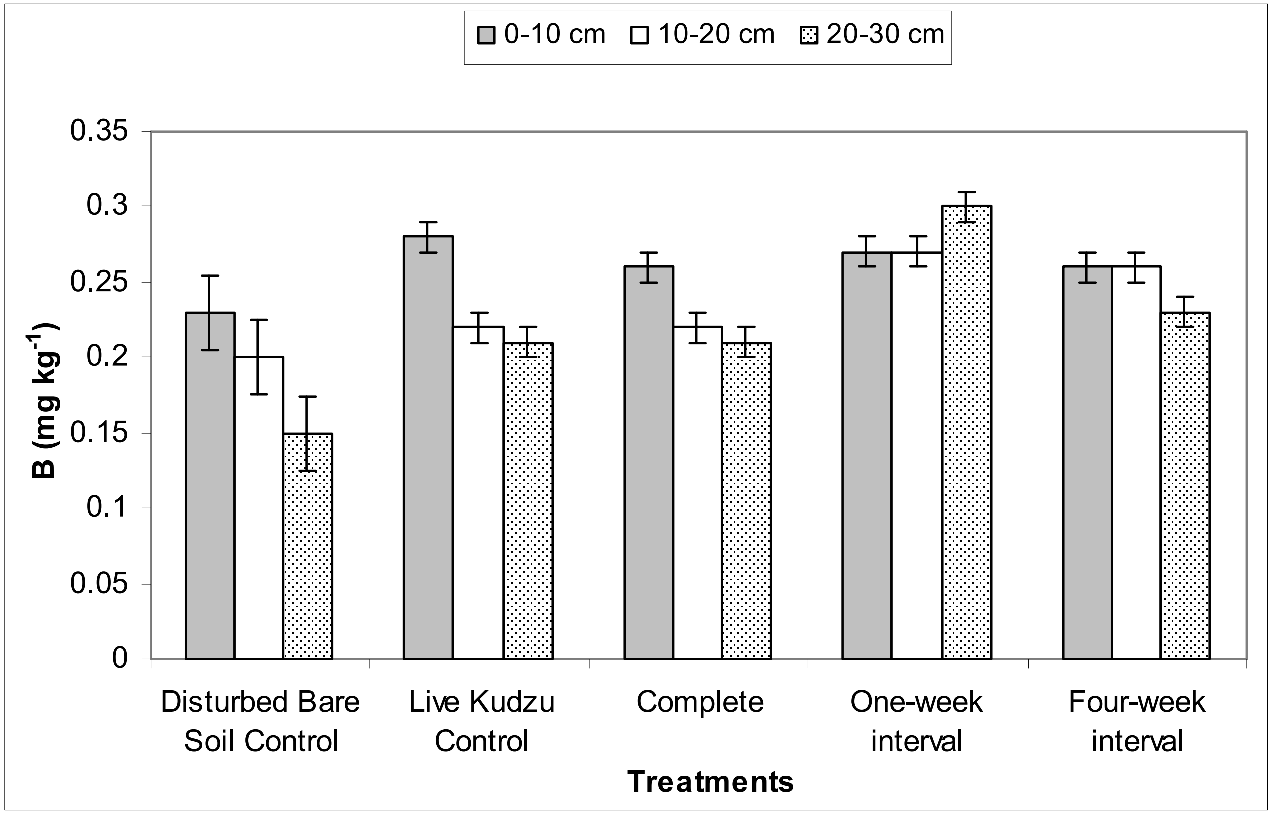

Figure 3.13. Boron (mg kg^{-1}) comparisons (mean values and standard errors) among treatments and depths.

Sodium

High concentrations of Na can cause imbalances in the uptake of K^+ or Ca^+, cause oxygen deficiency, and cause poor water relations (Brady and Weil, 2004). Live kudzu and disturbed bare soil controls had significantly higher concentration of Na than the solarized soils having lower concentrations (Figure 3.14). Soil solarization appears to decrease concentrations of Na in the soil (Figure 3.14). There is no significant difference in Na concentrations among depths ($p<0.0714$) (Table 3.2).

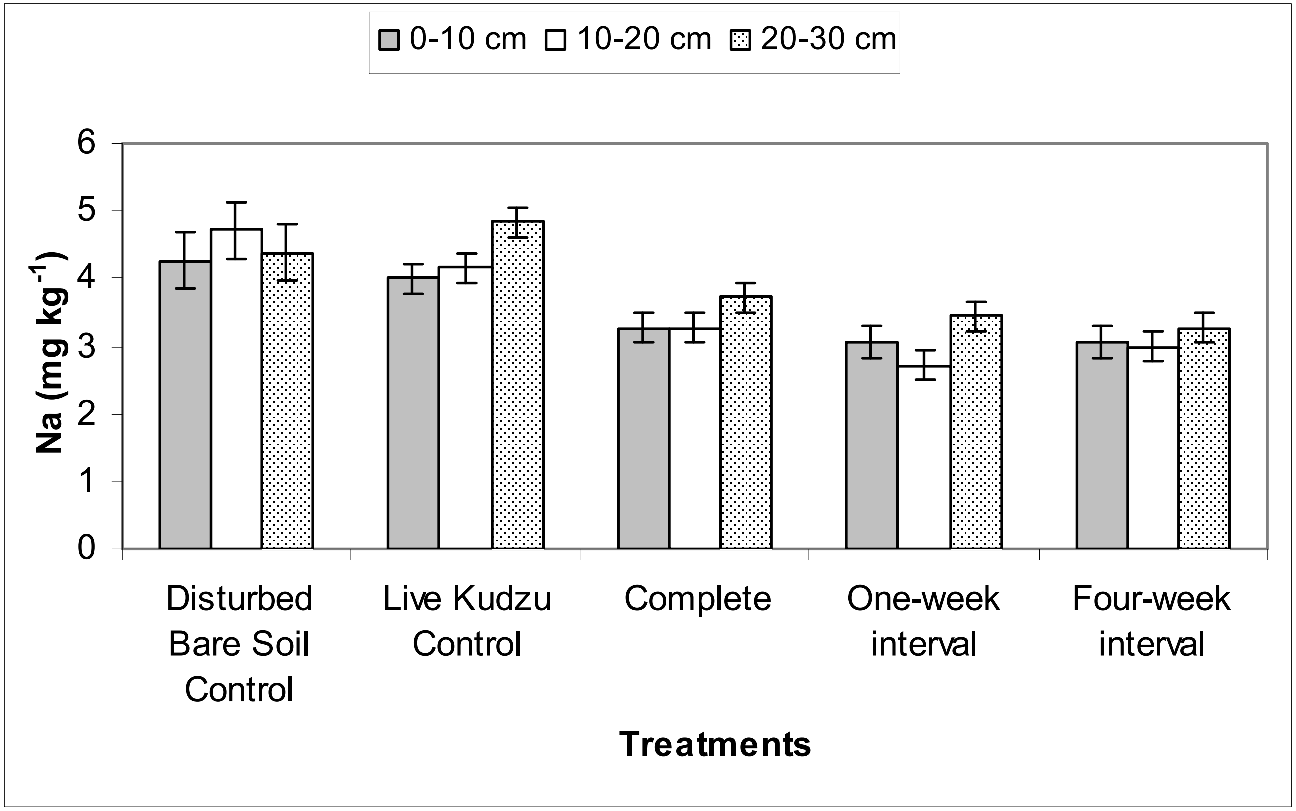

Figure 3.14. Sodium (mg kg^{-1}) comparisons (mean values and standard errors) among treatments and depths.

Total Base Saturation

Total Base saturation is concerned with the percentage of cation exchange sites that are occupied by a cation in the soil. Live kudzu control had the higher percentages of total base saturation than all other treatments (Figure 3.15). At depths below 10 cm the four-week treatment had a higher total base saturation after the kudzu live treatment. According to Reich (2005) base saturation is known to increase with increased concentrations of Ca, which was observed in the live kudzu control. An opposite trend was found in soils under *Hieracium* found in New Zealand where lower concentrations of base saturation were recorded under the invasive species (Scott et al., 2001).

A higher base saturation under live kudzu versus solarized soils may be due to the fact that increases in decomposing organic matter increase the release of Al^{3+} and H^+ ions. These ions tend to kick base cations off of the binding sites, thus the increase of the acid cations on binding sites causes a decrease in the base cation percentage.

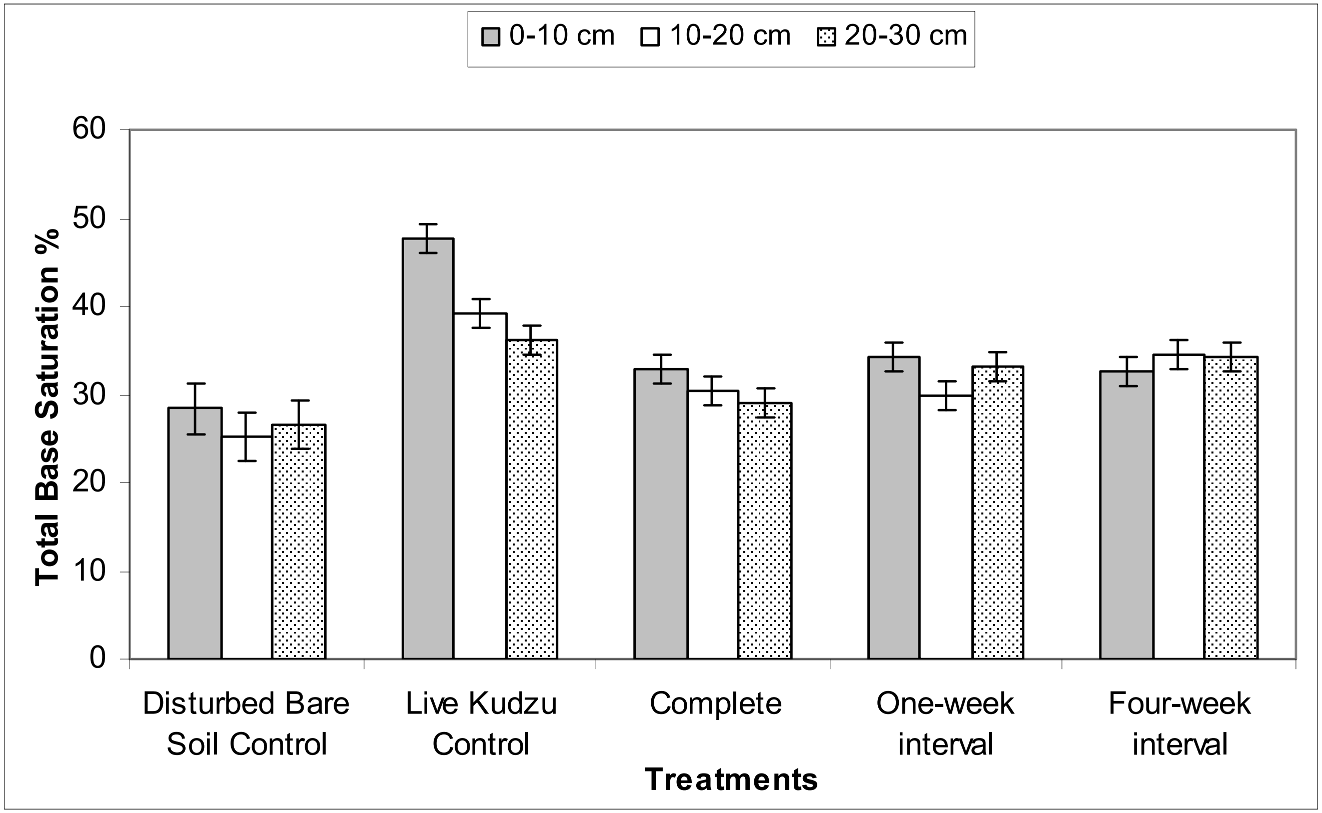

Figure 3.15. Total Base Saturation (%) comparisons (mean values and standard errors) among treatments and depths.

Effective Cation Exchange Capacity

Effective cation exchange capacity (ECEC) is the amount of cation charges that soil can hold at the actual, unbuffered, pH of the soil (Brady and Weil, 2004). For the treatments there was a general decreasing trend in ECEC as the depth increased ($p<0.0238$) (Table 3.2), with the exception of the one- week interval treatment (Figure 3.16). Live kudzu control had a higher ECEC at 0-10cm than the solarized treatments (Figure 3.16).

The study showed no significant difference between live kudzu plots and the disturbed bare soil plots. However in the study conducted in Belgium cation exchange capacity (CEC) increased on plots invaded by *Fallopia japonica* versus un-invaded plots (Vanderhoeven et al., 2005). According to the behavior of ECEC in this study, the use of solarization has the same effect as being bare soil and the presence of live plant in the live kudzu plot increases ECEC possibly due to the fact that the presence of roots which also have the ability of cation exchange.

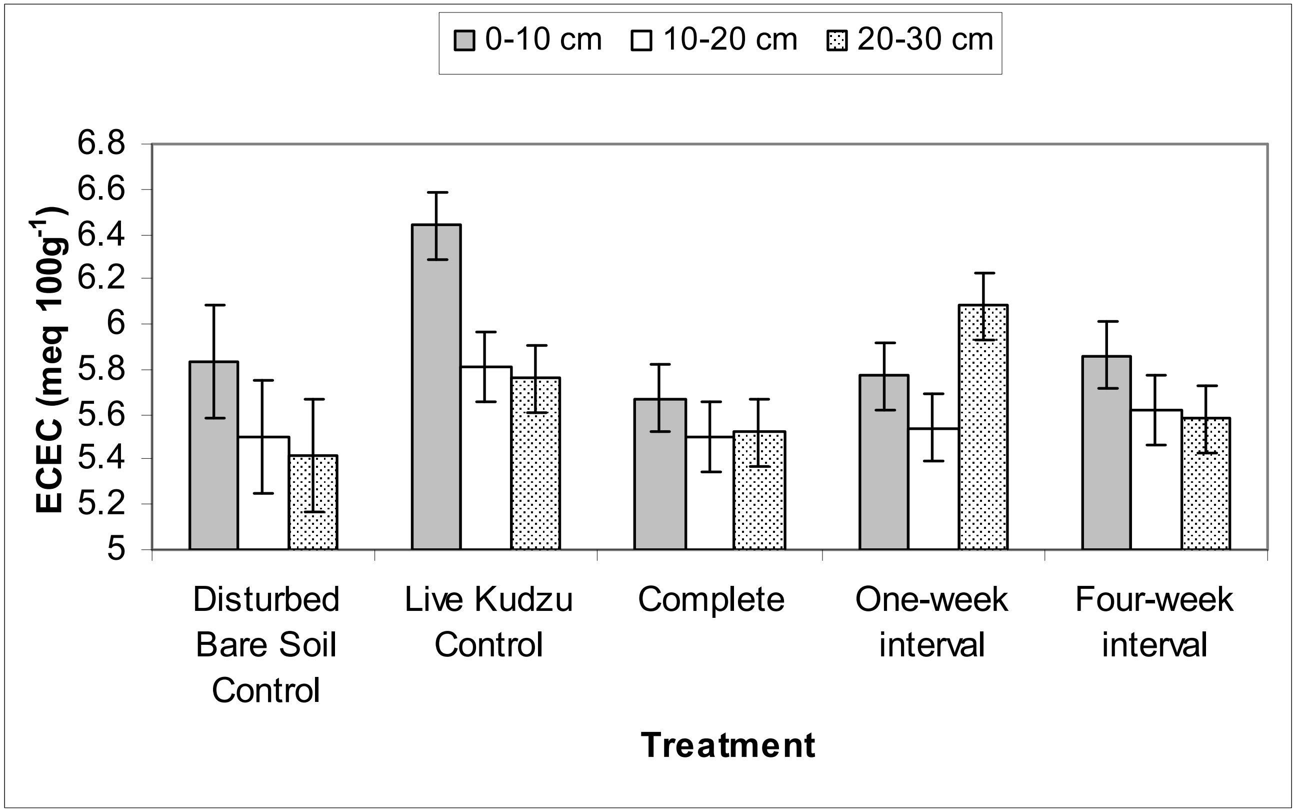

Figure 3.16. Effective cation exchange capacity (meq 100 g^{-1}) comparisons (mean values and standard errors) among treatments and depths.

Acidity

Acidity is the product of high H^+ cations in the soil that have taken over the binding sites. Live kudzu control had the lowest acidity measurements in 0-10cm depth (Figure 3.17). Complete season, one-week, four-week, and the disturbed bare soil shoed no significant difference comparing soil acidity. There was no significant difference among depths for all treatments ($p<0.7172$) (Table 3.2).

The live kudzu treatment producing the lowest measures of acidity may be explained by the larger concentrations of base cations that are present in this treatment such as Ca (Figure 3.8). We believe that the presence of living kudzu brought the used nutrient uplift which increased base cations in the soil and decreased acid cations, this decreasing the soil acidity. Intense decomposition taking place in the solarized soils was possibly an increaser of the production of H^+ ions from the decomposing plant matter causing the soil acidity to increase. Another acid forming cation is Al^{3+} and decreases in this ion were observed in the soil under the invasive species *Prunus serotina* in Belgium versus the un-invaded soils (Vanderhoeven et al., 2005).

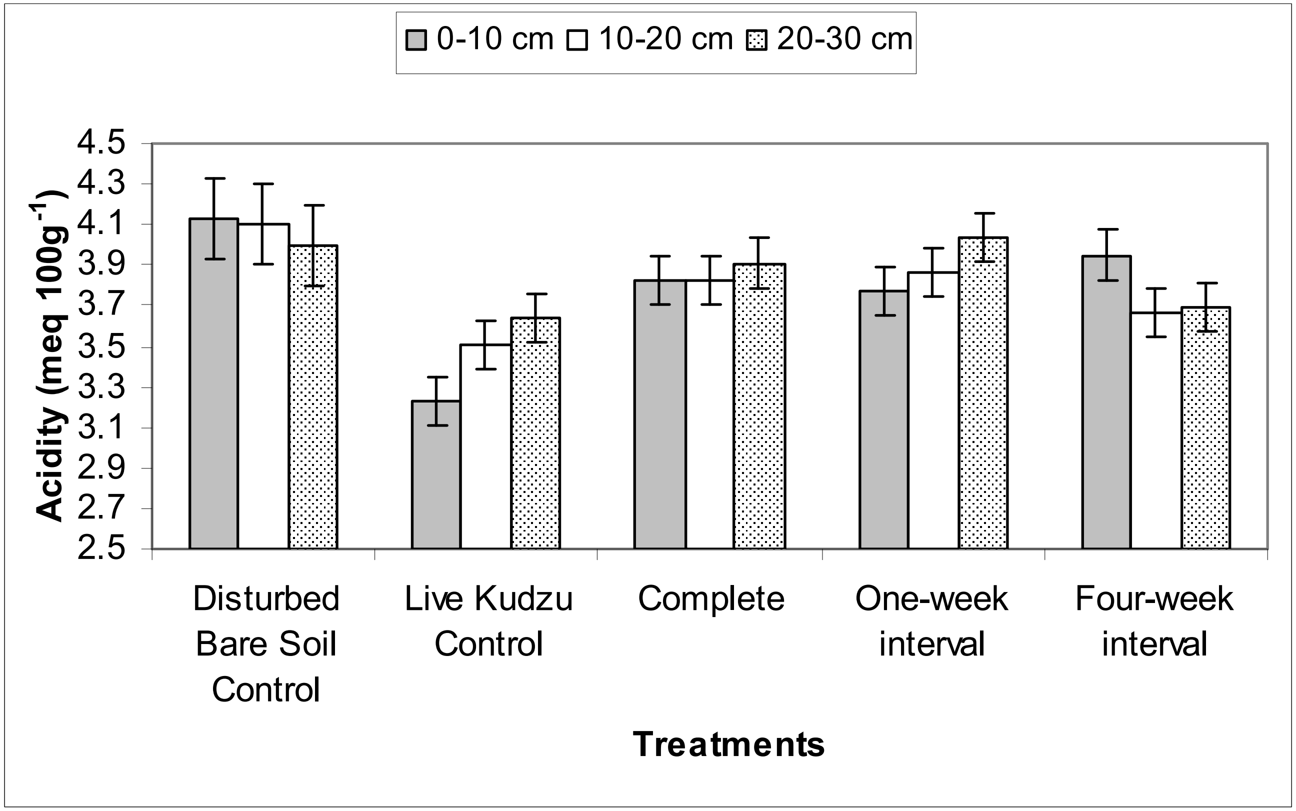

Figure 3.17. Acidity (meq 100 g^{-1}) comparisons (mean values and standard errors) among treatments and depths.

CONCLUSION

This study observed that solarization of kudzu led to significant increases in soil nutrient concentrations when compared with disturbed bare soil and soil under living kudzu. Phosphorus, Mn, pH, and C/N were significantly higher in 1-week and 4-week treatments than in complete season thermal treatments with complete season having significantly higher concentrations of NO_3N. The 1-week and 4-week treatments also showed significantly greater nutrient concentrations (C, N, P, K, Mn, and Cu) and pH than disturbed bare soil plots with the exception of Mg, Na and C/N (0-10cm).

Nutrient concentrations were significantly higher in thermally treated plots than plots with living kudzu for NO_3N, K and Mn, while significantly lower for pH, Ca, Na and total base saturation. Significantly higher nutrient concentrations under thermally treated plots than plots under living kudzu may be attributed to the release of nutrients from decomposing plant tissue during the solarization process. Kudzu contained significantly higher nutrient concentrations (K, S, N, P, B, Zn, Cu, and Mn) in above ground plant tissue, leaf, and stem than in root tissue with the exception of Ca, C/N, Mg, and Fe.

Nutrient concentrations (N, P, Ca, Cu, and total base saturation) and pH were significantly lower in disturbed bare soil than in plots with living kudzu. Magnesium, NO_3N, acidity and C/N were significantly higher in disturbed bare soil than in plots under living kudzu. This increase in nutrient concentrations in the soil may be influenced by kudzu's ability to grow roots at depths greater than 3m tapping into nutrient pools past the 1m zone of nutrient depletion (Forseth and Innis, 2004; Jobbagy and Jackson, 2001).

Decreases in nutrient concentrations (C, N, C/N, NO_3N, P, Ca, Zn, B, total base saturation) along with ECEC occurred with increases in depth with the exception of K, Mn, Cu, and pH which showed no significant difference, while Mg and Na had significant increases with depth.

Results suggest that the solarization method for kudzu control is a viable option not only for eliminating kudzu but also as a possible soil amendment, which is increasing soil nutrient concentrations. Future research should be conducted to determine kudzu's affect on soil physical properties.

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APPENDICES

Appendix A.

Mineral content of kudzu plant tissue.

Date of collection	Sample ID	Replication ID	N	C	P	K	Ca	Mg	S	B	Zn	Cu	Mn	Fe
			------------------------------ %						-------------------------	------------------ ppm				--------------
Jul-07	L-1†	1	3.24	44.31	0.23	2.27	0.49	0.31	0.18	39	27	11	131	116
Jul-07	L-2	1	3.16	44.88	0.24	2.35	0.44	0.30	0.17	37	26	11	125	128
Jul-07	L-3	1	3.12	44.92	0.22	2.28	0.45	0.30	0.17	31	26	10	137	105
Jul-07	L-4	1	3.08	45.08	0.23	2.40	0.46	0.30	0.17	33	25	11	135	113
Jul-07	L-5	1	3.10	44.55	0.22	2.31	0.44	0.29	0.17	31	25	10	130	110
Jul-07	S-1†	2	2.91	42.35	0.29	3.42	0.46	0.25	0.15	25	38	11	123	397
Jul-07	S-2	2	2.96	41.38	0.28	3.19	0.47	0.23	0.14	24	37	11	133	407
Jul-07	S-3	2	2.89	42.39	0.27	3.09	0.43	0.22	0.14	23	36	10	119	347
Jul-07	S-4	2	2.95	39.81	0.30	3.48	0.47	0.25	0.16	25	39	12	130	540
Jul-07	S-5	2	2.99	43.53	0.29	3.42	0.46	0.26	0.16	23	38	12	136	398
Aug-07	T-1†	3	0.97	40.72	0.04	1.02	0.23	0.25	0.05	18	28	11	54	5587
Aug-07	T-2	3	1.25	45.05	0.05	0.87	0.51	0.43	0.12	16	28	9	91	1442
Aug-07	T-3	3	1.41	44.3	0.02	0.79	0.81	0.46	0.10	20	24	6	59	1099
Aug-07	T-4	3	1.57	46.24	0.03	0.69	0.84	0.55	0.09	32	22	5	108	721
Aug-07	T-5	3	1.41	44.59	0.03	1.02	0.93	0.44	0.18	20	20	7	88	1332

† L is leaf, S is stem, T is root.

Appendix B.

SAS Plant Data out put.

```
                         The SAS System
                        The GLM Procedure


                     Class Level Information
                    Class       Levels   Values

                    Plant part     3      1 2 3


              Number of Observations Read        15
              Number of Observations Used        15

The SAS System

The GLM Procedure

Dependent Variable: Nitrogen

Sum of
Source              DF      Squares    Mean Square   F Value   Pr > F

Model[1]             2    9.93841333    4.96920667    260.99   <.0001

Error               12     0.22848000    0.01904000

Corrected Total     14    10.16689333


R-Square   Coeff Var    Root MSE      n Mean

0.977527    5.592496    0.137986    2.467333


Source              DF     Type I SS    Mean Square   F Value   Pr > F

part                 2    9.93841333    4.96920667    260.99   <.0001


Source              DF    Type III SS   Mean Square   F Value   Pr > F

part                 2    9.93841333    4.96920667    260.99   <.0001
```

---

[1] Model represents plant parts sampled (leaf, stem, and roots).

```
The SAS System

The GLM Procedure

Dependent Variable: Carbon

Sum of
Source                DF        Squares     Mean Square   F Value   Pr > F

Model                  2    22.85717333     11.42858667      5.42   0.0210

Error                 12    25.28056000      2.10671333

Corrected Total       14    48.13773333


R-Square    Coeff Var     Root MSE       c Mean

0.474829     3.328510     1.451452     43.60667


Source                DF       Type I SS     Mean Square   F Value   Pr > F

part                   2    22.85717333     11.42858667      5.42   0.0210


Source                DF     Type III SS     Mean Square   F Value   Pr > F

part                   2    22.85717333     11.42858667      5.42   0.0210
```

```
                              The SAS System

                             The GLM Procedure

Dependent Variable: Carbon-to-Nitrogen Ratio

                                Sum of
   Source              DF       Squares     Mean Square    F Value    Pr > F

   Model                2    1313.287268     656.643634      77.03    <.0001

   Error               12     102.292933       8.524411

   Corrected Total     14    1415.580201


           R-Square     Coeff Var      Root MSE      c_n Mean

           0.927738      13.98967      2.919659      20.87011


   Source              DF      Type I SS     Mean Square    F Value    Pr > F

   part                 2    1313.287268     656.643634      77.03    <.0001


   Source              DF    Type III SS     Mean Square    F Value    Pr > F

   part                 2    1313.287268     656.643634      77.03    <.0001
```

```
The SAS System

The GLM Procedure

Dependent Variable: Boron

Sum of
Source              DF       Squares    Mean Square   F Value   Pr > F

Model                2   468.1333333    234.0666667     13.15   0.0009

Error               12   213.6000000     17.8000000

Corrected Total     14   681.7333333


R-Square    Coeff Var    Root MSE     b Mean

0.686681     15.94082    4.219005   26.46667


Source              DF     Type I SS    Mean Square   F Value   Pr > F

part                 2   468.1333333    234.0666667     13.15   0.0009


Source              DF   Type III SS    Mean Square   F Value   Pr > F

part                 2   468.1333333    234.0666667     13.15   0.0009
```

```
The SAS System

The GLM Procedure

Dependent Variable: Phosphorus

Sum of
Source              DF       Squares     Mean Square    F Value    Pr > F

Model                2     0.17417333     0.08708667     791.70    <.0001

Error               12     0.00132000     0.00011000

Corrected Total     14     0.17549333


R-Square    Coeff Var    Root MSE      p Mean

0.992478     5.741654    0.010488    0.182667


Source              DF     Type I SS     Mean Square    F Value    Pr > F

part                 2    0.17417333     0.08708667     791.70    <.0001


Source              DF   Type III SS     Mean Square    F Value    Pr > F

part                 2    0.17417333     0.08708667     791.70    <.0001
```

```
The SAS System

The GLM Procedure

Dependent Variable: Potassium

Sum of
Source              DF      Squares    Mean Square   F Value   Pr > F

Model                2   15.07417333    7.53708667    429.95   <.0001

Error               12    0.21036000    0.01753000

Corrected Total     14   15.28453333

R-Square    Coeff Var    Root MSE     k Mean

0.986237    6.092066     0.132401    2.173333

Source              DF     Type I SS    Mean Square   F Value   Pr > F

part                 2   15.07417333    7.53708667    429.95   <.0001

Source              DF   Type III SS    Mean Square   F Value   Pr > F

part                 2   15.07417333    7.53708667    429.95   <.0001
```

```
The SAS System

The GLM Procedure

Dependent Variable: Calcium

Sum of
Source              DF       Squares     Mean Square    F Value    Pr > F

Model                2    0.14284000      0.07142000       2.54    0.1206

Error               12    0.33792000      0.02816000

Corrected Total     14    0.48076000

R-Square     Coeff Var     Root MSE      ca Mean

0.297113      31.90293     0.167809     0.526000

Source              DF     Type I SS     Mean Square    F Value    Pr > F

part                 2    0.14284000      0.07142000       2.54    0.1206

Source              DF   Type III SS     Mean Square    F Value    Pr > F

part                 2    0.14284000      0.07142000       2.54    0.1206
```

```
The SAS System

The GLM Procedure

Dependent Variable: Magnesium

Sum of
Source               DF       Squares     Mean Square    F Value    Pr > F

Model                 2     0.08849333      0.04424667      10.84    0.0020

Error                12      0.04900000      0.00408333

Corrected Total      14      0.13749333

R-Square     Coeff Var      Root MSE       mg Mean

0.643619      19.80402      0.063901      0.322667

Source               DF      Type I SS     Mean Square    F Value    Pr > F

part                  2     0.08849333      0.04424667      10.84    0.0020

Source               DF     Type III SS     Mean Square    F Value    Pr > F

part                  2      0.08849333      0.04424667      10.84    0.0020
```

```
The SAS System

The GLM Procedure

Dependent Variable: Sulfur

Sum of
Source               DF       Squares     Mean Square    F Value    Pr > F

Model                 2     0.01057333     0.00528667       6.64    0.0115

Error                12      0.00956000     0.00079667

Corrected Total      14      0.02013333


R-Square     Coeff Var      Root MSE       s Mean

0.525166      19.69206      0.028225      0.143333


Source               DF       Type I SS     Mean Square    F Value    Pr > F

part                  2      0.01057333     0.00528667       6.64    0.0115


Source               DF     Type III SS     Mean Square    F Value    Pr > F

part                  2     0.01057333     0.00528667       6.64    0.0115
```

```
The SAS System

The GLM Procedure

Dependent Variable: Zinc

Sum of
Source              DF       Squares     Mean Square    F Value    Pr > F

Model                2     525.7333333     262.8666667      53.28    <.0001

Error               12      59.2000000       4.9333333

Corrected Total     14     584.9333333


R-Square     Coeff Var      Root MSE       zn Mean

0.898792      7.589217      2.221111      29.26667


Source              DF      Type I SS     Mean Square    F Value    Pr > F

part                 2     525.7333333     262.8666667      53.28    <.0001


Source              DF     Type III SS    Mean Square    F Value    Pr > F

part                 2     525.7333333     262.8666667      53.28    <.0001
```

```
The SAS System

The GLM Procedure

Dependent Variable: Copper

Sum of
Source                DF        Squares     Mean Square    F Value    Pr > F

Model                  2     37.20000000     18.60000000       8.21    0.0057

Error                  12     27.20000000      2.26666667

Corrected Total       14     64.40000000


R-Square     Coeff Var      Root MSE       cu Mean

0.577640      15.36271      1.505545      9.800000


Source                DF       Type I SS     Mean Square    F Value    Pr > F

part                   2     37.20000000     18.60000000       8.21    0.0057


Source                DF     Type III SS     Mean Square    F Value    Pr > F

part                  2     37.20000000     18.60000000       8.21    0.0057
```

```
The SAS System

The GLM Procedure

Dependent Variable: Manganese

Sum of
Source              DF       Squares     Mean Square    F Value    Pr > F

Model                2     8328.93333      4164.46667      21.07    0.0001

Error               12      2372.00000       197.66667

Corrected Total     14     10700.93333


R-Square     Coeff Var      Root MSE       mn Mean

0.778337      12.41265      14.05940      113.2667


Source              DF       Type I SS     Mean Square    F Value    Pr > F

part                 2     8328.933333     4164.466667      21.07    0.0001


Source              DF     Type III SS     Mean Square    F Value    Pr > F

part                 2     8328.933333     4164.466667      21.07    0.0001
```

```
The SAS System

The GLM Procedure

Dependent Variable: Iron

Sum of
Source                DF       Squares     Mean Square    F Value    Pr > F

Model                  2     10674308.93      5337154.47       3.98    0.0472

Error                   12     16086430.80      1340535.90

Corrected Total        14     26760739.73

R-Square     Coeff Var      Root MSE       fe Mean

0.398879      135.2377      1157.815      856.1333

Source                DF      Type I SS     Mean Square    F Value    Pr > F

part                   2     10674308.93      5337154.47       3.98    0.0472

Source                DF     Type III SS     Mean Square    F Value    Pr > F

part                   2     10674308.93      5337154.47       3.98    0.0472
```

```
                         The SAS System

                        The GLM Procedure

                    t Tests (LSD) for Nitrogen

 NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error
rate.


          Alpha                                        0.05
          Error Degrees of Freedom                     12
          Error Mean Square                            0.01904
          Critical Value of t                          2.17881
          Least Significant Difference                 0.1901


        Means with the same letter are not significantly different.


      t Grouping     Mean      N    part

            A       3.14000     5    L

            B       2.94000     5    S

            C       1.32200     5    T
```

```
                         The SAS System

                        The GLM Procedure

                      t Tests (LSD) for Carbon

 NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error
rate.


              Alpha                                        0.05
              Error Degrees of Freedom                     12
              Error Mean Square                            2.106713
              Critical Value of t                          2.17881
              Least Significant Difference                 2.0001


          Means with the same letter are not significantly different.


            t Grouping     Mean      N    part

                 A       44.7480     5    L
                 A
                 A       44.1800     5    T

                 B       41.8920     5    S
```

```
                         The SAS System

                        The GLM Procedure

                 t Tests (LSD) for Carbon to Nitrogen Ratio

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error
                         rate.


              Alpha                                   0.05
              Error Degrees of Freedom                12
              Error Mean Square                       8.524411
              Critical Value of t                     2.17881
              Least Significant Difference            4.0233


          Means with the same letter are not significantly different.


          t Grouping        Mean      N    part

               A          34.103      5    T

               B          14.257      5    L
               B
               B          14.251      5    S
```

```
                    The SAS System

                   The GLM Procedure

                 t Tests (LSD) for Boron

 NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error
rate.


          Alpha                                    0.05
          Error Degrees of Freedom                 12
          Error Mean Square                        17.8
          Critical Value of t                      2.17881
          Least Significant Difference             5.8138


     Means with the same letter are not significantly different.


    t Grouping    Mean      N    part

         A       34.200     5    L

         B       24.000     5    S
         B
         B       21.200     5    T
```

```
                          The SAS System

                         The GLM Procedure

                    t Tests (LSD) for Phosphorus

 NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error
rate.


              Alpha                                    0.05
              Error Degrees of Freedom                 12
              Error Mean Square                        0.00011
              Critical Value of t                      2.17881
              Least Significant Difference             0.0145


          Means with the same letter are not significantly different.


        t Grouping     Mean      N    part

              A      0.286000     5    S

              B      0.228000     5    L

              C      0.034000     5    T
```

```
                         The SAS System

                        The GLM Procedure

                   t Tests (LSD) for Potassium

 NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error
rate.


              Alpha                                         0.05
              Error Degrees of Freedom                      12
              Error Mean Square                             0.01753
              Critical Value of t                           2.17881
              Least Significant Difference                  0.1824


          Means with the same letter are not significantly different.


           t Grouping    Mean      N    part

                A       3.32000    5    S

                B       2.32200    5    L

                C       0.87800    5    T
```

```
                              The SAS System

                             The GLM Procedure

                         t Tests (LSD) for Calcium

 NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error
rate.


                   Alpha                                     0.05
                   Error Degrees of Freedom                  12
                   Error Mean Square                         0.02816
                   Critical Value of t                       2.17881
                   Least Significant Difference              0.2312


               Means with the same letter are not significantly different.


                t Grouping    Mean      N    part

                     A       0.6640     5    T
                     A
                     A       0.4580     5    S
                     A
                     A       0.4560     5    L
```

```
                         The SAS System

                        The GLM Procedure

                    t Tests (LSD) for Magnesium

 NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error
rate.


                  Alpha                                    0.05
                  Error Degrees of Freedom                 12
                  Error Mean Square                        0.004083
                  Critical Value of t                      2.17881
                  Least Significant Difference             0.0881


              Means with the same letter are not significantly different.


               t Grouping     Mean      N    part

                    A       0.42600     5    T

                    B       0.30000     5    L
                    B
                    B       0.24200     5    S
```

```
                         The SAS System

                       The GLM Procedure

                     t Tests (LSD) for Sulfur

 NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error
rate.


             Alpha                                   0.05
             Error Degrees of Freedom                12
             Error Mean Square                       0.000797
             Critical Value of t                     2.17881
             Least Significant Difference            0.0389


         Means with the same letter are not significantly different.


           t Grouping     Mean      N    part

                A       0.17200     5    L
                A
                A       0.15000     5    S

                B       0.10800     5    T
```

```
                         The SAS System
                        The GLM Procedure

                     t Tests (LSD) for Zinc

 NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error
rate.


                 Alpha                                      0.05
                 Error Degrees of Freedom                   12
                 Error Mean Square                          4.933333
                 Critical Value of t                        2.17881
                 Least Significant Difference               3.0607


             Means with the same letter are not significantly different.


               t Grouping    Mean      N    part

                    A       37.600     5    S

                    B       25.800     5    L
                    B
                    B       24.400     5    T
```

```
                         The SAS System

                       The GLM Procedure

                   t Tests (LSD) for Copper

 NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error
rate.


              Alpha                                0.05
              Error Degrees of Freedom             12
              Error Mean Square                    2.266667
              Critical Value of t                  2.17881
              Least Significant Difference         2.0746


          Means with the same letter are not significantly different.


     t Grouping     Mean      N    part

          A       11.2000      5    S
          A
          A       10.6000      5    L

          B        7.6000      5    T
```

```
                         The SAS System

                        The GLM Procedure

                   t Tests (LSD) for Manganese

 NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error
rate.


            Alpha                                    0.05
            Error Degrees of Freedom                 12
            Error Mean Square                        197.6667
            Critical Value of t                      2.17881
            Least Significant Difference             19.374


        Means with the same letter are not significantly different.


          t Grouping     Mean      N    part

               A       131.600     5    L
               A
               A       128.200     5    S

               B        80.000     5    T
```

```
                         The SAS System

                        The GLM Procedure

                      t Tests (LSD) for Iron

 NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error
rate.

                  Alpha          0.05
                  Error Degrees of Freedom                 12
                  Error Mean Square                        1340536
                  Critical Value of t                      2.17881
                  Least Significant Difference             1595.5


            Means with the same letter are not significantly different.

              t Grouping    Mean     N    part

                  A       2036.2     5    T

                  B        417.8     5    S
                  B
                  B        114.4     5    L


                         The SAS System

------------------------------------------- part=Leaf --------------------------------------------

                        The MEANS Procedure

            Variable    N         Mean        Std Error

               n        5      3.1400000      0.0282843
               c        5     44.7480000      0.1393341
               b        5     34.2000000      1.6248077
               p        5      0.2280000      0.0037417
               k        5      2.3220000      0.0239583
               ca       5      0.4560000      0.0092736
               mg       5      0.3000000      0.0031623
               s        5      0.1720000      0.0020000
               zn       5     25.8000000      0.3741657
               cu       5     10.6000000      0.2449490
               mn       5    131.6000000      2.0880613
               fe       5    114.4000000      3.8548671
```

```
------------------------------------------ part=Stem ------------------------------------------

            Variable    N        Mean          Std Error

              n         5     2.9400000      0.0178885
              c         5    41.8920000      0.6220000
              b         5    24.0000000      0.4472136
              p         5     0.2860000      0.0050990
              k         5     3.3200000      0.0759605
              ca        5     0.4580000      0.0073485
              mg        5     0.2420000      0.0073485
              s         5     0.1500000      0.0044721
              zn        5    37.6000000      0.5099020
              cu        5    11.2000000      0.3741657
              mn        5   128.2000000      3.1527766
              fe        5   417.8000000     32.3162498


------------------------------------------ part=Tuber ------------------------------------------


            Variable    N        Mean          Std Error

              n         5     1.3220000      0.1015086
              c         5    44.1800000      0.9261371
              b         5    21.2000000      2.8000000
              p         5     0.0340000      0.0050990
              k         5     0.8780000      0.0646065
              ca        5     0.6640000      0.1294450
              mg        5     0.4260000      0.0488467
              s         5     0.1080000      0.0213073
              zn        5    24.4000000      1.6000000
              cu        5     7.6000000      1.0770330
              mn        5    80.0000000     10.2127371
              fe        5       2036.20    896.2490391
```

Appendix C.

Raw soil data.

Treatment	Depth	Soil pH	C	N	C/N	P	K	Ca	Mg	Zn
	cm		------- % -----			mg kg^{-1}				
1	10	4.8	0.528	0.061	8.724	2.5	74	242	48.5	1.15
1	20	4.8	0.469	0.081	5.758	1.5	64.5	199	46	0.65
1	30	4.9	0.574	0.096	5.967	1	72	202.5	55	0.65
1	10	4.9	1.784	0.144	12.348	2	79.5	287.5	41	1.35
1	20	4.9	0.587	0.075	7.804	1	91	254	52	0.75
1	30	4.9	0.447	0.071	6.252	0.5	100	255.5	55	0.6
1	10	4.8	1.457	0.108	13.537	2	53.5	192.5	23.5	1.2
1	20	4.8	1.173	0.114	10.302	1.5	62	179	30	1.05
1	30	4.8	0.808	0.083	9.722	1.5	66.5	183	29.5	0.85
2	10	5.3	0.700	0.069	10.120	1.5	69.5	257	44	0.75
2	20	5.2	0.608	0.075	8.086	1	71.5	250.5	48	0.65
2	30	5.2	0.717	0.073	9.785	1	73	291.5	52.5	0.75
2	10	5.2	0.709	0.077	9.226	1	103	231.5	46.5	0.5
2	20	5.3	0.760	0.071	10.678	1	104	281.5	56.5	0.65
2	30	5.2	0.862	0.094	9.166	1	103	310.5	60	0.7
2	10	5.3	1.266	0.117	10.842	2.5	70.5	242	77.5	1.45
2	20	5	1.061	0.096	11.038	2	65	152.5	54	1.15
2	30	5	1.496	0.117	12.772	1.5	106.5	338	65.5	1.5
3	10	4.8	1.432	0.098	14.664	2.5	69.5	124.5	32	1.55
3	20	5.1	1.460	0.103	14.229	2.5	97	169.5	79.5	1.7
3	30	4.9	1.171	0.079	14.841	2.5	77	122.5	44.5	1.45

Treatments:

1- Complete Season
2- One week
3- Four week
5- Bare soil control
6- Live kudzu control

Treatment	Depth	Mn	Cu	B	Na	NO3-N	CEC	Acidity	Total BS
	cm	---------------- mg kg^{-1}			------------------	ppm	------- meq 100g^{-1}	-----	%
1	10	91	1.2	0.2	5	32	6.2	4.4	29
1	20	71.5	1.15	0.2	3.5	18	5.6	4	28
1	30	66.5	1.25	0.2	3.5	15	6.1	4.4	27
1	10	45	1.05	0.25	2.5	16	5.6	3.6	36
1	20	31.5	1.1	0.2	3.5	15	6	4	33
1	30	33	1.05	0.25	4	15	5.6	3.6	36
1	10	65.5	1.25	0.2	3	16	4.9	3.6	27
1	20	103	1.45	0.2	3	16	5.7	4.4	23
1	30	106.5	1.25	0.2	3	15	6.1	4.8	22
2	10	86	1.35	0.25	2.5	3	5.4	3.6	34
2	20	75.5	1.25	0.25	2	3	5.4	3.6	34
2	30	80	1.3	0.25	2.5	4	6.1	4	34
2	10	58	1.2	0.25	2.5	3	5.4	3.6	34
2	20	49	1.15	0.3	2.5	4	5.8	3.6	37
2	30	56	1.1	0.25	3.5	5	6.3	4	37
2	10	99	0.85	0.35	2.5	9	5.6	3.6	37
2	20	93	0.95	0.3	2.5	9	5	3.6	28
2	30	116	1.3	0.4	3.5	13	6.9	4.4	37
3	10	47	1.75	0.2	3	17	5.5	4.4	20
3	20	54.5	1.6	0.3	3	15	5.4	3.6	33
3	30	47.5	1.4	0.2	3	12	5.2	4	23
3	10	52	1.2	0.35	2.5	5	5.4	2.8	48
3	20	62	1.15	0.25	2.5	4	4.3	2.4	44

Treatment	Depth	Soil pH	C	N	C/N	P	K	Ca	Mg	Zn
	cm		------ % ------			-------------------------- mg kg^{-1}	--------------------------			
3	10	5.8	0.842	0.068	12.312	2.5	91	335	83	1.6
3	20	5.6	0.800	0.057	14.064	1.5	87.5	233	61	1
3	30	5.7	0.675	0.044	15.271	1.5	81.5	230.5	44.5	1
3	10	4.9	1.414	0.063	22.281	2	63.5	157	33.5	1.55
3	20	5	1.326	0.078	17.006	2	82.5	174	40.5	1.3
3	30	4.9	1.669	0.109	15.348	2	108.5	230	49.5	1.25
2	10	5	1.347	0.080	16.917	2.5	47	166.5	17.5	2.05
2	20	4.9	0.752	0.046	16.474	3	44.5	97	13	1.45
2	30	5	1.019	0.056	18.170	2.5	66	147	19.5	1.25
2	10	5	1.356	0.126	10.767	2	86.5	254	36	2.95
2	20	4.9	1.026	0.102	10.097	2	72	189.5	34	1.8
2	30	5.2	0.934	0.090	10.362	1.5	81	337	63.5	1.75
2	10	5	0.980	0.088	11.102	1.5	86	194	29	1.25
2	20	5	0.820	0.091	9.060	1	82.5	197	31.5	1.2
2	30	5	0.720	0.068	10.540	1	68	177.5	30	0.75
3	10	4.7	1.885	0.130	14.466	2.5	51.5	109	15	1.5
3	20	4.8	1.026	0.082	12.584	2	52.5	89.5	15.5	1.1
3	30	4.9	0.789	0.060	13.247	2	64	106.5	22.5	1.05
3	10	5.1	1.185	0.139	8.508	2	78	216	39.5	1.15
3	20	4.9	0.647	0.071	9.113	1	64	126	26.5	0.95
3	30	4.9	0.585	0.071	8.239	1	56.5	111	25	1

Treatment	Depth	Mn	Cu	B	Na	NO3-N	CEC	Acidity	Total BS
	cm	------------------ mg kg^{-1}			-----------------	ppm	------- meq 100g^{-1}------		%
3	30	69	0.9	0.2	3	4	3.7	2	47
3	10	83.5	1.2	0.2	2.5	11	4.8	3.6	26
3	20	77	1.15	0.25	2.5	9	5.4	4	26
3	30	91.5	1.2	0.25	4	11	5.9	4	31
2	10	50	1.05	0.2	3	5	4.7	3.6	24
2	20	50.5	1.15	0.15	3	3	4.3	3.6	17
2	30	78.5	1.1	0.2	3	3	5.1	4	21
2	10	118.5	1.75	0.2	3.5	16	7	5.2	26
2	20	119	1.55	0.25	2.5	11	6.2	4.8	23
2	30	117	1.3	0.35	3.5	7	7.2	4.8	34
2	10	98.5	1.25	0.25	2.5	13	5.8	4.4	25
2	20	99	1.1	0.2	2	12	5.9	4.4	25
2	30	89	1	0.2	2.5	10	5.3	4	25
3	10	102	1.35	0.2	3	8	6.4	5.6	13
3	20	93	1.25	0.2	3	6	5.5	4.8	13
3	30	86	1.15	0.2	2.5	4	5.7	4.8	16
3	10	113.5	1.6	0.25	3	6	6.4	4.8	25
3	20	92	1.2	0.2	2.5	8	5.8	4.8	18
3	30	93	1.15	0.15	2	7	5.7	4.8	16
3	10	85	1.3	0.25	3	19	5.9	4.4	25
3	20	63	1.1	0.25	2.5	15	6.2	4.4	29
3	30	75.5	1.2	0.25	3	15	6.3	4.4	30
1	10	90.5	1.25	0.3	2	22	5.9	4	33

Treatment	Depth	Soil pH	C	N	C/N	P	K	Ca	Mg	Zn
	cm		------ % ------			-------------------------- mg kg^{-1}--------------------------				
3	10	4.8	0.664	0.073	9.096	1.5	90.5	174.5	41.5	1.2
3	20	5	0.608	0.079	7.696	1	97.5	220.5	54	0.8
3	30	5	0.715	0.066	10.833	1	97.5	234	58	0.95
1	10	5.1	1.079	0.118	9.144	1.5	87.5	256.5	51.5	1
1	20	5	0.439	0.058	7.569	1	90	193	45.5	0.5
1	30	5	0.471	0.057	8.263	0.5	80	198.5	45.5	0.4
1	10	5	0.759	0.079	9.608	2	125	215	36	0.95
1	20	5.1	0.547	0.062	8.839	1	111.5	207	45	0.6
1	30	5.2	0.373	0.044	8.420	1	107	250.5	59	0.4
1	10	4.5	0.624	0.084	7.470	1	80.5	187	32.5	0.75
1	20	4.9	0.793	0.102	7.802	1	108.5	275	55	0.65
1	30	4.8	0.490	0.053	9.230	1	100.5	237.5	50.5	0.6
3	10	5.9	0.810	0.095	8.524	1.5	75	447	39.5	0.95
3	20	6	0.337	0.042	7.954	1	75	382.5	41	0.7
3	30	6	0.410	0.053	7.733	1	71	399.5	43.5	0.7
3	10	5.5	0.703	0.081	8.709	1.5	88	420	56	0.8
3	20	5.5	0.676	0.068	9.990	1.5	92.5	402.5	63	0.7
3	30	5.7	0.744	0.097	7.675	1	86.5	458.5	71	0.75
3	10	5.5	0.652	0.094	6.968	1	124	400.5	61	0.8
3	20	5.7	1.126	0.091	12.370	1	128.5	513.5	75.5	1.1

Treatment	Depth	Mn	Cu	B	Na	NO3-N	CEC	Acidity	Total BS
	cm	----------------- mg kg^{-1}	---------------			ppm	------- meq 100g^{-1}	------	%
1	20	56.5	1	0.25	2.5	19	5.2	3.6	30
1	30	49	0.85	0.2	4	18	4.8	3.2	33
1	10	92	1.05	0.3	3	14	5.7	4	30
1	20	68.5	1	0.25	3.5	11	5.3	3.6	32
1	30	47	0.95	0.2	3.5	14	5.6	3.6	36
1	10	103	1.25	0.2	3	53	6.2	4.8	23
1	20	66.5	1.1	0.2	4	28	6.5	4.4	33
1	30	71	1.1	0.2	3.5	23	6.3	4.4	30
3	10	51	0.8	0.3	2.5	4	5.6	2.8	49
3	20	37.5	1	0.25	3.5	2	4.9	2.4	50
3	30	38.5	1.05	0.25	4	2	5	2.4	51
3	10	83	1	0.35	4.5	18	6.4	3.6	44
3	20	63.5	1	0.3	4	16	6.4	3.6	44
3	30	55	1.2	0.3	4	18	6.3	3.2	50
3	10	60.5	1.2	0.3	3.5	17	6.4	3.6	44
3	20	64.5	1.25	0.35	3.5	16	6.7	3.2	53
3	30	57.5	1.15	0.3	4	13	6.5	3.6	45
2	10	20	1.25	0.25	3	12	4.4	3.2	27
2	20	12.5	1.7	0.3	3	10	5.4	4	26
2	30	15	1.7	0.3	4.5	6	5.6	4	29
2	10	33	0.9	0.4	4.5	17	7.1	3.6	49
2	20	14.5	1.5	0.4	4	12	5.8	3.6	38
2	30	12	1.3	0.3	3.5	9	5.9	4	31

Treatment	Depth	Soil pH	C	N	C/N	P	K	Ca	Mg	Zn
	cm		------ % ------			-------------------------- mg kg^{-1}--------------------------				
3	30	5.6	0.848	0.114	7.449	1	124	405	68	1
2	10	4.8	1.124	0.103	10.917	2	68.5	157	26	2.35
2	20	4.8	1.084	0.105	10.349	1.5	89.5	164	38.5	2.05
2	30	4.9	0.788	0.086	9.168	1	97	187.5	48	1.5
2	10	5	2.041	0.187	10.914	2.5	82.5	539.5	66.5	3.7
2	20	5	1.166	0.109	10.664	1.5	105	265	68	1.3
2	30	5	0.919	0.100	9.195	1	83	224	61	0.95
2	10	5.2	1.740	0.154	11.308	1.5	78.5	549	54	3.65
2	20	5.1	1.234	0.130	9.524	1	76	345.5	63.5	1.7
2	30	5.5	1.303	0.131	9.981	1	87.5	408	112.5	2.1
1	10	4.8	1.147	0.096	11.912	1.5	86.5	206	62	1.4
1	20	4.8	1.017	0.104	9.793	1	84	158.5	71.5	0.75
1	30	4.6	0.689	0.075	9.167	1	61.5	97.5	37	0.45
1	10	4.9	1.139	0.109	10.466	1.5	60.5	377	50	2.75
1	20	4.7	0.692	0.067	10.324	1	54	194.5	32	1.2
1	30	4.7	0.455	0.059	7.739	0.5	45.5	132	23.5	0.65
1	10	4.8	1.392	0.146	9.534	1.5	61	340.5	52	2.65
1	20	5	0.722	0.103	7.035	0.5	49.5	253.5	43	0.8
1	30	4.9	0.953	0.107	8.921	1	52.5	288.5	47	1.2
6	10	5	1.312	0.089	14.688	2.5	72	169	24.5	1.3
6	20	5	0.826	0.076	10.877	2.5	79	119	20.5	0.9
6	30	5	0.589	0.056	10.560	2	63	108	26.5	0.75
6	10	5.4	1.427	0.109	13.058	1.5	53.5	307.5	48.5	0.95
6	20	5	0.836	0.083	10.056	1.5	51.5	165	71.5	0.8
6	30	4.9	0.460	0.055	8.395	1.5	48	114	34.5	0.65

Treatment	Depth	Mn	Cu	B	Na	NO3-N	CEC	Acidity	Total BS
	cm	------------------ mg kg^{-1}			-----------------	ppm	------- meq $100g^{-1}$	-------	%
2	10	25.5	0.9	0.35	3.5	13	6.6	3.2	52
2	20	11	1.25	0.35	3	8	6.1	3.6	40
2	30	15.5	1.3	0.45	4.5	9	6.4	3.2	50
1	10	12	1.4	0.35	3.5	13	5.4	3.6	33
1	20	6.5	1.55	0.3	3.5	12	5.6	4	29
1	30	3.5	1.5	0.2	3.5	16	5.4	4.4	18
1	10	14	1.2	0.3	3.5	23	5.3	2.8	47
1	20	6.5	1.35	0.2	3	16	4.6	3.2	30
1	30	3.5	1.25	0.2	4	14	4.2	3.2	24
1	10	14	1.5	0.25	4	15	5.9	3.6	39
1	20	4.5	1.25	0.2	3	14	5	3.2	35
1	30	7.5	1.3	0.2	4.5	14	5.6	3.6	36
6	10	26.5	1.45	0.2	4	7	4.9	3.6	26
6	20	43.5	1.45	0.2	4.5	4	5	4	20
6	30	56	1.1	0.2	3.5	2	4.9	4	19
6	10	29	1.1	0.2	3.5	5	5.7	3.6	37
6	20	52.5	1.15	0.2	4	5	5.6	4	28
6	30	59	1	0.2	3.5	3	5.4	4.4	18
6	10	34	1.05	0.25	4.5	4	5.8	4	30
6	20	55.5	1.05	0.25	3.5	3	5.6	4.4	22
6	30	66.5	0.9	0.2	4.5	2	6	4.8	20
6	10	28.5	0.9	0.35	3	4	6	2.4	59

Treatment	Depth	Soil pH	C	N	C/N	P	K	Ca	Mg	Zn
	cm		------ % ------			-------------------------- mg kg^{-1}--------------------------				
6	10	5.1	1.453	0.136	10.645	1.5	59	256	36.5	1.15
6	20	5.1	0.770	0.083	9.232	1.5	55	161.5	33.5	0.9
6	30	5	0.646	0.086	7.537	1.5	57	153	34	0.5
6	10	6.4	0.865	0.097	8.883	1	56.5	610.5	41	1.05
6	20	6.2	0.394	0.047	8.316	1	51	402.5	38	0.5
6	30	6.3	0.397	0.059	6.711	1	50	430.5	41.5	0.5
6	10	6.4	0.450	0.061	7.401	1	51	487.5	39	0.5
6	20	6.6	0.348	0.067	5.208	1	44.5	486	42	0.3
6	30	6.4	0.372	0.060	6.218	1	46.5	469.5	39.5	0.35
6	10	5.9	2.177	0.206	10.578	2	98.5	836.5	77	1.55
6	20	5.8	0.904	0.108	8.342	1.5	111	490.5	66	0.75
6	30	6	0.613	0.093	6.600	1.5	101.5	437	75	0.7
6	10	5.7	1.264	0.115	10.953	2	41.5	784.5	40.5	7.85
6	20	5.5	0.897	0.080	11.209	1.5	34.5	490	42.5	2.9
6	30	5.6	1.105	0.113	9.778	1	36	484	47.5	1.75
6	10	5.7	1.469	0.130	11.256	2	71.5	641.5	49.5	6.05
6	20	5.6	0.963	0.097	9.957	0.5	82	393	58	2
6	30	5.8	0.521	0.077	6.742	0	60.5	333.5	51	0.65
6	10	5.7	1.138	0.105	10.841	1	83.5	532	59	2.1
6	20	5.6	0.857	0.079	10.788	0.5	58.5	396	54.5	0.85
6	30	5.4	0.583	0.063	9.266	0.5	65	313	55	0.4
5	10	4.8	0.878	0.079	11.114	1	91	158.5	55.5	1
5	20	5	0.419	0.062	6.7581	0	84.5	134.5	67.5	0.65
5	30	5.2	0.323	0.02	16.15	0	69	144.5	84	0.65
5	10	4.8	3.225	0.158	20.411	1.5	71	441.5	92.5	3
5	20	4.8	0.92	0.083	11.084	0.5	53	194.5	70.5	1.15
5	30	5	0.504	0.042	12	0	35.5	124	91.5	0.85

Treatment	**Depth**	**Mn**	**Cu**	**B**	**Na**	**NO3-N**	**CEC**	**Acidity**	**Total BS**
	cm	**------------------ mg kg^{-1}-----------------**				**ppm**	**------- meq 100g^{-1} -------**		**%**
6	20	20	1	0.2	3.5	4	4.9	2.4	51
6	30	22	1	0.2	4.5	3	5.4	2.8	49
6	10	31	1.1	0.2	3.5	3	6.1	3.2	48
6	20	23	1.15	0.15	4	3	6.1	3.2	48
6	30	25	1.1	0.2	3.5	3	6	3.2	47
6	10	54	1.05	0.5	4	7	9.5	4.4	54
6	20	52.5	1.2	0.25	3	6	7.3	4	45
6	30	49.5	1.2	0.25	4	7	7.1	4	43
6	10	26	1.45	0.2	4.5	6	7.2	2.8	61
6	20	18	1.65	0.25	4.5	8	6.1	3.2	48
6	30	13	1.45	0.3	5.5	8	6.1	3.2	48
6	10	21.5	1	0.3	4.5	9	6.6	2.8	58
6	20	11	1.4	0.25	5	5	5.9	3.2	45
6	30	6	1.25	0.15	6.5	5	5.5	3.2	41
6	10	16.5	1.15	0.35	4.5	7	6.2	2.8	55
6	20	11.5	1.25	0.25	5.5	6	5.8	3.2	45
6	30	6	1.2	0.2	8	5	5.4	3.2	41
5	10	15.5	0.7	0.3	3.5	13	5.9	4.4	25
5	20	5	0.75	0.25	4.5	10	5.5	4	27
5	30	2	0.7	0.15	4	11	5.2	3.6	31
5	10	32	0.7	0.3	4	22	8	4.8	40
5	20	9.5	0.75	0.2	5	15	6.1	4.4	28
5	30	3.5	0.85	0.15	4	12	5.5	4	27
5	10	6.5	0.8	0.2	4	13	5.3	4	24
5	20	3	0.8	0.2	5	11	5.3	4	24

Treatment	Depth	Soil pH	C	N	C/N	P	K	Ca	Mg	Zn
	cm		------ % ------			-------------------------- mg kg^{-1}--------------------------				
5	20	5	0.264	0.04	6.6	0	34	95.5	84	0.6
5	30	5.1	0.262	0.037	7.0811	0	25	91	107.5	0.6
5	10	4.8	1.243	0.071	17.507	1	50.5	268	61	1.45
5	20	4.9	0.557	0.045	12.378	0.5	57	170	58	0.6
5	30	5	0.306	0.047	6.5106	0	62	163	74	0.6
5	10	5.1	0.512	0.044	11.636	1	120.5	126	63.5	0.45
5	20	4.9	0.377	0.041	9.1951	0	53	110	70.5	0.6
5	30	5.1	0.214	0.041	5.2195	0	38	119.5	92	0.8
5	10	4.8	1.268	0.08	15.85	1	51	186	53.5	1
5	20	5	0.431	0.051	8.451	0	49.5	122.5	72	0.7
5	30	5.1	0.277	0.05	5.54	0	38	102	79.5	0.75
5	10	4.8	0.68	0.047	14.468	1.5	41.5	158	44	0.55
5	20	5	0.584	0.041	14.244	1.5	31	125	39.5	0.65
5	30	4.9	0.751	0.046	16.326	1.5	35.5	158	48.5	1.05
5	10	4.7	1.296	0.09	14.4	1	47.5	186.5	44	0.75
5	20	4.8	0.785	0.082	9.5732	0.5	41	179.5	57.5	0.7
5	30	4.9	0.407	0.054	7.537	0	27	139.5	69.5	0.6
5	10	5	1.378	0.055	25.055	1.5	73	181.5	56.5	0.4
5	20	5	0.492	0.035	14.057	0.5	76.5	133.5	57	0.4
5	30	4.9	0.301	0.042	7.1667	0	69.5	110.5	57.5	0.5

Treatment	Depth	Mn	Cu	B	Na	NO3-N	CEC	Acidity	Total BS
	cm	------------------ mg kg^{-1}			-----------------	ppm	------- meq 100g^{-1}	-------	%
5	30	1.5	0.8	0.1	4.5	10	5.4	4	27
5	10	21	0.65	0.25	4.5	18	6	4	33
5	20	6.5	0.75	0.25	5	10	5.5	4	27
5	30	2.5	0.8	0.2	2.5	13	5.6	4	29
5	10	13	0.9	0.25	4	6	5.5	4	27
5	20	3.5	0.95	0.15	3	9	5.3	4	24
5	30	2	0.95	0.15	3	10	5.5	4	27
5	10	29	1.05	0.2	4.5	16	5.5	4	28
5	20	6	1.05	0.15	6.5	11	5.4	4	25
5	30	8.5	0.9	0.1	7	9	4.9	3.6	27
5	10	24	0.7	0.15	5	23	5.3	4	24
5	20	16.5	0.8	0.15	4	8	5.9	4.8	18
5	30	20	0.9	0.2	5	6	6.5	5.2	20
5	10	20.5	0.85	0.2	5	20	5.8	4.4	25
5	20	10.5	0.9	0.2	5	15	5.5	4	27
5	30	3	0.85	0.15	5	15	5.4	4	25
5	10	19	0.7	0.25	4	14	5.2	3.6	30
5	20	8	0.7	0.25	4.5	10	5	3.6	27
5	30	2	0.7	0.2	4.5	10	4.8	3.6	26

Appendix D.

SOIL DATA ANALYSIS

```
                         The GLM Procedure

                      Class Level Information

                    Class      Levels      Values
                   Trt           5         1 2 3 5 6
                   Depth         3         10 20 30
                    rep           4         1 2 3 5


                Number of Observations Read        39
                Number of Observations Used        39


                 The GLM Procedure

Dependent Variable: Soil pH

                             Sum of
   Source             DF      Squares     Mean Square   F Value   Pr > F

   Model              22     6.28999683    0.28590895     83.83   <.0001

   Error              16    0.05456790    0.00341049

   Corrected Total    38     6.34456474


          R-Square    Coeff Var    Root MSE   SoilpH Mean

          0.991399     1.125409    0.058399     5.189174


   Source           DF     Type I SS     Mean Square   F Value   Pr > F

   Trt               4    3.07559354     0.76889839    225.45     <.0001
   rep(Trt)          8    3.15580247     0.39447531    115.67     <.0001
   Depth             2    0.00336815     0.00168408      0.49     0.6193
   Trt*Depth         8    0.05523267     0.00690408      2.02     0.1094

   Source           DF    Type III SS    Mean Square   F Value   Pr > F

   Trt               4    3.07559354     0.76889839    225.45    <.0001
   rep(Trt)          8    3.15580247     0.39447531    115.67    <.0001
   Depth             2    0.00804233     0.00402116      1.18     0.3329
   Trt*Depth         8    0.05523267     0.00690408      2.02     0.1094
```

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                          The SAS System

--------------------------------------- Date=JunJul07 ----------------------------------------

                          The GLM Procedure

Dependent Variable: Carbon

                                  Sum of
     Source                DF        Squares     Mean Square    F Value    Pr > F

     Model                 22     3.16074434      0.14367020       7.52    <.0001

     Error                 16     0.30564938      0.01910309

     Corrected Total       38     3.46639372


               R-Square     Coeff Var      Root MSE       C Mean

               0.911825      15.34870      0.138214     0.900493


     Source              DF       Type I SS     Mean Square    F Value    Pr > F

     Trt                  4      0.43521875      0.10880469       5.70    0.0048
     rep(Trt)             8      0.84288010      0.10536001       5.52    0.0019
     Depth                2      1.55758559      0.77879280      40.77    <.0001
     Trt*Depth            8      0.32505990      0.04063249       2.13    0.0946


     Source              DF     Type III SS     Mean Square    F Value    Pr > F

     Trt                  4      0.43521875      0.10880469       5.70    0.0048
     rep(Trt)             8      0.84288010      0.10536001       5.52    0.0019
     Depth                2      1.58591531      0.79295765      41.51    <.0001
     Trt*Depth            8      0.32505990      0.04063249       2.13    0.0946
```

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                              The SAS System

-------------------------------------- date=JunJul07 ---------------------------------------

                             The GLM Procedure

Dependent Variable: Nitrogen

                                  Sum of
    Source               DF        Squares     Mean Square     F Value    Pr > F

    Model                22     0.01501989      0.00068272        5.67    0.0004

    Error                16     0.00192780      0.00012049

    Corrected Total      38     0.01694769


              R-Square     Coeff Var      Root MSE       N Mean

              0.886250      12.65917      0.010977     0.086709


    Source               DF      Type I SS     Mean Square    F Value    Pr > F

    Trt                   4     0.00408695      0.00102174       8.48    0.0007
    rep(Trt)              8     0.00401294      0.00050162       4.16    0.0074
    Depth                 2     0.00610029      0.00305014      25.31    <.0001
    Trt*Depth             8     0.00081971      0.00010246       0.85    0.5744


    Source               DF    Type III SS     Mean Square    F Value    Pr > F

    Trt                   4     0.00408695      0.00102174       8.48    0.0007
    rep(Trt)              8     0.00401294      0.00050162       4.16    0.0074
    Depth                 2     0.00515992      0.00257996      21.41    <.0001
    Trt*Depth             8     0.00081971      0.00010246       0.85    0.5744
```

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                               The SAS System

--------------------------------------- date=JunJul07 ----------------------------------------

                              The GLM Procedure

Dependent Variable: Carbon to Nitrogen Ratio

                                  Sum of
    Source               DF        Squares     Mean Square    F Value    Pr > F

    Model                22     198.2720488      9.0123659      11.41    <.0001

    Error                16      12.6333877      0.7895867

    Corrected Total      38     210.9054364365


             R-Square     Coeff Var      Root MSE      C_N Mean

             0.940099      8.597936      0.888587      10.33489


    Source               DF      Type I SS     Mean Square    F Value    Pr > F

    Trt                   4     47.1290536      11.7822634      14.92    <.0001
    rep(Trt)              8    106.4148978      13.3018622      16.85    <.0001
    Depth                 2     24.0296286      12.0148143      15.22    0.0002
    Trt*Depth             8     20.6984689       2.5873086       3.28    0.0207


    Source               DF    Type III SS     Mean Square    F Value    Pr > F

    Trt                   4     47.1290536      11.7822634      14.92    <.0001
    rep(Trt)              8    106.4148978      13.3018622      16.85    <.0001
    Depth                 2     34.8769386      17.4384693      22.09    <.0001
    Trt*Depth             8     20.6984689       2.5873086       3.28    0.0207
```

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                          The SAS System

-------------------------------------- Date=JunJul07 ---------------------------------------

                         The GLM Procedure
```

Dependent Variable: Phosphorus mg kg^{-1}

```
                                Sum of
    Source              DF        Squares     Mean Square    F Value    Pr > F

    Model               22     9.20196265      0.41827103       9.59    <.0001

    Error               16     0.69753086      0.04359568

    Corrected Total     38     9.89949351


             R-Square     Coeff Var      Root MSE    Pmg_kg Mean

             0.929539      15.28411      0.208796       1.366097


    Source             DF       Type I SS     Mean Square    F Value    Pr > F

    Trt                 4     3.18755935      0.79688984      18.28      <.0001
    rep(Trt)            8     3.11728395      0.38966049       8.94     0.0001
    Depth               2     2.66302627      1.33151314      30.54      <.0001
    Trt*Depth           8     0.23409307      0.02926163       0.67      0.7098


    Source             DF     Type III SS     Mean Square    F Value    Pr > F

    Trt                 4     3.18755935      0.79688984      18.28      <.0001
    rep(Trt)            8     3.11728395      0.38966049       8.94     0.0001
    Depth               2     2.46296296      1.23148148      28.25      <.0001
    Trt*Depth           8     0.23409307      0.02926163       0.67     0.7098
```

```
                        The SAS System

----------------------------------- Date=JunJul07 -----------------------------------

                       The GLM Procedure

Dependent Variable: Potassium mg kg-1

                                  Sum of
    Source               DF      Squares     Mean Square    F Value    Pr > F

    Model                22    7865.541944    357.524634      11.54    <.0001

    Error                16     495.703704     30.981481

    Corrected Total      38    8361.245647


             R-Square     Coeff Var      Root MSE    Kmg_kg Mean

             0.940714      7.466280      5.566101       74.54986


    Source               DF      Type I SS     Mean Square    F Value    Pr > F

    Trt                   4    3808.527540     952.131885      30.73     <.0001
    rep(Trt)              8    3586.629630     448.328704      14.47     <.0001
    Depth                 2      12.090377       6.045188       0.20     0.8247
    Trt*Depth             8     458.294397      57.286800       1.85     0.1406


    Source               DF     Type III SS    Mean Square    F Value    Pr > F

    Trt                   4    3808.527540     952.131885      30.73     <.0001
    rep(Trt)              8    3586.629630     448.328704      14.47     <.0001
    Depth                 2      75.741623      37.870811       1.22     0.3206
    Trt*Depth             8     458.294397      57.286800       1.85     0.1406
```

```
                         The SAS System

------------------------------------- Date=JunJul07 -------------------------------------

                         The GLM Procedure

Dependent Variable: Calcium mg kg-1

                                 Sum of
    Source               DF        Squares     Mean Square    F Value    Pr > F

    Model                22     643262.8362      29239.2198      17.73    <.0001

    Error                16      26379.2654       1648.7041

    Corrected Total      38     669642.1016


              R-Square     Coeff Var      Root MSE    Camg_kg Mean

              0.960607      14.84987      40.60424        273.4316


    Source               DF      Type I SS     Mean Square    F Value    Pr > F

    Trt                   4    191938.4720      47984.6180      29.10    <.0001
    rep(Trt)              8    366487.3827      45810.9228      27.79    <.0001
    Depth                 2     43682.6686      21841.3343      13.25    0.0004
    Trt*Depth             8     41154.3129       5144.2891       3.12    0.0251


    Source               DF    Type III SS     Mean Square    F Value    Pr > F

    Trt                   4    191938.4720      47984.6180      29.10    <.0001
    rep(Trt)              8    366487.3827      45810.9228      27.79    <.0001
    Depth                 2     35525.5697      17762.7848      10.77    0.0011
    Trt*Depth             8     41154.3129       5144.2891       3.12    0.0251
```

```
                              The SAS System

-------------------------------------- Date=JunJul07 --------------------------------------

                             The GLM Procedure

Dependent Variable: Magnesium mg kg-1

                                Sum of
    Source              DF        Squares     Mean Square    F Value    Pr > F

    Model               22    4757.300095      216.240913       6.09    0.0003

    Error               16     568.395062       35.524691

    Corrected Total     38    5325.695157


           R-Square     Coeff Var      Root MSE    Mgmg_kg Mean

           0.893273      12.29461      5.960259        48.47863


    Source              DF      Type I SS     Mean Square    F Value    Pr > F

    Trt                  4    1222.812441      305.703110       8.61    0.0007
    rep(Trt)             8    2966.938272      370.867284      10.44    <.0001
    Depth                2     156.782051       78.391026       2.21    0.1424
    Trt*Depth            8     410.767331       51.345916       1.45    0.2521


    Source              DF    Type III SS     Mean Square    F Value    Pr > F

    Trt                  4    1222.812441      305.703110       8.61    0.0007
    rep(Trt)             8    2966.938272      370.867284      10.44    <.0001
    Depth                2     241.011464      120.505732       3.39    0.0591
    Trt*Depth            8     410.767331       51.345916       1.45    0.2521
```

```
                          The SAS System

--------------------------------------- Date=JunJul07 ----------------------------------------

                         The GLM Procedure

Dependent Variable: Zinc mg kg-1

                                   Sum of
    Source                 DF         Squares     Mean Square    F Value    Pr > F

    Model                  22     21.68003007      0.98545591       2.25    0.0505

    Error                  16      7.01172840      0.43823302

    Corrected Total        38     28.69175847


             R-Square     Coeff Var      Root MSE    Znmg_kg Mean

             0.755619      54.07472      0.661992        1.224217


    Source                 DF       Type I SS     Mean Square    F Value    Pr > F

    Trt                     4      2.65673789      0.66418447       1.52    0.2447
    rep(Trt)                8     11.07382716      1.38422840       3.16    0.0240
    Depth                   2      5.64734251      2.82367126       6.44    0.0089
    Trt*Depth               8      2.30212251      0.28776531       0.66    0.7211


    Source                 DF     Type III SS     Mean Square    F Value    Pr > F

    Trt                     4      2.65673789      0.66418447       1.52    0.2447
    rep(Trt)                8     11.07382716      1.38422840       3.16    0.0240
    Depth                   2      3.92281305      1.96140653       4.48    0.0286
    Trt*Depth               8      2.30212251      0.28776531       0.66    0.7211
```

```
                              The SAS System

--------------------------------------- Date=JunJul07 ---------------------------------------

                              The GLM Procedure

Dependent Variable: Manganese mg kg-1

                                  Sum of
    Source              DF       Squares     Mean Square    F Value    Pr > F

    Model               22    33806.25594     1536.64800      17.44    <.0001

    Error               16     1409.93827       88.12114

    Corrected Total     38    35216.19421


              R-Square     Coeff Var      Root MSE    Mnmg_kg Mean

              0.959963      18.69627      9.387286        50.20940


    Source              DF      Type I SS     Mean Square    F Value    Pr > F

    Trt                  4    12734.27445     3183.56861      36.13     <.0001
    rep(Trt)             8    20311.65432     2538.95679      28.81     <.0001
    Depth                2      343.88082      171.94041       1.95     0.1745
    Trt*Depth            8      416.44634       52.05579       0.59     0.7718


    Source              DF    Type III SS     Mean Square    F Value    Pr > F

    Trt                  4    12734.27445     3183.56861      36.13     <.0001
    rep(Trt)             8    20311.65432     2538.95679      28.81     <.0001
    Depth                2      375.51058      187.75529       2.13     0.1512
    Trt*Depth            8      416.44634       52.05579       0.59     0.7718
```

```
                              The SAS System

--------------------------------------- Date=JunJul07 ---------------------------------------

                              The GLM Procedure

Dependent Variable: Copper mg kg-1

                                  Sum of
    Source              DF       Squares     Mean Square    F Value    Pr > F

    Model               22     0.87365305     0.03971150       2.61    0.0267

    Error               16     0.24327160     0.01520448

    Corrected Total     38     1.11692466


             R-Square     Coeff Var      Root MSE    Cumg_kg Mean

             0.782195      10.47955      0.123306        1.176638


    Source              DF      Type I SS     Mean Square    F Value    Pr > F

    Trt                  4     0.44887939     0.11221985       7.38      0.0014
    rep(Trt)             8     0.34172840     0.04271605       2.81      0.0375
    Depth                2     0.01869104     0.00934552       0.61      0.5531
    Trt*Depth            8     0.06435423     0.00804428       0.53      0.8179


    Source              DF    Type III SS     Mean Square    F Value    Pr > F

    Trt                  4     0.44887939     0.11221985       7.38      0.0014
    rep(Trt)             8     0.34172840     0.04271605       2.81      0.0375
    Depth                2     0.01249559     0.00624780       0.41      0.6698
    Trt*Depth            8     0.06435423     0.00804428       0.53      0.8179
```

```
                         The SAS System

-------------------------------------- date=JunJul07 ---------------------------------------

                         The GLM Procedure

Dependent Variable: Boron mg kg-1

                                  Sum of
     Source              DF        Squares     Mean Square    F Value    Pr > F

     Model               22     0.08295030      0.00377047       5.62    0.0004

     Error               16     0.01074074      0.00067130

     Corrected Total     38     0.09369104


              R-Square     Coeff Var      Root MSE    Bmg_kg Mean

              0.885360      10.46513      0.025909       0.247578


     Source              DF      Type I SS     Mean Square    F Value    Pr > F

     Trt                  4     0.02453466      0.00613367       9.14    0.0005
     rep(Trt)             8     0.03851852      0.00481481       7.17    0.0004
     Depth                2     0.00994460      0.00497230       7.41    0.0053
     Trt*Depth            8     0.00995252      0.00124406       1.85    0.1397


     Source              DF    Type III SS     Mean Square    F Value    Pr > F

     Trt                  4     0.02453466      0.00613367       9.14    0.0005
     rep(Trt)             8     0.03851852      0.00481481       7.17    0.0004
     Depth                2     0.01032628      0.00516314       7.69    0.0046
     Trt*Depth            8     0.00995252      0.00124406       1.85    0.1397
```

```
                         The SAS System

--------------------------------------- Date=JunJul07 ----------------------------------------

                         The GLM Procedure

Dependent Variable: Sodium mg kg-1

                                    Sum of
    Source               DF        Squares     Mean Square    F Value    Pr > F

    Model                22     23.52342513      1.06924660       6.49    0.0002

    Error                16      2.63580247      0.16473765

    Corrected Total      38     26.15922760


             R-Square     Coeff Var      Root MSE    Namg_kg Mean

             0.899240      11.39708      0.405879        3.561254


    Source               DF       Type I SS     Mean Square    F Value    Pr > F

    Trt                   4     11.92877493      2.98219373      18.10    <.0001
    rep(Trt)              8      9.01234568      1.12654321       6.84    0.0006
    Depth                 2      1.78031022      0.89015511       5.40    0.0161
    Trt*Depth             8      0.80199430      0.10024929       0.61    0.7582


    Source               DF     Type III SS     Mean Square    F Value    Pr > F

    Trt                   4     11.92877493      2.98219373      18.10    <.0001
    rep(Trt)              8      9.01234568      1.12654321       6.84    0.0006
    Depth                 2      1.02998236      0.51499118       3.13    0.0714
    Trt*Depth             8      0.80199430      0.10024929       0.61    0.7582
```

```
                         The SAS System

------------------------------------- date=JunJul07 -------------------------------------

                         The GLM Procedure

Dependent Variable: NO3_Nppm

                                Sum of
    Source             DF      Squares     Mean Square    F Value    Pr > F

    Model              22   1147.007281     52.136695      18.08    <.0001

    Error              16     46.148148      2.884259

    Corrected Total    38   1193.155429


              R-Square    Coeff Var     Root MSE    NO3_Nppm Mean

              0.961323     15.82865     1.698311        10.72934


    Source             DF      Type I SS     Mean Square    F Value    Pr > F

    Trt                 4    886.4558405     221.6139601      76.84    <.0001
    rep(Trt)            8    136.3703704      17.0462963       5.91    0.0013
    Depth               2     88.2323520      44.1161760      15.30    0.0002
    Trt*Depth           8     35.9487179       4.4935897       1.56    0.2141


    Source             DF    Type III SS     Mean Square    F Value    Pr > F

    Trt                 4    886.4558405     221.6139601      76.84    <.0001
    rep(Trt)            8    136.3703704      17.0462963       5.91    0.0013
    Depth               2     85.8518519      42.9259259      14.88    0.0002
    Trt*Depth           8     35.9487179       4.4935897       1.56    0.2141
```

```
                          The SAS System

--------------------------------------- Date=JunJul07 ----------------------------------------

                         The GLM Procedure

Dependent Variable: ECEC

                                   Sum of
     Source              DF       Squares     Mean Square    F Value    Pr > F

     Model               22      6.70511554      0.30477798       4.74    0.0012

     Error               16      1.02814815      0.06425926

     Corrected Total      38      7.73326369


              R-Square     Coeff Var      Root MSE      CEC Mean

              0.867049      4.406519      0.253494      5.752707


     Source              DF       Type I SS     Mean Square    F Value    Pr > F

     Trt                  4     1.01861349      0.25465337      3.96       0.0202
     rep(Trt)             8     4.07037037      0.50879630      7.92       0.0002
     Depth                2     0.70688192      0.35344096      5.50       0.0152
     Trt*Depth            8     0.90924976      0.11365622      1.77       0.1578


     Source              DF     Type III SS     Mean Square    F Value    Pr > F

     Trt                  4     1.01861349      0.25465337      3.96        0.0202
     rep(Trt)             8     4.07037037      0.50879630      7.92        0.0002
     Depth                2     0.61220459      0.30610229      4.76        0.0238
     Trt*Depth            8     0.90924976      0.11365622      1.77        0.1578
```

```
                         The SAS System

-------------------------------------- Date=JunJul07 ---------------------------------------

                         The GLM Procedure

Dependent Variable: Acidity

                                   Sum of
    Source               DF       Squares     Mean Square    F Value    Pr > F

    Model                22    9.21476417      0.41885292      10.28    <.0001

    Error                16    0.65185185      0.04074074

    Corrected Total      38    9.86661602


             R-Square     Coeff Var      Root MSE    Acidity Mean

             0.933934      5.344525      0.201843        3.776638


    Source               DF     Type I SS     Mean Square    F Value    Pr > F

    Trt                   4    1.22924976      0.30731244       7.54    0.0013
    rep(Trt)              8    7.51407407      0.93925926      23.05    <.0001
    Depth                 2    0.06878126      0.03439063       0.84    0.4482
    Trt*Depth             8    0.40265907      0.05033238       1.24    0.3408


    Source               DF   Type III SS     Mean Square    F Value    Pr > F

    Trt                   4    1.22924976      0.30731244       7.54    0.0013
    rep(Trt)              8    7.51407407      0.93925926      23.05    <.0001
    Depth                 2    0.02765432      0.01382716       0.34    0.7172
    Trt*Depth             8    0.40265907      0.05033238       1.24    0.3408
```

```
                         The SAS System

-------------------------------------- Date=JunJul07 ---------------------------------------

                          The GLM Procedure

Dependent Variable: Total Base Saturation

                                    Sum of
    Source                DF       Squares     Mean Square    F Value    Pr > F

    Model                 22    3642.813549     165.582434      20.52    <.0001

    Error                 16     129.086420       8.067901

    Corrected Total       38    3771.899968


             R-Square     Coeff Var      Root MSE    Total_BS Mean

             0.965777      8.380114      2.840405        33.89459


    Source                DF       Type I SS     Mean Square    F Value    Pr > F

    Trt                    4     709.521368      177.380342      21.99     <.0001
    rep(Trt)               8    2658.172840      332.271605      41.18     <.0001
    Depth                  2     104.942703       52.471352       6.50     0.0086
    Trt*Depth              8     170.176638       21.272080       2.64     0.0470


    Source                DF     Type III SS     Mean Square    F Value    Pr > F

    Trt                    4     709.521368      177.380342      21.99     <.0001
    rep(Trt)               8    2658.172840      332.271605      41.18     <.0001
    Depth                  2      80.469136       40.234568       4.99     0.0207
    Trt*Depth              8     170.176638       21.272080       2.64     0.0470
```

```
----------------------------------- BYGROUP=1 Effect=Depth -----------------------------------

                                             Standard          Letter
 Obs     date     Dependent    Trt      LSMean          Error    Depth    Group

   1   JunJul07    Acidity           3.79556       0.06166     10        A
   2   JunJul07    Acidity           3.79556       0.06166     20        A
   3   JunJul07    Acidity           3.85778       0.06166     30        A


------------------------------------ BYGROUP=2 Effect=Trt ------------------------------------

                                             Standard      Letter
 Obs    date     Dependent    Trt       LSMean       Error    Depth    Group

   4   JunJul07    Acidity    1        3.85185       0.32305            A
   5   JunJul07    Acidity    2        3.89630       0.32305            A
   6   JunJul07    Acidity    3        3.77778       0.32305            A
   7   JunJul07    Acidity    5        4.07407       0.55954            A
   8   JunJul07    Acidity    6        3.48148       0.32305            A


--------------------------------- BYGROUP=3 Effect=Trt_Depth ---------------------------------

                                             Standard        Letter
 Obs     date     Dependent    Trt      LSMean       Error     Depth    Group

   9   JunJul07    Acidity    1        3.82222       0.11653    10      ABC
  10    JunJul07    Acidity    1        3.82222       0.11653    20      ABC
  11    JunJul07    Acidity    1        3.91111       0.11653    30      AB
  12    JunJul07    Acidity    2        3.77778       0.11653    10      ABC
  13    JunJul07    Acidity    2        3.86667       0.11653    20      AB
  14    JunJul07    Acidity    2        4.04444       0.11653    30      A
  15    JunJul07    Acidity    3        3.95556       0.11653    10      AB
  16    JunJul07    Acidity    3        3.68889       0.11653    20      BC
  17    JunJul07    Acidity    3        3.68889       0.11653    30      BC
  18    JunJul07    Acidity    5        4.13333       0.20184    10      AB
  19    JunJul07    Acidity    5        4.08889       0.20184    20      AB
  20    JunJul07    Acidity    5        4.00000       0.20184    30      ABC
  21    JunJul07    Acidity    6        3.28889       0.11653    10      D
  22    JunJul07    Acidity    6        3.51111       0.11653    20      CD
  23    JunJul07    Acidity    6        3.64444       0.11653    30      BC
```

```
---------------------------------- BYGROUP=10 Effect=Depth -----------------------------------

                                              Standard      Letter
 Obs    date      Dependent    Trt     LSMean      Error     Depth   Group

  70   JunJul07    Bmg_kg              0.26444     0.00792    10      A
  71   JunJul07    Bmg_kg              0.23667     0.00792    20      B
  72   JunJul07    Bmg_kg              0.22111     0.00792    30      B


----------------------------------- BYGROUP=11 Effect=Trt ------------------------------------

                                              Standard       Letter
 Obs    date      Dependent    Trt     LSMean       Error   Depth   Group

  73   JunJul07    Bmg_kg       1      0.22963     0.02313           A
  74   JunJul07    Bmg_kg       2      0.28519     0.02313           A
  75   JunJul07    Bmg_kg       3      0.25370     0.02313           A
  76   JunJul07    Bmg_kg       5      0.19630     0.04006           A
  77   JunJul07    Bmg_kg       6      0.23889     0.02313           A



-------------------------------- BYGROUP=12 Effect=Trt_Depth ---------------------------------

                                              Standard       Letter
 Obs    date      Dependent    Trt     LSMean       Error   Depth   Group

  78   JunJul07    Bmg_kg       1      0.26111     0.01496    10    ABCDE
  79   JunJul07    Bmg_kg       1      0.22222     0.01496    20    DEF
  80   JunJul07    Bmg_kg       1      0.20556     0.01496    30    FG
  81   JunJul07    Bmg_kg       2      0.27778     0.01496    10    ABC
  82   JunJul07    Bmg_kg       2      0.27778     0.01496    20    ABC
  83   JunJul07    Bmg_kg       2      0.30000     0.01496    30    A
  84   JunJul07    Bmg_kg       3      0.26667     0.01496    10    ABCD
  85   JunJul07    Bmg_kg       3      0.26111     0.01496    20    ABCDE
  86   JunJul07    Bmg_kg       3      0.23333     0.01496    30    CDEF
  87   JunJul07    Bmg_kg       5      0.23333     0.02591    10    BCDEF
  88   JunJul07    Bmg_kg       5      0.20000     0.02591    20    EFG
  89   JunJul07    Bmg_kg       5      0.15556     0.02591    30    G
  90   JunJul07    Bmg_kg       6      0.28333     0.01496    10    AB
  91   JunJul07    Bmg_kg       6      0.22222     0.01496    20    DEF
  92   JunJul07    Bmg_kg       6      0.21111     0.01496    30    FG
```

```
---------------------------------- BYGROUP=16 Effect=Depth ----------------------------------

                                        Standard      Letter
  Obs    date     Dependent   Trt     LSMean        Error   Depth   Group

  116   JunJul07      C              1.18418      0.04223    10      A
  117   JunJul07      C              0.76844      0.04223    20      B
  118   JunJul07      C              0.67233      0.04223    30      B


----------------------------------- BYGROUP=17 Effect=Trt ------------------------------------

                                          Standard      Letter
  Obs    date    Dependent   Trt          LSMean       Error   Depth   Group

  119   JunJul07      C        1        0.80030       0.10820            A
  120   JunJul07      C        2        1.05674       0.10820            A
  121   JunJul07      C        3        0.93330       0.10820            A
  122   JunJul07      C        5        0.70919       0.18740            A
  123   JunJul07      C        6        0.87541       0.10820            A


-------------------------------- BYGROUP=18 Effect=Trt_Depth ---------------------------------

                                         Standard      Letter
  Obs    date     Dependent   Trt       LSMean        Error   Depth   Group

  124   JunJul07      C       1      1.10100      0.07980    10     AB
  125   JunJul07      C       1      0.71544      0.07980    20     EFG
  126   JunJul07      C       1      0.58444      0.07980    30     GH
  127   JunJul07      C       2      1.25144      0.07980    10     A
  128   JunJul07      C       2      0.94567      0.07980    20     BCDE
  129   JunJul07      C       2      0.97311      0.07980    30     BCD
  130   JunJul07      C       3      1.06522      0.07980    10     ABC
  131   JunJul07      C       3      0.88956      0.07980    20     BCDE
  132   JunJul07      C       3      0.84511      0.07980    30     CDEF
  133   JunJul07      C       5      1.21933      0.13821    10     AB
  134   JunJul07      C       5      0.53656      0.13821    20     FGH
  135   JunJul07      C       5      0.37167      0.13821    30     H
  136   JunJul07      C       6      1.28389      0.07980    10     A
  137   JunJul07      C       6      0.75500      0.07980    20     DEFG
  138   JunJul07      C       6      0.58733      0.07980    30     GH
```

```
---------------------------------- BYGROUP=19 Effect=Depth ----------------------------------

                                          Standard         Letter
 Obs    date      Dependent   Trt         LSMean           Error    Depth   Group

 139   JunJul07     CEC                   5.92000        0.07744    10       A
 140   JunJul07     CEC                   5.59556        0.07744    20       B
 141   JunJul07     CEC                   5.67556        0.07744    30       B


----------------------------------- BYGROUP=20 Effect=Trt -----------------------------------

                                          Standard         Letter
 Obs    date      Dependent   Trt         LSMean           Error    Depth   Group

 142   JunJul07     CEC        1          5.56667        0.23777             A
 143   JunJul07     CEC        2          5.80370        0.23777             A
 144   JunJul07     CEC        3          5.69259        0.23777             A
 145   JunJul07     CEC        5          5.58519        0.41182             A
 146   JunJul07     CEC        6          6.00370        0.23777             A


-------------------------------- BYGROUP=21 Effect=Trt_Depth --------------------------------

                                          Standard         Letter
 Obs    date      Dependent   Trt         LSMean           Error    Depth   Group

 147   JunJul07     CEC        1          5.67778        0.14635    10      BC
 148   JunJul07     CEC        1          5.50000        0.14635    20      C
 149   JunJul07     CEC        1          5.52222        0.14635    30      C
 150   JunJul07     CEC        2          5.77778        0.14635    10      BC
 151   JunJul07     CEC        2          5.54444        0.14635    20      C
 152   JunJul07     CEC        2          6.08889        0.14635    30      AB
 153   JunJul07     CEC        3          5.86667        0.14635    10      BC
 154   JunJul07     CEC        3          5.62222        0.14635    20      C
 155   JunJul07     CEC        3          5.58889        0.14635    30      C
 156   JunJul07     CEC        5          5.83333        0.25349    10      ABC
 157   JunJul07     CEC        5          5.50000        0.25349    20       BC
 158   JunJul07     CEC        5          5.42222        0.25349    30       C
 159   JunJul07     CEC        6          6.44444        0.14635    10       A
 160   JunJul07     CEC        6          5.81111        0.14635    20       BC
 161   JunJul07     CEC        6          5.75556        0.14635    30       BC
```

```
---------------------------------- BYGROUP=22 Effect=Depth -----------------------------------

                                         Standard          Letter
   Obs     date     Dependent    Trt       LSMean          Error    Depth    Group

   162    JunJul07      C_N                11.95444       0.27147     10       A
   163    JunJul07      C_N                10.05617       0.27147     20       B
   164    JunJul07      C_N                 9.52876       0.27147     30       B


----------------------------------- BYGROUP=23 Effect=Trt ------------------------------------

                                         Standard          Letter
   Obs     date     Dependent    Trt       LSMean          Error    Depth    Group

   165    JunJul07      C_N       1         8.95000       1.21572              A
   166    JunJul07      C_N       2        11.00822       1.21572              A
   167    JunJul07      C_N       3        11.52481       1.21572              A
   168    JunJul07      C_N       5        11.67164       2.10570              A
   169    JunJul07      C_N       6         9.41093       1.21572              A


-------------------------------- BYGROUP=24 Effect=Trt_Depth ---------------------------------

                                         Standard          Letter
   Obs     date     Dependent    Trt       LSMean          Error    Depth    Group

   170    JunJul07      C_N       1        10.30478       0.51303     10       BCD
   171    JunJul07      C_N       1         8.35844       0.51303     20       EF
   172    JunJul07      C_N       1         8.18678       0.51303     30       EF
   173    JunJul07      C_N       2        11.34589       0.51303     10       BC
   174    JunJul07      C_N       2        10.66333       0.51303     20       BCD
   175    JunJul07      C_N       2        11.01544       0.51303     30       BC
   176    JunJul07      C_N       3        11.72533       0.51303     10       B
   177    JunJul07      C_N       3        11.66733       0.51303     20       B
   178    JunJul07      C_N       3        11.18178       0.51303     30       BC
   179    JunJul07      C_N       5        15.47364       0.88859     10       A
   180    JunJul07      C_N       5        10.26006       0.88859     20       BCDE
   181    JunJul07      C_N       5         9.28122       0.88859     30       CDEF
   182    JunJul07      C_N       6        10.92256       0.51303     10       BC
   183    JunJul07      C_N       6         9.33167       0.51303     20       DEF
   184    JunJul07      C_N       6         7.97856       0.51303     30       F
```

```
---------------------------------- BYGROUP=34 Effect=Depth ----------------------------------

                                          Standard          Letter
 Obs     date     Dependent    Trt         LSMean           Error    Depth    Group

 254    JunJul07     Camg_kg              304.90000        12.40480    10        A
 255    JunJul07     Camg_kg              234.12222        12.40480    20        B
 256    JunJul07     Camg_kg              234.63333        12.40480    30        B


----------------------------------- BYGROUP=35 Effect=Trt ------------------------------------

                                          Standard          Letter
 Obs     date     Dependent    Trt         LSMean           Error    Depth    Group

 257    JunJul07     Camg_kg     1         224.55556        71.34495            A
 258    JunJul07     Camg_kg     2         257.55556        71.34495            A
 259    JunJul07     Camg_kg     3         258.96296        71.34495            A
 260    JunJul07     Camg_kg     5         156.83333       123.57309            A
 261    JunJul07     Camg_kg     6         391.51852        71.34495            A


-------------------------------- BYGROUP=36 Effect=Trt_Depth ---------------------------------

                                          Standard          Letter
 Obs     date     Dependent    Trt         LSMean           Error      Depth    Group

 262    JunJul07     Camg_kg     1         256.00000        23.44287     10      CDE
 263    JunJul07     Camg_kg     1         212.61111        23.44287     20      EF
 264    JunJul07     Camg_kg     1         205.05556        23.44287     30      EF
 265    JunJul07     Camg_kg     2         287.83333        23.44287     10      BCD
 266    JunJul07     Camg_kg     2         215.83333        23.44287     20      EF
 267    JunJul07     Camg_kg     2         269.00000        23.44287     30      CDE
 268    JunJul07     Camg_kg     3         264.83333        23.44287     10      CDE
 269    JunJul07     Camg_kg     3         256.77778        23.44287     20      CDE
 270    JunJul07     Camg_kg     3         255.27778        23.44287     30      CDE
 271    JunJul07     Camg_kg     5         201.94444        40.60424     10      DEF
 272    JunJul07     Camg_kg     5         140.55556        40.60424     20      F
 273    JunJul07     Camg_kg     5         128.00000        40.60424     30      F
 274    JunJul07     Camg_kg     6         513.88889        23.44287     10      A
 275    JunJul07     Camg_kg     6         344.83333        23.44287     20      B
 276    JunJul07     Camg_kg     6         315.83333        23.44287     30      BC
```

```
---------------------------------- BYGROUP=43 Effect=Depth -----------------------------------

                                          Standard        Letter
  Obs     date      Dependent    Trt       LSMean          Error    Depth    Group

  323    JunJul07     Cumg_kg              1.11889       0.03767     10        A
  324    JunJul07     Cumg_kg              1.15556       0.03767     20        A
  325    JunJul07     Cumg_kg              1.11000       0.03767     30        A


----------------------------------- BYGROUP=44 Effect=Trt ------------------------------------

                                          Standard        Letter
  Obs     date      Dependent    Trt       LSMean          Error    Depth    Group

  326    JunJul07     Cumg_kg     1         1.20741       0.06889              A
  327    JunJul07     Cumg_kg     2         1.24074       0.06889              A
  328    JunJul07     Cumg_kg     3         1.20370       0.06889              A
  329    JunJul07     Cumg_kg     5         0.81296       0.11933              B
  330    JunJul07     Cumg_kg     6         1.17593       0.06889              A


-------------------------------- BYGROUP=45 Effect=Trt_Depth ---------------------------------

                                          Standard        Letter
  Obs     date      Dependent    Trt       LSMean          Error    Depth    Group

  331    JunJul07     Cumg_kg     1         1.23889       0.07119     10        A
  332    JunJul07     Cumg_kg     1         1.21667       0.07119     20        A
  333    JunJul07     Cumg_kg     1         1.16667       0.07119     30        A
  334    JunJul07     Cumg_kg     2         1.16667       0.07119     10        A
  335    JunJul07     Cumg_kg     2         1.28889       0.07119     20        A
  336    JunJul07     Cumg_kg     2         1.26667       0.07119     30        A
  337    JunJul07     Cumg_kg     3         1.26667       0.07119     10        A
  338    JunJul07     Cumg_kg     3         1.18889       0.07119     20        A
  339    JunJul07     Cumg_kg     3         1.15556       0.07119     30        A
  340    JunJul07     Cumg_kg     5         0.78333       0.12331     10        B
  341    JunJul07     Cumg_kg     5         0.82778       0.12331     20        B
  342    JunJul07     Cumg_kg     5         0.82778       0.12331     30        B
  343    JunJul07     Cumg_kg     6         1.13889       0.07119     10        A
  344    JunJul07     Cumg_kg     6         1.25556       0.07119     20        A
  345    JunJul07     Cumg_kg     6         1.13333       0.07119     30        A
```

```
---------------------------------- BYGROUP=55 Effect=Depth -----------------------------------

                                         Standard          Letter
   Obs     date      Dependent    Trt       LSMean          Error    Depth    Group

   415    JunJul07     Kmg_kg              73.58889       1.70047     10       A
   416    JunJul07     Kmg_kg              72.18889       1.70047     20       A
   417    JunJul07     Kmg_kg              69.86667       1.70047     30       A


----------------------------------- BYGROUP=56 Effect=Trt ------------------------------------

                                         Standard          Letter
   Obs     date      Dependent    Trt       LSMean          Error    Depth    Group

   418    JunJul07     Kmg_kg       1       78.09259       7.05792              A
   419    JunJul07     Kmg_kg       2       80.25926       7.05792              A
   420    JunJul07     Kmg_kg       3       84.24074       7.05792              A
   421    JunJul07     Kmg_kg       5       54.53704      12.22468              A
   422    JunJul07     Kmg_kg       6       62.27778       7.05792              A


-------------------------------- BYGROUP=57 Effect=Trt_Depth ---------------------------------

                                         Standard          Letter
   Obs     date      Dependent    Trt       LSMean          Error    Depth    Group

   423    JunJul07     Kmg_kg       1       78.66667       3.21359     10       ABC
   424    JunJul07     Kmg_kg       1       79.44444       3.21359     20       ABC
   425    JunJul07     Kmg_kg       1       76.16667       3.21359     30       BC
   426    JunJul07     Kmg_kg       2       76.88889       3.21359     10       ABC
   427    JunJul07     Kmg_kg       2       78.88889       3.21359     20       ABC
   428    JunJul07     Kmg_kg       2       85.00000       3.21359     30       AB
   429    JunJul07     Kmg_kg       3       81.22222       3.21359     10       AB
   430    JunJul07     Kmg_kg       3       86.33333       3.21359     20       A
   431    JunJul07     Kmg_kg       3       85.16667       3.21359     30       AB
   432    JunJul07     Kmg_kg       5       65.94444       5.56610     10       CD
   433    JunJul07     Kmg_kg       5       53.27778       5.56610     20       DE
   434    JunJul07     Kmg_kg       5       44.38889       5.56610     30       E
   435    JunJul07     Kmg_kg       6       65.22222       3.21359     10       D
   436    JunJul07     Kmg_kg       6       63.00000       3.21359     20       D
   437    JunJul07     Kmg_kg       6       58.61111       3.21359     30       D
```

```
---------------------------------- BYGROUP=67 Effect=Depth -----------------------------------

                                              Standard          Letter
   Obs     date      Dependent    Trt          LSMean           Error    Depth    Group

   507    JunJul07     Mgmg_kg               47.73333         1.82089     10        B
   508    JunJul07     Mgmg_kg               50.81111         1.82089     20        AB
   509    JunJul07     Mgmg_kg               54.43333         1.82089     30        A


----------------------------------- BYGROUP=68 Effect=Trt ------------------------------------

                                              Standard          Letter
   Obs     date      Dependent    Trt          LSMean           Error    Depth    Group

   510    JunJul07     Mgmg_kg     1          45.14815         6.41930              A
   511    JunJul07     Mgmg_kg     2          48.75926         6.41930              A
   512    JunJul07     Mgmg_kg     3          47.55556         6.41930              A
   513    JunJul07     Mgmg_kg     5          67.33333        11.11856              A
   514    JunJul07     Mgmg_kg     6          46.16667         6.41930              A


-------------------------------- BYGROUP=69 Effect=Trt_Depth ---------------------------------

                                              Standard          Letter
   Obs     date      Dependent    Trt          LSMean           Error    Depth    Group

   515    JunJul07     Mgmg_kg     1          44.11111         3.44116     10       E
   516    JunJul07     Mgmg_kg     1          46.66667         3.44116     20       CDE
   517    JunJul07     Mgmg_kg     1          44.66667         3.44116     30       E
   518    JunJul07     Mgmg_kg     2          44.11111         3.44116     10       E
   519    JunJul07     Mgmg_kg     2          45.22222         3.44116     20       DE
   520    JunJul07     Mgmg_kg     2          56.94444         3.44116     30       BC
   521    JunJul07     Mgmg_kg     3          44.55556         3.44116     10       E
   522    JunJul07     Mgmg_kg     3          50.72222         3.44116     20       BCDE
   523    JunJul07     Mgmg_kg     3          47.38889         3.44116     30       CDE
   524    JunJul07     Mgmg_kg     5          59.72222         5.96026     10       BCD
   525    JunJul07     Mgmg_kg     5          64.05556         5.96026     20       AB
   526    JunJul07     Mgmg_kg     5          78.22222         5.96026     30       A
   527    JunJul07     Mgmg_kg     6          46.16667         3.44116     10       DE
   528    JunJul07     Mgmg_kg     6          47.38889         3.44116     20       CDE
   529    JunJul07     Mgmg_kg     6          44.94444         3.44116     30       E
```

```
---------------------------------- BYGROUP=76 Effect=Depth -----------------------------------

                                              Standard       Letter
 Obs    date      Dependent   Trt      LSMean         Error   Depth   Group

 576   JunJul07    Mnmg_kg              49.78889      2.86786    10       A
 577   JunJul07    Mnmg_kg              42.26667      2.86786    20       A
 578   JunJul07    Mnmg_kg              42.84444      2.86786    30       A


----------------------------------- BYGROUP=77 Effect=Trt ------------------------------------

                                              Standard       Letter
 Obs    date      Dependent   Trt      LSMean         Error   Depth   Group

 579   JunJul07    Mnmg_kg     1       49.24074      16.79602            A
 580   JunJul07    Mnmg_kg     2       62.64815      16.79602            A
 581   JunJul07    Mnmg_kg     3       70.29630      16.79602            A
 582   JunJul07    Mnmg_kg     5       10.88889      29.09156            A
 583   JunJul07    Mnmg_kg     6       31.75926      16.79602            A


-------------------------------- BYGROUP=78 Effect=Trt_Depth ---------------------------------

                                              Standard       Letter
 Obs    date      Dependent   Trt      LSMean         Error   Depth   Group

 584   JunJul07    Mnmg_kg     1       58.55556       5.41975    10      BC
 585   JunJul07    Mnmg_kg     1       46.11111       5.41975    20      CD
 586   JunJul07    Mnmg_kg     1       43.05556       5.41975    30      CDE
 587   JunJul07    Mnmg_kg     2       65.38889       5.41975    10      AB
 588   JunJul07    Mnmg_kg     2       58.22222       5.41975    20      BC
 589   JunJul07    Mnmg_kg     2       64.33333       5.41975    30      AB
 590   JunJul07    Mnmg_kg     3       75.27778       5.41975    10      A
 591   JunJul07    Mnmg_kg     3       67.44444       5.41975    20      AB
 592   JunJul07    Mnmg_kg     3       68.16667       5.41975    30      AB
 593   JunJul07    Mnmg_kg     5       20.05556       9.38729    10      FGH
 594   JunJul07    Mnmg_kg     5        7.61111      9.38729    20     GH
 595   JunJul07    Mnmg_kg     5        5.00000      9.38729    30     H
 596   JunJul07    Mnmg_kg     6       29.66667       5.41975    10      EFG
 597   JunJul07    Mnmg_kg     6       31.94444       5.41975    20      DEF
 598   JunJul07    Mnmg_kg     6       33.66667       5.41975    30      DEF
```

```
---------------------------------- BYGROUP=79 Effect=Depth -----------------------------------

                                           Standard        Letter
 Obs     date     Dependent   Trt    LSMean         Error   Depth    Group

 599    JunJul07       N               0.10033        0.00335     10       A
 600    JunJul07       N               0.07693        0.00335     20       B
 601    JunJul07       N               0.07098        0.00335     30       B


----------------------------------- BYGROUP=80 Effect=Trt ------------------------------------

                                           Standard        Letter
 Obs     date     Dependent   Trt       LSMean        Error   Depth    Group

 602    JunJul07       N         1        0.08726        0.00747            AB
 603    JunJul07       N         2        0.09781        0.00747            A
 604    JunJul07       N         3        0.08167        0.00747            AB
 605    JunJul07       N         5        0.05700        0.01293            B
 606    JunJul07       N         6        0.09000        0.00747            AB


-------------------------------- BYGROUP=81 Effect=Trt_Depth ---------------------------------

                                             Standard         Letter
 Obs     date     Dependent   Trt       LSMean          Error   Depth    Group

 607    JunJul07       N        1       0.10500       0.00634     10      ABC
 608    JunJul07       N        1       0.08511       0.00634     20      DEF
 609    JunJul07       N        1       0.07167       0.00634     30      FG
 610    JunJul07       N        2       0.11122       0.00634     10      AB
 611    JunJul07       N        2       0.09167       0.00634     20      CDE
 612    JunJul07       N        2       0.09056       0.00634     30      CDEF
 613    JunJul07       N        3       0.09344       0.00634     10      BCD
 614    JunJul07       N        3       0.07456       0.00634     20      DEFG
 615    JunJul07       N        3       0.07700       0.00634     30      DEFG
 616    JunJul07       N        5       0.07556       0.01098     10      DEFG
 617    JunJul07       N        5       0.05333       0.01098     20      GH
 618    JunJul07       N        5       0.04211       0.01098     30      H
 619    JunJul07       N        6       0.11644       0.00634     10      A
 620    JunJul07       N        6       0.08000       0.00634     20      DEFG
 621    JunJul07       N        6       0.07356       0.00634     30      EFG
```

```
---------------------------------- BYGROUP=82 Effect=Depth -----------------------------------

                                              Standard        Letter
 Obs     date     Dependent    Trt          LSMean          Error   Depth   Group

 622    JunJul07    NO3_Nppm             13.26667       0.51884     10       A
 623    JunJul07    NO3_Nppm             10.11111       0.51884     20       B
 624    JunJul07    NO3_Nppm              9.55556       0.51884     30       B


----------------------------------- BYGROUP=83 Effect=Trt ------------------------------------

                                                  Standard        Letter
 Obs     date     Dependent        Trt          LSMean          Error     Depth   Group

 625    JunJul07    NO3_Nppm     1        18.40741       1.37624            A
 626    JunJul07    NO3_Nppm     2         8.48148       1.37624            BC
 627    JunJul07    NO3_Nppm     3        10.44444       1.37624            B
 628    JunJul07    NO3_Nppm     5        12.59259       2.38372            AB
 629    JunJul07    NO3_Nppm     6         4.96296       1.37624            C


-------------------------------- BYGROUP=84 Effect=Trt_Depth ---------------------------------

                                              Standard        Letter
 Obs     date     Dependent    Trt          LSMean          Error   Depth   Group

 630    JunJul07    NO3_Nppm     1        22.66667       0.98052     10      A
 631    JunJul07    NO3_Nppm     1        16.55556       0.98052     20      B
 632    JunJul07    NO3_Nppm     1        16.00000       0.98052     30      B
 633    JunJul07    NO3_Nppm     2        10.11111       0.98052     10      CD
 634    JunJul07    NO3_Nppm     2         8.00000       0.98052     20      DE
 635    JunJul07    NO3_Nppm     2         7.33333       0.98052     30      DEF
 636    JunJul07    NO3_Nppm     3        11.66667       0.98052     10      C
 637    JunJul07    NO3_Nppm     3        10.11111       0.98052     20      CD
 638    JunJul07    NO3_Nppm     3         9.55556       0.98052     30      CD
 639    JunJul07    NO3_Nppm     5        16.11111       1.69831     10      B
 640    JunJul07    NO3_Nppm     5        11.00000       1.69831     20      CD
 641    JunJul07    NO3_Nppm     5        10.66667       1.69831     30      CD
 642    JunJul07    NO3_Nppm     6         5.77778       0.98052     10      EFG
 643    JunJul07    NO3_Nppm     6         4.88889       0.98052     20      FG
 644    JunJul07    NO3_Nppm     6         4.22222       0.98052     30      G
```

```
---------------------------------- BYGROUP=94 Effect=Depth ----------------------------------

                                           Standard         Letter
  Obs     date      Dependent    Trt        LSMean           Error   Depth   Group

  714   JunJul07    Namg_kg                3.53333         0.12400    10      B
  715   JunJul07    Namg_kg                3.57778         0.12400    20      AB
  716   JunJul07    Namg_kg                3.93333         0.12400    30      A


----------------------------------- BYGROUP=95 Effect=Trt ------------------------------------

                                           Standard         Letter
  Obs     date      Dependent    Trt        LSMean           Error   Depth   Group

  717   JunJul07    Namg_kg       1         3.42593         0.35380           AB
  718   JunJul07    Namg_kg       2         3.07407         0.35380           B
  719   JunJul07    Namg_kg       3         3.11111         0.35380           B
  720   JunJul07    Namg_kg       5         4.46296         0.61279           AB
  721   JunJul07    Namg_kg       6         4.33333         0.35380           A


-------------------------------- BYGROUP=96 Effect=Trt_Depth ---------------------------------

                                           Standard         Letter
  Obs     date      Dependent    Trt        LSMean           Error   Depth   Group

  722   JunJul07    Namg_kg       1         3.27778         0.23433    10      EFG
  723   JunJul07    Namg_kg       1         3.27778         0.23433    20      EFG
  724   JunJul07    Namg_kg       1         3.72222         0.23433    30      CDE
  725   JunJul07    Namg_kg       2         3.05556         0.23433    10      EFG
  726   JunJul07    Namg_kg       2         2.72222         0.23433    20      G
  727   JunJul07    Namg_kg       2         3.44444         0.23433    30      DEF
  728   JunJul07    Namg_kg       3         3.05556         0.23433    10      EFG
  729   JunJul07    Namg_kg       3         3.00000         0.23433    20      FG
  730   JunJul07    Namg_kg       3         3.27778         0.23433    30      EFG
  731   JunJul07    Namg_kg       5         4.27778         0.40588    10      ABCD
  732   JunJul07    Namg_kg       5         4.72222         0.40588    20      AB
  733   JunJul07    Namg_kg       5         4.38889         0.40588    30      ABCD
  734   JunJul07    Namg_kg       6         4.00000         0.23433    10      BCD
  735   JunJul07    Namg_kg       6         4.16667         0.23433    20      ABC
  736   JunJul07    Namg_kg       6         4.83333         0.23433    30      A
```

```
---------------------------------- BYGROUP=106 Effect=Depth ----------------------------------

                                           Standard          Letter
 Obs    date     Dependent    Trt          LSMean            Error    Depth    Group

 806   JunJul07    Pmg_kg                  1.63333         0.06379     10       A
 807   JunJul07    Pmg_kg                  1.15556         0.06379     20       B
 808   JunJul07    Pmg_kg                  0.97778         0.06379     30       B


----------------------------------- BYGROUP=107 Effect=Trt -----------------------------------

                                           Standard          Letter
 Obs    date     Dependent    Trt          LSMean            Error    Depth    Group

 809   JunJul07    Pmg_kg      1           1.22222         0.20808             AB
 810   JunJul07    Pmg_kg      2           1.57407         0.20808             A
 811   JunJul07    Pmg_kg      3           1.61111         0.20808             A
 812   JunJul07    Pmg_kg      5           0.53704         0.36040             B
 813   JunJul07    Pmg_kg      6           1.33333         0.20808             AB


-------------------------------- BYGROUP=108 Effect=Trt_Depth --------------------------------

                                           Standard          Letter
 Obs    date     Dependent    Trt          LSMean            Error    Depth    Group

 814   JunJul07    Pmg_kg      1           1.72222         0.12055     10       AB
 815   JunJul07    Pmg_kg      1           1.05556         0.12055     20       FG
 816   JunJul07    Pmg_kg      1           0.88889         0.12055     30       GH
 817   JunJul07    Pmg_kg      2           1.88889         0.12055     10       A
 818   JunJul07    Pmg_kg      2           1.55556         0.12055     20       ABCD
 819   JunJul07    Pmg_kg      2           1.27778         0.12055     30       CDEF
 820   JunJul07    Pmg_kg      3           1.88889         0.12055     10       A
 821   JunJul07    Pmg_kg      3           1.50000         0.12055     20       BCD
 822   JunJul07    Pmg_kg      3           1.44444         0.12055     30       BCDE
 823   JunJul07    Pmg_kg      5           1.05556         0.20880     10       DEFG
 824   JunJul07    Pmg_kg      5           0.38889         0.20880     20       HI
 825   JunJul07    Pmg_kg      5           0.16667         0.20880     30       I
 826   JunJul07    Pmg_kg      6           1.61111         0.12055     10       ABC
 827   JunJul07    Pmg_kg      6           1.27778         0.12055     20       CDEF
 828   JunJul07    Pmg_kg      6           1.11111         0.12055     30       EFG
```

```
---------------------------------- BYGROUP=109 Effect=Depth ----------------------------------

                                              Standard        Letter
  Obs    date     Dependent   Trt      LSMean          Error   Depth   Group

  829   JunJul07    SoilpH             5.14222      0.01784   10       A
  830   JunJul07    SoilpH             5.14667      0.01784   20       A
  831   JunJul07    SoilpH             5.17778      0.01784   30       A


----------------------------------- BYGROUP=110 Effect=Trt -----------------------------------

                                              Standard        Letter
  Obs    date     Dependent   Trt      LSMean          Error   Depth   Group

  832   JunJul07    SoilpH     1       4.86667      0.20936            B
  833   JunJul07    SoilpH     2       5.07407      0.20936            AB
  834   JunJul07    SoilpH     3       5.26667      0.20936            AB
  835   JunJul07    SoilpH     5       4.93704      0.36262            AB
  836   JunJul07    SoilpH     6       5.63333      0.20936            A


-------------------------------- BYGROUP=111 Effect=Trt_Depth --------------------------------

                                              Standard        Letter
  Obs    date     Dependent   Trt      LSMean          Error   Depth   Group

  837   JunJul07    SoilpH     1       4.84444      0.03372    10      F
  838   JunJul07    SoilpH     1       4.88889      0.03372    20      EF
  839   JunJul07    SoilpH     1       4.86667      0.03372    30      F
  840   JunJul07    SoilpH     2       5.08889      0.03372    10      C
  841   JunJul07    SoilpH     2       5.02222      0.03372    20      CD
  842   JunJul07    SoilpH     2       5.11111      0.03372    30      C
  843   JunJul07    SoilpH     3       5.22222      0.03372    10      B
  844   JunJul07    SoilpH     3       5.28889      0.03372    20      B
  845   JunJul07    SoilpH     3       5.28889      0.03372    30      B
  846   JunJul07    SoilpH     5       4.85556      0.05840    10      EF
  847   JunJul07    SoilpH     5       4.93333      0.05840    20      DEF
  848   JunJul07    SoilpH     5       5.02222      0.05840    30      CDE
  849   JunJul07    SoilpH     6       5.70000      0.03372    10      A
  850   JunJul07    SoilpH     6       5.60000      0.03372    20      A
  851   JunJul07    SoilpH     6       5.60000      0.03372    30      A
```

```
---------------------------------- BYGROUP=112 Effect=Depth ----------------------------------

                                              Standard          Letter
 Obs     date      Dependent    Trt         LSMean           Error    Depth    Group

 852    JunJul07    Total_BS               35.17778        0.86776     10       A
 853    JunJul07    Total_BS               31.77778        0.86776     20       B
 854    JunJul07    Total_BS               31.86667        0.86776     30       B

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----------------------------------- BYGROUP=113 Effect=Trt -----------------------------------

                                              Standard          Letter
 Obs     date      Dependent    Trt         LSMean           Error    Depth    Group

 855    JunJul07    Total_BS     1          30.81481        6.07611             A
 856    JunJul07    Total_BS     2          32.37037        6.07611             A
 857    JunJul07    Total_BS     3          33.81481        6.07611             A
 858    JunJul07    Total_BS     5          26.74074       10.52412             A
 859    JunJul07    Total_BS     6          40.96296        6.07611             A


-------------------------------- BYGROUP=114 Effect=Trt_Depth --------------------------------

                                              Standard          Letter
 Obs     date      Dependent    Trt         LSMean           Error    Depth    Group

 860    JunJul07    Total_BS     1          33.00000        1.63991     10      CDE
 861    JunJul07    Total_BS     1          30.33333        1.63991     20      DEF
 862    JunJul07    Total_BS     1          29.11111        1.63991     30      EF
 863    JunJul07    Total_BS     2          34.22222        1.63991     10      BCD
 864    JunJul07    Total_BS     2          29.77778        1.63991     20      DEF
 865    JunJul07    Total_BS     2          33.11111        1.63991     30      CDE
 866    JunJul07    Total_BS     3          32.66667        1.63991     10      CDE
 867    JunJul07    Total_BS     3          34.44444        1.63991     20      BCD
 868    JunJul07    Total_BS     3          34.33333        1.63991     30      BCD
 869    JunJul07    Total_BS     5          28.44444        2.84041     10      DEF
 870    JunJul07    Total_BS     5          25.22222        2.84041     20      F
 871    JunJul07    Total_BS     5          26.55556        2.84041     30      EF
 872    JunJul07    Total_BS     6          47.55556        1.63991     10      A
 873    JunJul07    Total_BS     6          39.11111        1.63991     20      B
 874    JunJul07    Total_BS     6          36.22222        1.63991     30      BC
```

```
---------------------------------- BYGROUP=121 Effect=Depth ----------------------------------

                                            Standard        Letter
 Obs     date      Dependent    Trt          LSMean          Error   Depth   Group

 921    JunJul07    Znmg_kg                 1.65667        0.20224    10      A
 922    JunJul07    Znmg_kg                 0.98222        0.20224    20      B
 923    JunJul07    Znmg_kg                 0.86333        0.20224    30      B


----------------------------------- BYGROUP=122 Effect=Trt -----------------------------------

                                            Standard        Letter
 Obs     date      Dependent    Trt          LSMean          Error   Depth   Group

 924    JunJul07    Znmg_kg      1           0.96111        0.39218          A
 925    JunJul07    Znmg_kg      2           1.55000        0.39218          A
 926    JunJul07    Znmg_kg      3           1.09630        0.39218          A
 927    JunJul07    Znmg_kg      5           0.79815        0.67927          A
 928    JunJul07    Znmg_kg      6           1.43148        0.39218          A


-------------------------------- BYGROUP=123 Effect=Trt_Depth --------------------------------

                                            Standard        Letter
 Obs     date      Dependent    Trt          LSMean          Error   Depth   Group

 929    JunJul07    Znmg_kg      1           1.46667        0.38220    10     ABC
 930    JunJul07    Znmg_kg      1           0.77222        0.38220    20     C
 931    JunJul07    Znmg_kg      1           0.64444        0.38220    30     C
 932    JunJul07    Znmg_kg      2           2.07222        0.38220    10     AB
 933    JunJul07    Znmg_kg      2           1.32778        0.38220    20     BC
 934    JunJul07    Znmg_kg      2           1.25000        0.38220    30     BC
 935    JunJul07    Znmg_kg      3           1.23333        0.38220    10     BC
 936    JunJul07    Znmg_kg      3           1.03889        0.38220    20     BC
 937    JunJul07    Znmg_kg      3           1.01667        0.38220    30     BC
 938    JunJul07    Znmg_kg      5           1.01111        0.66199    10     ABC
 939    JunJul07    Znmg_kg      5           0.67222        0.66199    20     BC
 940    JunJul07    Znmg_kg      5           0.71111        0.66199    30     BC
 941    JunJul07    Znmg_kg      6           2.50000        0.38220    10     A
 942    JunJul07    Znmg_kg      6           1.10000        0.38220    20     BC
 943    JunJul07    Znmg_kg      6           0.69444        0.38220    30     C
```

Appendix E.

Soil testing results for thermal treatment and depth combinations. Main effect means of thermal treatments and means are also included. Means with similar letters are not significantly different based on Fisher's protected LSD (α=0.05) (Summer 2007)

Soil chemical properties	Soil depth (cm)	Complete	One-week interval	Four-week interval	Disturbed bare soil Control	Live kudzu Control	Depth Effect
Soil pH	0-10	4.84(0.03)F	5.09(0.03)C	5.22(0.33)B	4.85(0.06)EF	5.70(0.03)A	5.14(0.02)A
	10-20	4.88(0.03)EF	5.02(0.03)CD	5.29(0.03)B	4.93(0.06)DEF	5.60(0.03)A	5.15(0.02)A
	20-30	4.86(0.03)F	5.11(0.03)C	5.29(0.03)B	5.02(0.06)CDE	5.60(0.03)A	5.17(0.02)A
		4.87(0.21)B	5.07(0.21)AB	5.26(0.21)AB	4.94(0.36)AB	5.63(0.21)A	
C (%)	0-10	1.10(0.08) AB	1.25(0.08) A	1.07(0.08)ABC	1.22(0.14)AB	1.28(0.08)A	1.18(0.04)A
	10-20	0.72(0.08) EFG	0.95(0.08)BCDE	0.89(0.08)BCDE	0.54(0.14)FGH	0.75(0.08)DEFG	0.76(0.04)B
	20-30	0.58(0.08) GH	0.97(0.08)BCD	0.85(0.08)CDEF	0.37(0.14)H	0.59(0.08)GH	0.67(0.04)B
		0.80(0.11) A	1.05(0.11)A	0.93(0.11)A	0.71(0.19)A	0.88(0.11)A	
N (%)	0-10	0.11(0.01)ABC	0.11(0.01)AB	0.09(0.01)BCD	0.08(0.01)DEFG	0.12(0.01)A	0.10(0.003)A
	10-20	0.09(0.01)DEF	0.09(0.01)CDE	0.07(0.01)DEFG	0.05(0.01)GH	0.08(0.01)DEFG	0.08(0.003)B
	20-30	0.07(0.01)FG	0.09(0.01)CDEF	0.08(0.01)DEFG	0.04(0.01)H	0.07(0.01)EFG	0.07(0.003)B
		0.09(0.01)AB	0.10(0.01)A	0.08(0.01)AB	0.06(0.01)B	0.09(0.01)AB	
C/N	0-10	10.30(0.51)BCD	11.35(0.51)BC	11.73(0.51)B	15.47(0.88)A	10.92(0.51)BC	11.95(0.27)A
	10-20	8.36(0.51)EF	10.66(0.51)BCD	11.67(0.51)B	10.26(0.88)BCDE	9.33(0.51)DEF	10.05(0.27)B
	20-30	8.18(0.51)EF	11.02(0.51)BC	11.18(0.51)BC	9.28(0.88)CDEF	7.98(0.51)F	9.52(0.27)B
		8.95(1.22)A	11.01(1.22)A	11.52(1.22)A	11.67(2.11)A	9.41(1.22)A	
NO_3-N (ppm)	0-10	22.66(0.98)A	10.11(0.98)CD	11.66(0.98)C	16.11(1.70)B	5.77(0.98)EFG	13.26(0.52)A
	10-20	16.55(0.98)B	8.00(0.98)DE	10.11(0.98)CD	11.00(1.70)CD	4.88(0.98)FG	10.11(0.52)B
	20-30	16.00(0.98)B	7.33(0.98)DEF	9.55(0.98)CD	10.66(1.70)CD	4.22(0.98)G	9.55(0.51)B
		18.41(1.38)A	8.48(1.38)BC	10.44(1.38)B	12.59(2.38)AB	4.96(1.38)C	

P (mg kg^{-1})	0-10	1.72(0.12)AB	1.88(0.12)A	1.88(0.12)A	1.05(0.21)DEFG	1.61(0.12)ABC	1.63(0.06)A
	10-20	1.05(0.12)FG	1.55(0.12)ABCD	1.50(0.12)BCD	0.38(0.21)HI	1.27(0.12)CDEF	1.15(0.06)B
	20-30	0.88(0.12)GH	1.27(0.12)CDEF	1.44(0.12)BCDE	0.16(0.21)I	1.11(0.12)EFG	0.97(0.06)B
		1.22(0.21)AB	1.57(0.21)A	1.61(0.21)A	0.54(0.36)B	1.33(0.21)AB	
K (mg kg^{-1})	0-10	78.66(3.21)ABC	76.88(3.21)ABC	81.22(3.21)AB	65.94(5.56)CD	65.22(3.21)D	73.58(1.70)A
	10-20	79.44(3.21)ABC	78.88(3.21)ABC	86.33(3.21)A	53.27(5.56)DE	63.00(3.21)D	72.18(1.70)A
	20-30	76.16(3.21)BC	85.00(3.21)AB	85.16(3.21)AB	44.38(5.56)E	58.61(3.21)D	69.86(1.70)A
		78.09(7.06)A	80.26(7.06)A	84.24(7.06)A	54.53(12.22)A	62.27(7.06)A	
Ca (mg kg^{-1})	0-10	256.00(23.44)CDE	287.83(23.44)BCD	264.83(23.44)CDE	201.94(40.60)DEF	513.88(23.44)A	304.9(12.40)A
	10-20	212.61(23.44)EF	215.83(23.44)EF	256.77(23.44)CDE	140.55(40.60)F	344.83(23.44)B	234.12(12.40)B
	20-30	205.05(23.44)EF	269.00(23.44)CDE	255.27(23.44)CDE	128.00(40.60)F	315.83(23.44)BC	234.63(12.40)B
		224.55(71.34)A	257.55(71.34)A	258.96(71.34)A	156.83(123.57)A	391.51(71.34)A	
Mg (mg kg^{-1})	0-10	44.11(3.44)E	44.11(3.44)E	44.55(3.44)E	59.72(5.96)BCD	46.16(3.44)DE	47.73(1.82)B
	10-20	46.66(3.44)CDE	45.22(3.44)DE	50.72(3.44)BCDE	64.05(5.96)AB	47.38(3.44)CDE	50.81(1.82)AB
	20-30	44.66(3.44)E	56.94(3.44)BC	47.38(3.44)CDE	78.22(5.96)A	44.94(3.44)E	54.43(1.82)A
		45.14(6.42)A	48.76(6.42)A	47.55(6.42)A	67.33(11.11)A	46.16(6.42)A	
Zn (mg kg^{-1})	0-10	1.46(0.38)ABC	2.07(0.38)AB	1.23(0.38)BC	1.01(0.66)ABC	2.50(0.38)A	1.65(0.20)A
	10-20	0.77(0.38)C	1.32(0.38)BC	1.04(0.38)BC	0.67(0.66)BC	1.10(0.38)BC	0.98(0.20)B
	20-30	0.64(0.38)C	1.25(0.38)BC	1.02(0.38)BC	0.71(0.66)BC	0.69(0.38)C	0.86(0.20)B
		0.96(0.39)A	1.55(0.39)A	1.09(0.39)A	0.79(0.67)A	1.43(0.39)A	

Mn (mg kg^{-1})	0-10	58.55(5.42)BC	65.38(5.42)AB	75.27(5.42)A	20.05(9.38)FGH	29.66(5.42)EFG	46.78(2.86)A
	10-20	46.11(5.42)CD	58.22(5.42)BC	67.44(5.42)AB	7.61(9.38)GH	31.94(5.42)DEF	42.26(2.86)A
	20-30	43.05(5.42)CDE	64.33(5.42)AB	68.16(5.42)AB	5.00(9.38)H	33.66(5.42)DEF	42.84(2.86)A
		49.24(16.80)A	62.64(16.80)A	70.30(16.80)A	10.88(29.09)A	31.76(16.79)A	
Cu (mg kg^{-1})	0-10	1.24(0.07)A	1.16(0.07)A	1.26(0.07)A	0.78(0.12)B	1.14(0.07)A	1.12(0.04)A
	10-20	1.22(0.07)A	1.28(0.07)A	1.18(0.07)A	0.83(0.12)B	1.25(0.07)A	1.15(0.04)A
	20-30	1.16(0.07)A	1.26(0.07)A	1.15(0.07)A	0.82(0.12)B	1.13(0.07)A	1.11(0.04)A
		1.21(0.07)A	1.24(0.07)A	1.20(0.07)A	0.81(0.12)B	1.17(0.07)A	
B (mg kg^{-1})	0-10	0.26(0.01)ABCDE	0.27(0.01)ABC	0.27(0.01)ABCD	0.23(0.02)BCDEF	0.28(0.01)AB	0.26(0.01)A
	10-20	0.22(0.01)DEF	0.27(0.01)ABC	0.26(0.01)ABCDE	0.20(0.02)EFG	0.22(0.01)DEF	0.24(0.01)B
	20-30	0.21(0.01)FG	0.30(0.01)A	0.23(0.01)CDEF	0.15(0.02)G	0.21(0.01)FG	0.22(0.01)B
		0.23(0.02)A	0.28(0.02)A	0.25(0.02)A	0.20(0.04)A	0.24(0.02)A	
Na (mg kg^{-1})	0-10	3.27(0.23)EFG	3.05(0.23)EFG	3.05(0.23)EFG	4.27(0.41)ABCD	4.00(0.23)BCD	3.53(0.12)B
	10-20	3.27(0.23)EFG	2.72(0.23)G	3.00(0.23)FG	4.72(0.41)AB	4.16(0.23)ABC	3.58(0.12)AB
	20-30	3.72(0.23)CDE	3.44(0.23)DEF	3.27(0.23)EFG	4.38(0.41)ABCD	4.83(0.23)A	3.93(0.12)A
		3.42(0.35)AB	3.07(0.35)B	3.11(0.35)B	4.46(0.61)AB	4.33(0.35)A	
Total base sat. (%)	0-10	33.00(1.64)CDE	34.22(1.64)BCD	32.66(1.64)CDE	28.44(2.84)DEF	47.55(1.64)A	35.17(0.86)A
	10-20	30.33(1.64)DEF	29.77(1.64)DEF	34.44(1.64)BCD	25.22(2.84)F	39.11(1.64)B	31.77(0.86)B
	20-30	29.11(1.64)EF	33.11(1.64)CDE	34.33(1.64)BCD	26.55(2.84)EF	36.22(1.64)BC	31.86(0.86)B
		30.81(6.10)A	32.37(6.10)A	33.81(6.10)A	26.74(10.52)A	40.96(6.10)A	

ECEC (meq 100 g^{-1})	0-10	5.67(0.15)BC	5.77(0.15)BC	5.86(0.15)BC	5.83(0.25)ABC	6.44(0.15)A	5.92(0.07)A
	10-20	5.50(0.15)C	5.54(0.15)C	5.62(0.15)C	5.50(0.25)BC	5.81(0.15)BC	5.59(0.07)B
	20-30	5.52(0.15)C	6.08(0.15)AB	5.58(0.15)C	5.42(0.25)C	5.76(0.15)BC	5.67(0.07)B
		5.56(0.24)A	5.80(0.24)A	5.69(0.24)A	5.59(0.41)A	6.00(0.24)A	
Acidity (meq 100 g^{-1})	0-10	3.82(0.12)ABC	3.77(0.12)ABC	3.95(0.12)AB	4.13(0.20)AB	3.29(0.12)D	3.79(0.06)A
	10-20	3.82(0.12)ABC	3.86(0.12)AB	3.69(0.12)BC	4.10(0.20)AB	3.51(0.12)CD	3.79(0.06)A
	20-30	3.91(0.12)AB	4.04(0.12)A	3.69(0.12)BC	4.00(0.20)ABC	3.64(0.12)BC	3.85(0.06)A
		3.85(0.32)A	3.90(0.32)A	3.77(0.32)A	4.07(0.56)A	3.48(0.32)A	