IMPACT OF SLASH PILE BURNING ON PHYSICAL/CHEMICAL CHARACTERISTICS OF SOIL IN THE PONDEROSA PINE (*PINUS PONDEROSA*) FOREST TYPE

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Abstract

This paper presents a preliminary analysis of data on soil characteristics that could affect native and non-native floral species establishment following slash pile burns associated with restoration thinning treatments. Changes in species establishment could result in habitat reduction for native fauna, and have broad implications for ecological functions, processes, and management. The soil characteristics measured after the slash pile burns include levels of soil nutrients (N, P, K, Ca, Mg, Na and three micro-nutrients), and water infiltration rates. These characteristics were used to compare burned plots with plots where slash was removed by chipping, as well as with control plots.

Ten replicates were constructed, each consisting of four large piles and four small piles for a total of eight piles per replicate. Both size classes include burned and unburned slash piles. This creates a suite of conditions affecting post burn soil characteristics. We expect burned slash pile plots to have higher soil nutrient levels overall. Formation of a hydrophobic layer caused by intense heat that bakes the organic material is expected to accompany an increase in fine particles and result in a slower water infiltration rate. Further, these changes in burned soils should increase with increased slash pile size. To date, four replications have complete nutrients and infiltration data. Thus this preliminary report shall present only the findings from those four replicates.

Introduction

Forest restoration throughout the Intermountain West has become a paramount interest to researchers and managers recently. However, one unforeseen aspect of the effort to thin the forests and rekindle approximately the historic fire regime is that exotic species of herbaceous flora seem to invade more successfully. Burning slash piles associated with forest thinning prescriptions could usher in an invasion of exotic species of flora by creating especially vulnerable sites. Changes in species and subsequent community establishment would likely result in habitat reduction for native fauna, and have broad implications for ecological functions, processes, and management. This study will evaluate soil characteristics that could affect native and non-native floral species

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establishment following the slash pile burns associated with restoration thinning treatments, as well as the changes (if any) in plant community after slash pile burns.

Forest restoration in much of the southwest involves thinning of trees to reduce fuel loads of forested areas before fire is reintroduced in the form of prescribed burns or natural fires such as those originating from lightening strikes (Covington et al. 1997; U.S.F.S. 1998). Treating forest restoration sites to prevent invasion of exotic herbaceous flora has recently become an additional expense to this restoration process (Loope and Stone 1996). The practice of forest thinning for harvesting or restoration creates large amounts of unmarketable debris. This unmarketable debris, or slash, is often piled and removed through chipping or burning (Smith et al. 1997). According to The Grand Canyon Forests Partnership, using fire as a tool to consume slash is thought by some to be the appropriate method since fire historically consumed the dead fallen branches that comprise the majority of slash piles (U.S.F.S. 1998). Burning slash piles also fertilizes the soil at that site by reducing slash to wood ash, which is high in readily available forms of potassium, magnesium, calcium, and phosphorus (Brady and Weil 1996). Other factors such as removal of vegetation, and heating of the soil also affect the microclimate and help to create conditions ripe for exotic plant invasion (Smith et al. 1997).

The suspicion that burning slash piles could enhance or accelerate the process of exotic invasion has some backing in the literature. One of the first studies of exotic species response to burning occurred in a woodland region in Southwestern Australia. Burning along roadsides increased not only the number of weedy species such as *Eragrostis curula* and *Ehrharta calycina*, but their frequency and cover as well (Milberg and Lamont 1995). Even seven years after fires, the impacts on vegetation were still evident while the unburned control areas were almost unchanged (Milberg and Lamont 1995). Another study by Milberg and Lamont in Western Australia (1999) indicated that the five exotic species studied responded "more positively to higher nutrient additions than the native species." Therefore, exotics might have a competitive advantage in nutrient enhanced situations such as after a fire.

Objectives

Burning slash piles associated with forest thinning prescriptions could usher in an invasion of exotic species of flora by creating especially vulnerable sites. This study will be the first to investigate the concern of exotic invasion that has been expressed by various organizations including some members of the Arboretum at Flagstaff, Northern Arizona Weed Council, U.S. Forest Service, and the School of Forestry and Ecological Restoration Institute at Northern Arizona University (personal communications). This study will also assess the impacts of slash plies in relation to pile size. Currently in the Flagstaff area two sizes of hand-piled slash piles are built. The piles within the U.S.F.S. Peaks Ranger District tend to be smaller, less than five feet high. While the piles in the U.S.F.S. Mormon Lake Ranger District tend to be larger and wider, in excess of ten feet wide and at least six feet tall.

We expect that the burned slash pile plots will have higher soil nutrient levels overall, with larger piles having higher levels than the smaller piles, indicating some kind of fertilization effect from the burns. We also expect slower water infiltration in the burned soils due to increased amount of fines in the soil and formation of a hydrophobic layer caused by intense heat baking the organic material.

This study will not look into mechanically built slash piles because much of the restoration burning currently in the Flagstaff Urban/ Forest Interface is hand pile burns being conducted by the Flagstaff Fuels Management Team of the fire department. Further more, heavy equipment would be severely detrimental to the arboretum grounds and contrary to the mission of restoration.

Study Area

The study occurred on the grounds of The Arboretum at Flagstaff, approximately 6 miles west of Flagstaff, AZ within the ponderosa pine (*Pinus ponderosa*)/Arizona fescue (*Festuca arizonica*) type forest. The slash piles were constructed from ponderosa pine slash material that exists on the forested grounds of The Arboretum at Flagstaff. The slash piles are remains of a forest restoration thinning that occurred in 1999, in which approximately one third of the overall basal area was removed. An important note is that the burning of these piles occurred in conjunction with further thinning in August 2001 by Flagstaff Fuels Management, in which an addition third of the original basal area was removed. These piles were constructed from various sizes of slash, including needle litter, branches, and poles that were too small (less than 6") to be removed by the harvesting crew. These slash sizes were grouped into classes and the percentage of piles made up by each size class was determined by measuring slash piles at the NAU Ecological Restoration Institute and the School of Forestry's research area in Fort Valley outside of Flagstaff, AZ. This process allows all slash piles to be constructed in a similar manner on the Arboretum sites.

Methods

Prior to burning the slash piles, plant coverage and locations were mapped using six cross-sections for large slash pile plots and four cross-sections for the small plots. This mapping allows for calculations of baseline percent cover, relative abundance, and species composition from which the future vegetation community can be compared. Ten replicates were then constructed, each consisting of four large piles and four small piles for a total of eight piles per replicate. To date, four of these replications have complete data. Each size class has four treatments (one treatment per size pile): unburned, burned, burned then seeded, and burned then planted with propagules. These treatments, along with control plots, create the suite of conditions affecting the post burn characteristics. The soil samples were taken as monoliths near the center of the plot using hand shovels marked with centimeter lines to allow for accurate measuring. Infiltration rates were also tested near the center of the plot using a double-ring infiltrometer following the sampling of soils. The information obtained is used to determine whether the soils have been hydrophobically sealed by the burning process, and if so, to what extent.

Treatments

Ten replicates, each having similar slope, aspect, and tree density conditions were selected for this study. Each replicate consists of four large piles and four small piles for a total of eight piles per replicate. Each size class has four treatments (one treatment per size pile): unburned, burned, burned then seeded, and burned then planted with propagules. Consequently within each replicate, one large and one small pile receive each treatment. The treatments were assigned randomly to the large and small piles within each block (replicate). The piles within each replicate are placed in close proximity to each other whereas the replicates themselves spread throughout the forested area owned by The Arboretum at Flagstaff.

Burning of piles started at the first opportunity for safe burning conditions during the monsoon period in late summer (August 2001). The exact days and times were established by conferring with the Flagstaff City Fuels Manager. During the monsoon period, we were able to safely burn eight of the ten replicates. Half of the burn piles (3 piles) were burned in replicate number seven, but for safety concerns we were forced to cease burning until a series of rain events created safe conditions. Safe conditions returned in early October. At this time, we burned the remaining piles in replicate number seven and burned all of replicate number one. Thus completing all of the burns for the study. The slash on the unburned plots was manually removed at the same time the burning took place (unburned slash in replicate number seven was removed during the completion of the burn in October). After the fires were officially out and the soils had cooled off (10 days), Festuca arizonica seed was broadcast across two (one small and one large) of the six burned plots within each replicate. This decision was made during the monsoonal burns in an effort to capitalize on the moist soils as well as the natural seeding time.

Field Measurements

Prior to constructing the slash piles, plot sites were randomly assigned within the parameters of safe burn sites (i.e. sites directly below or immediately upwind of tree canopies, or sites in close proximity to other slash piles were not used). The vegetation within the plot sites was then mapped. This study involves two sizes of slash piles and consequently two plot sizes. Plant coverage and locations were assessed using six cross-sections for large plots and four cross-sections for small plots. The cross sections, created using metric tapes helped to guide the placement of plants on the maps, as well as indicating the sizes of the plants. This mapping allows for calculations of baseline percent cover, relative abundance, and species composition to which the future vegetation community can be compared. Once the mapping was complete, two sizes of slash piles were constructed. Small piles are four feet high by eight feet in diameter, while large piles stand six feet high, 12 feet wide and 16 feet long forming an oval or oblong shape. Slash from existing piles (from the 1999 thinning) was used to construct the new experimental piles on those sites whose vegetation had been mapped.

After the piles had burned and cooled, and immediately prior to seeding and planting the propagules, soil from every plot was sampled. The samples were taken from near the center of each plot. The soil samples were taken as monoliths using hand shovels marked with cm lines to allow accurate measurement. These monoliths were taken from a depth of three cm in the soil and their dimension was three cm thick and approximately ten cm square. These samples were tested for levels of total nutrients (N, P, K, Mg, Ca, Mn, Fe, Zn, and Na). The samples were ground using an aluminum-ceramic mortar and pestle. After grinding, the samples were oven dried overnight at 105 C. and 0.5 gram (±0.025) was weighed into each beaker for digestion.

In the field, infiltration rates were tested using a double-ring infiltrometer following the sampling of soils. Infiltration was measured in the burned, unburned, and control plots in the study. Infiltration tests also took place near the center of the plot but not adjacent to the soil sampling site. This information is used to determine whether or not burning has any effect on soil infiltration capacity.

Lab Measurements

Soil samples were reduced to approximately one gram using a method of mixing the sample and dividing it in half and repeating the mixing and dividing until achieving the sample weight. The one-gram samples from each plot were then combined into composites. The composite groups consist of samples from large and small piles for each of the four treatments, and a control. Each composite group contains sample material from either replicates 1,2,3, replicates 4,5,6, or replicates 7,8,9,10. Henceforth, these groups of replicates are referred to as Group I, Group II, and Group III respectively. Two size classes of three replicate groups and four treatments each, plus three composite samples for the control plots create 27 composite samples. The replicates are combined into these groups in accordance with their similarities with respect to canopy cover, slopes, proximity to other replicates, rockiness and vegetation cover. Since this paper only presents information from replicates 4,6,9,and 10, Group I is not included in the analysis.

The composite samples were dried overnight at 105° C. then reduced to one gram using the same methods as individual sampling above to prepare them for precise weighing into volumetric flasks. A Composite sample weighing 0.9500 (± 0.0250) grams was placed into 100 ml volumetric flasks.

Under a fume hood, 10 ml of concentrated nitric acid (18 M.) was added to each of the flasks. The flasks were heated on hot plates to boil the nitric acid / soil sample solution for 1 hour until all the nitrous oxide fumes had dissipated from the flasks. The flasks were allowed to cool. Five (5) ml. of hydrogen peroxide (H_2O_2) was then added to each flask to recharge the oxygen component, and the flasks were boiled again for an hour until the nitrous oxide fumes had dissipated. The hydrogen peroxide procedure was repeated once more. After cooling, the flasks were filled to 100 ml with distilled, de-ionized water, inverted 20 times, and left to settle overnight before measuring the sample. An atomic absorption flame spectrometer measured the elements within the sample solution.

Results

This study analyzes the impacts that two different sizes of slash pile burnings have on soil nutrients and other characteristics. These slash pile sizes, as well as burned and unburned treatments were described previously. Also, the data were compared to those in plots where the slash piles were removed by chipping, as well as with control sites.

Preliminary analysis of the data suggests that the large and small burned piles appear to have no appreciable differences in nutritional content. It does appear however that burned piles tend to have higher nutrient availability than the controls. The amounts of Ca, K, Zn, and Na in Figures 1,2,3,4 displayed this pattern, while Fe, Mg, and Mn in Figures 5,6,7 did not support this trend. The trends in the amounts of nitrogen and phosphorus in Figures 8 – 12 are mixed, with some replicates supporting this pattern and other not supporting it. Potassium in Figure 2 was expected to have obvious and distinct changes between unburned and control plots, and burned plots. The burned plots do seem to have larger levels of Group II K than the control plots. However K levels from the large unburned plots of GroupII spiked high and undermined the expected outcome by making the unburned plots to have similar levels of K as the burned. Generally, calcium and potassium appear to have higher values in the burned sites than in the unburned or control sites. The amount of sodium seems higher in the burned plots than in the control plots, but not appreciably higher than in the unburned slash pile plots (Figure 5). According to nutrient balancing conducted by Geraldson (1984), the levels of sodium are low but still within the adequate range for plant growth.

Total phosphorous appears higher in the small plots than in the large burned plots except in replicate 4 were the small plot has similar P to that of the large plot. While appreciably different values of N and P did exist when comparing treated piles to the other treatments or control piles across the replications, the results do not seem to create any distinct patterns overall. Further, replicates 10 and 4 in Figures 8 and 11, displayed consistently higher values of total phosphorous compared to nitrogen. This pattern also does not hold true with replicates 6 and 9 as shown in Figures 9 and 10.

With respect to infiltration capacity across the different treatments, there seems to be no distinct differences between treatments (Figures 12 – 15). This indicates the absences of any significant formation of hydrophobic layers in the soils. The only pattern observed is a high initial infiltration rate that reduces to a constant rate within a short period of about 15 minutes. Typically, the infiltration rate becomes constant at about 2 liters/hour.

Based on the preliminary evidence, it appears that burning of slash piles does not result in appreciably higher nutrient levels overall. Burning also does not seem to create hydrophobic layer in the soil. However, since the amount of precipitation has been historically low, it is possible that the hydrophobic layer has not yet formed and that future precipitation will draw the hydrophobic compounds lying on or near the surface, into the ground to form such a layer. Although it is also quite possible that the slash pile fires burned hot enough (in excess of 460° C.) to break down and consume all of the organic material in the plots. This would prohibit the formation of any hydrophobic layer since hydrophobic compounds are organic materials that can readily burn under very high temperatures.

Conclusion

The goal of thinning the forest area at the Arboretum and the subsequent burning of the slash piles was to reduce wildfire risk and promote or restore understory health. These reasons are the same for all burning practices throughout several regions of the U.S. However, we must be careful regarding the flora that revegetates the post burn areas. Invasion by cheatgrass (*Bromus tectorum*) may increase the occurrence of annual fires due to its early seeding and very low moisture content during the summer months. Other species such as dalmatian toadflax (Linaria dalmatica), scotch thistle (Onopurdum acanthyum) and woolly mullein (verbascum thapsus) can dramatically alter the understory and ultimately the composition, structure, and function of the forest. For these reasons, the soil properties and infiltration rates are important factors in understanding the re-establishment of native species or the encroachment of exotics.

Given the original goal of thinning the forest and removing fuels for wildfires, and based on this initial data, we would recommend burning slash piles to reduce their presence as opposed to chipping or leaving them on site. This preliminary opinion is based on the fact that calcium and potassium appear to be somewhat higher in the burned sites, while most of the other nutrients do not show any truly appreciable differences between treatments. Consequently, vegetation might benefit somewhat from the marginal increases in calcium and potassium while there should not be any deleterious effects from the other nutrients measured in the plots.

The major limitation of this paper is that material is based on preliminary analysis of partial data in the study. Once complete sets of data are obtained and analyzed, the trends may change or be enhanced. Having said that however, based on this initial information, any changes in vegetation (yet unmeasured) may very likely be due to some other mechanism apart from the physical/chemical changes in the soil. Hopefully when the vegetative regrowth is analyzed that data will yield some relevant pieces of information that may help piece the picture together.

Literature Cited

Brady, Nyle C., Ray R.Weil. The Nature and Properties of Soils, eleventh edition. Prentice Hall, New Jersey, 1996. pp. 446-486.

Covington, Wallace W., DeBano, Leonard F., Huntsberger, Thomas G. Soil Nitrogen Changes Associated with Slash Pile Burning in Pinyon-Juniper Woodlands. Forest Science, vol. 37(1), 1991. 347-355.

Geraldson, C.M. Nutrient Intensity and Balance. *In*, Stelly, Matthias. Soil Testing: Correlating and Interpreting the Analytical Results, ASA Special Publication Number 29. American Society of Agronomy. Madison, Wisconsin. 1984.

Loope, Loyde L., Charles P. Stone. Strategies to Reduce Erosion of Biodiversity by Exotic Terrestrial Species. *In:* Biodiversity in Managed Landscapes. 1996. pp. 261-279.

Milberg, P., B.B. Lamont. Fire Enhances Weed Invasion of Roadside Vegetation in Southwestern Australia. Biological Conservation. 1995. vol. 73: 1, 45-49.

Milberg, P., B.B. Lamont, Survival and Growth of Native and Exotic Composition in Response to a Nutrient Gradient. Plant Ecology, 1999. vol. 145, no.1, pp. 125-132.

Smith, David M., Bruce C. Larson, Matthew J. Kelty, P. Mark S. Ashton. The Practice of Silviculture: Applied Forest Ecology. Wiley & Sons, Inc. New York. 1997. pp. 203-205.

U.S.F.S. 1998. A Guide to the Grand Canyon Forest Partnership: Working together in Flagstaff's Urban Wildland Interface.

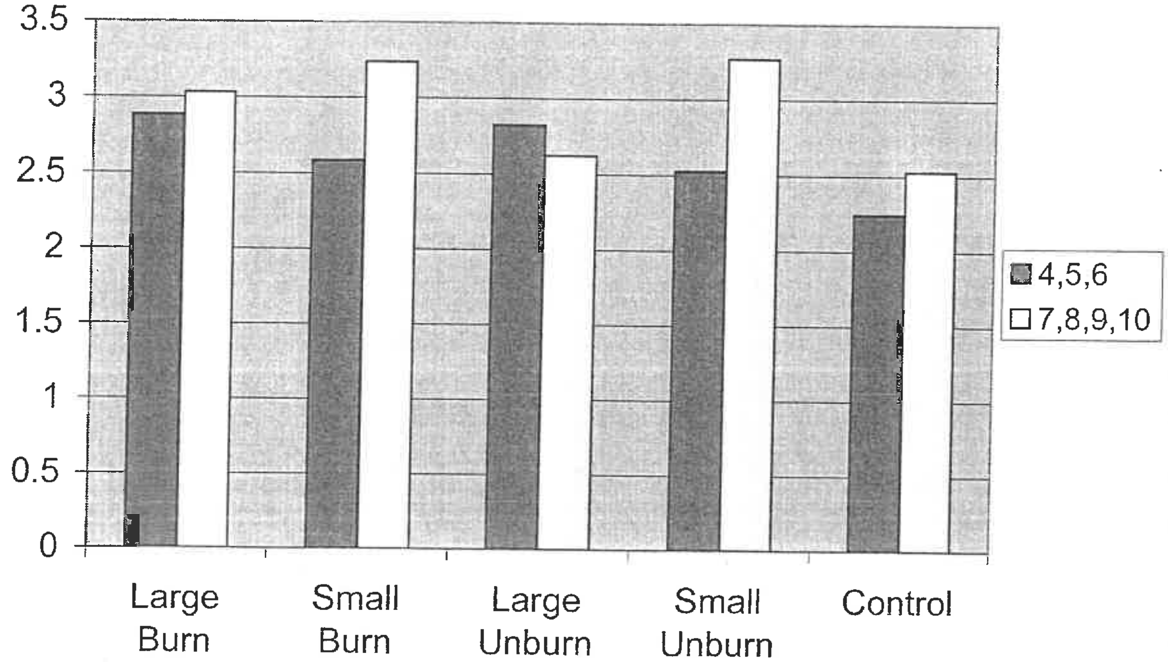

Figure 1: Calcium Concentration in Treatments (g/kg)

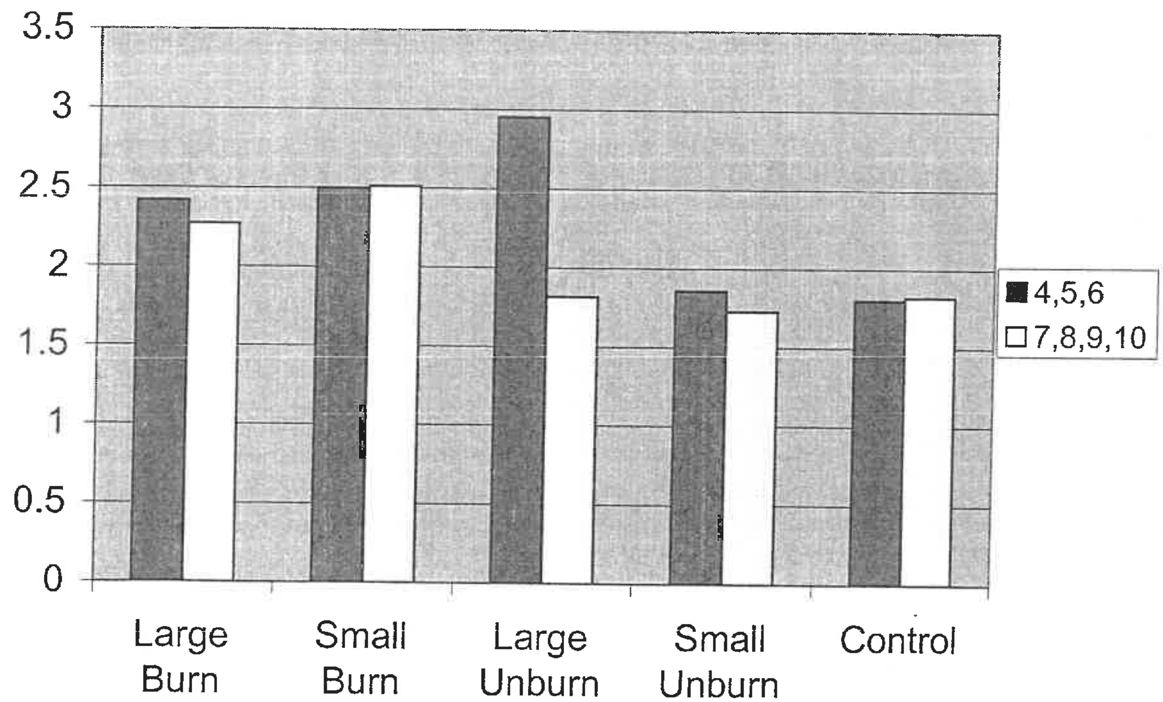

Figure 2: Potasium Concentration in Treatments (g/kg)

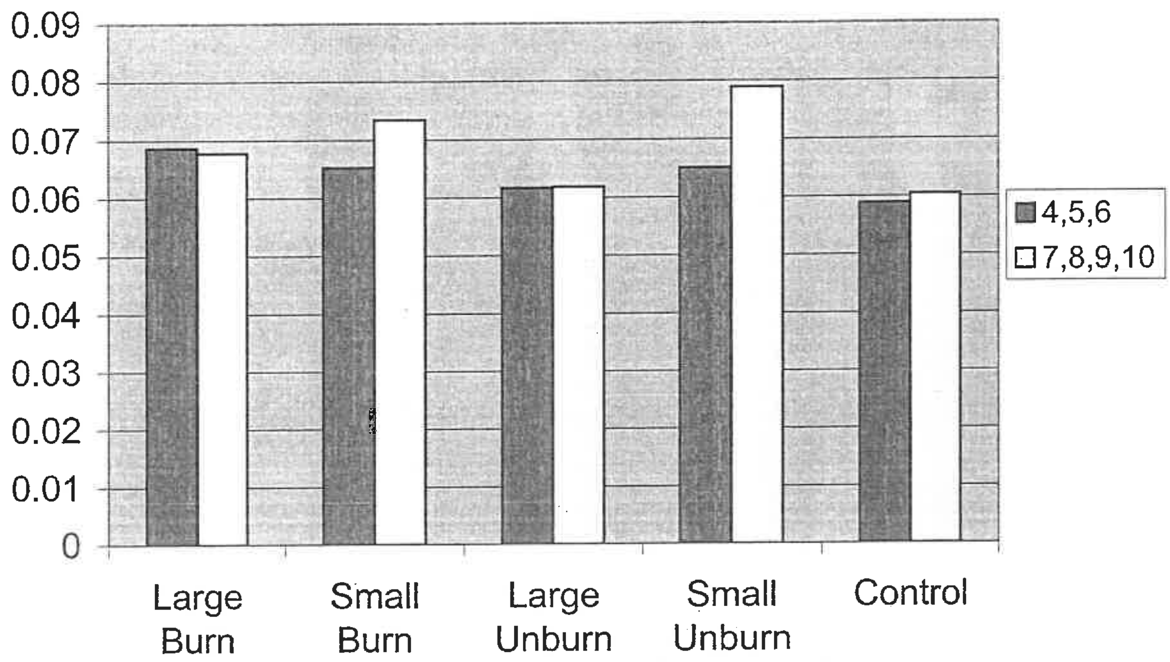

Figure 3: Zinc Concentration in Treatments (g/kg)

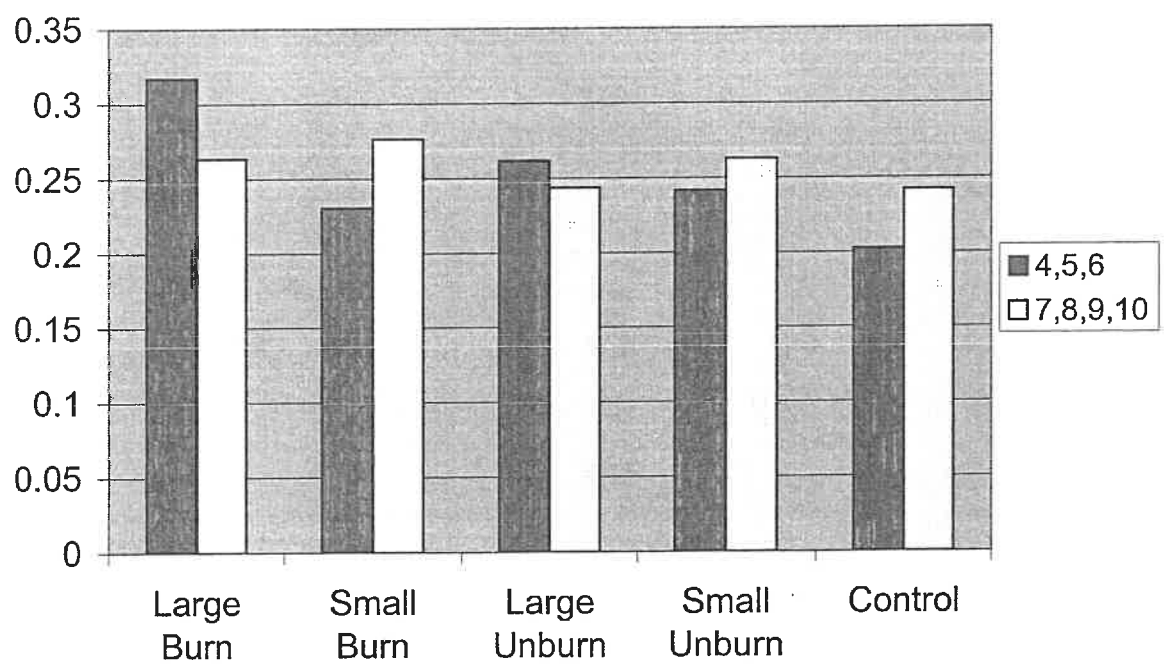

Figure 4: Sodium Concentration in Treatments (g/kg)

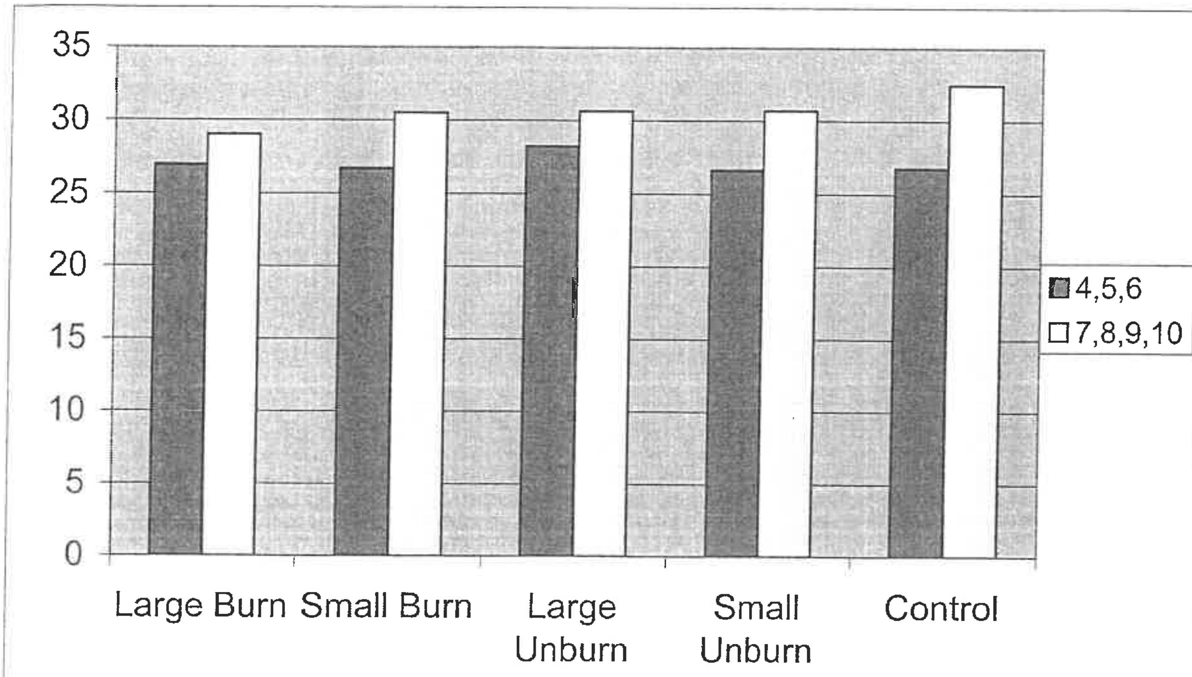

Figure 5: Iron Concentration in Treatments (g/kg)

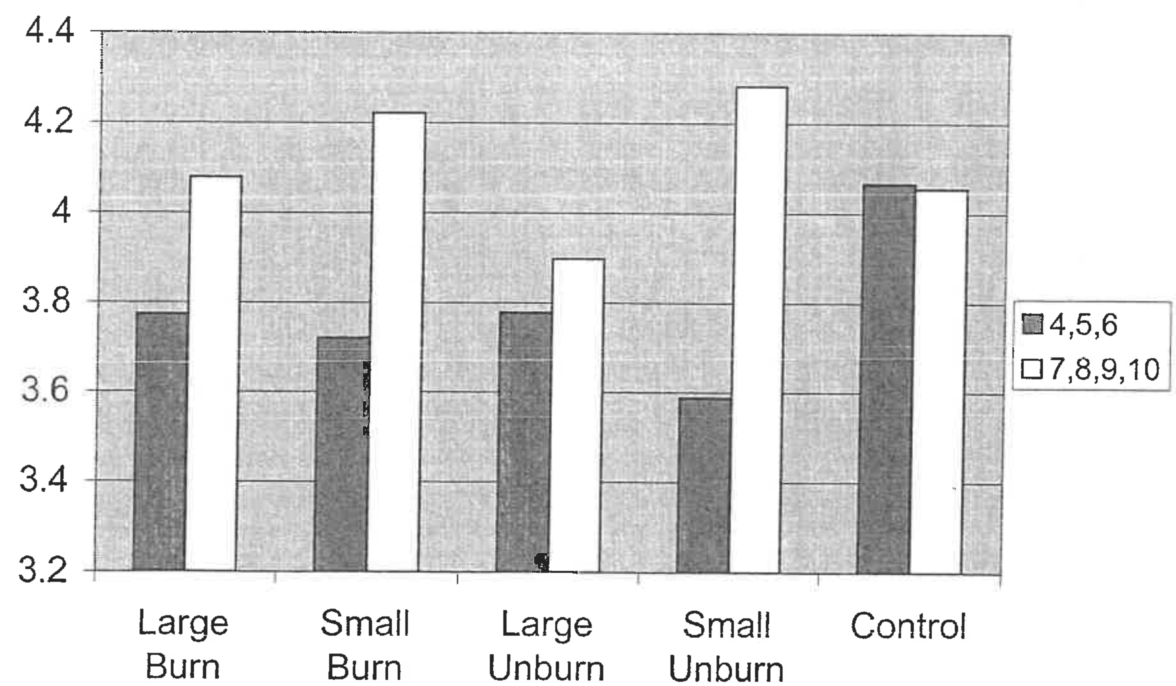

Figure 6: Magnesium Concentration in Treatments (g/kg)

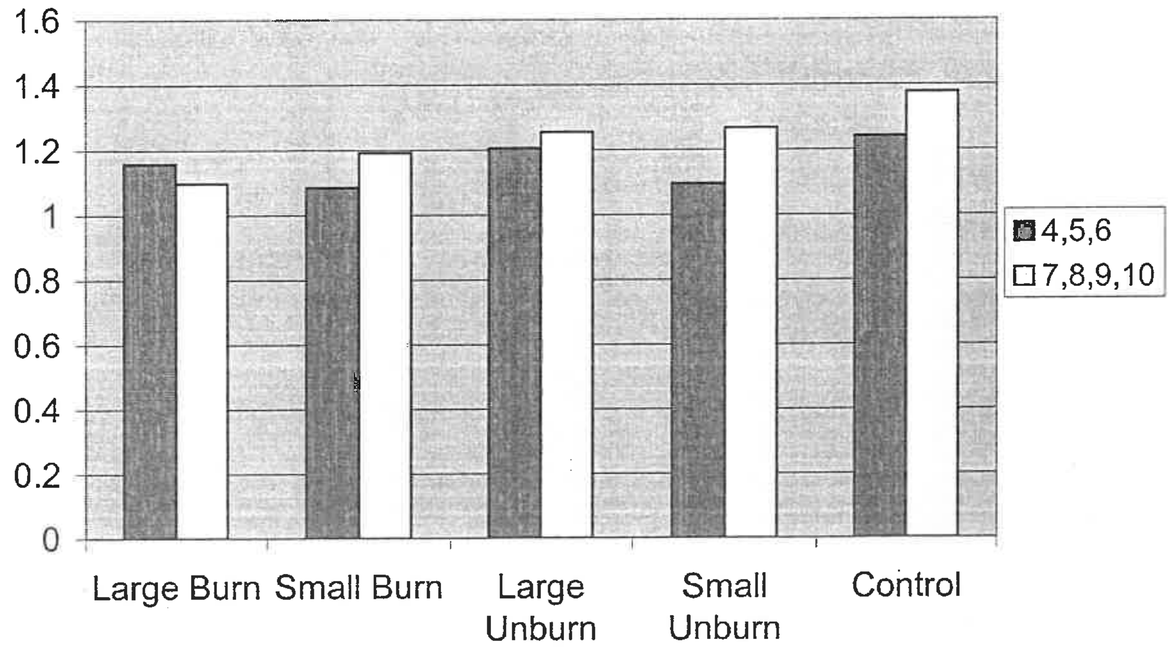

Figure 7: Manganese Concentration in Treatments (g/kg)

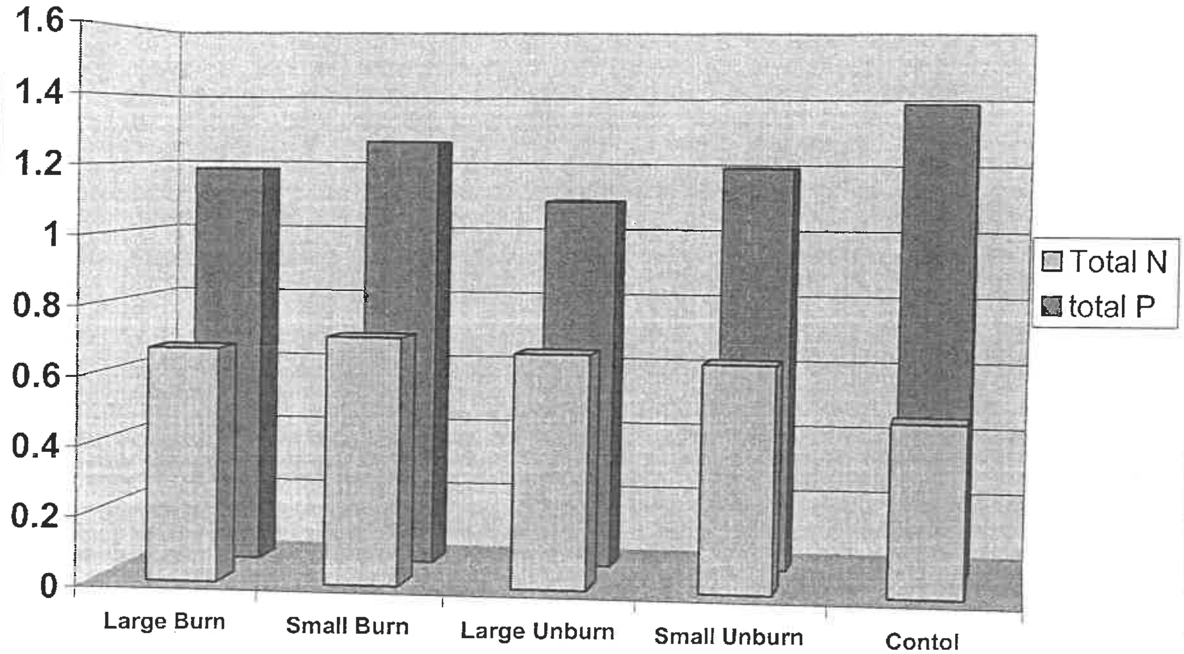

Figure 8: Total N and P for Replicate 10 (g/kg)

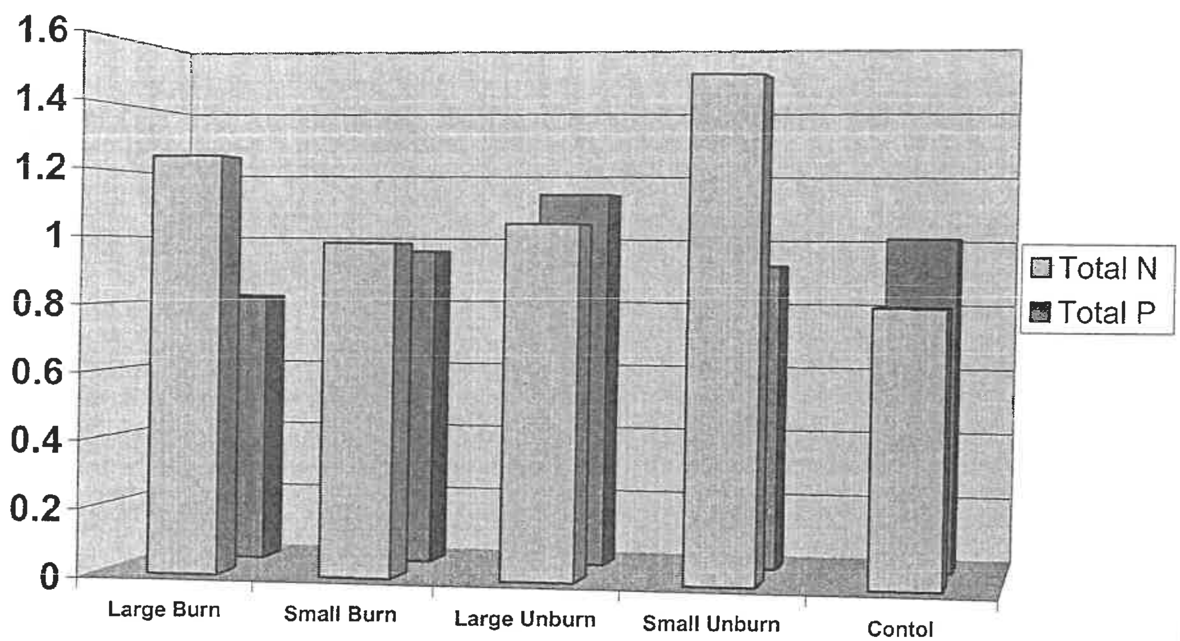

Figure 9: Total N and P for Replicate 9 (g/kg)

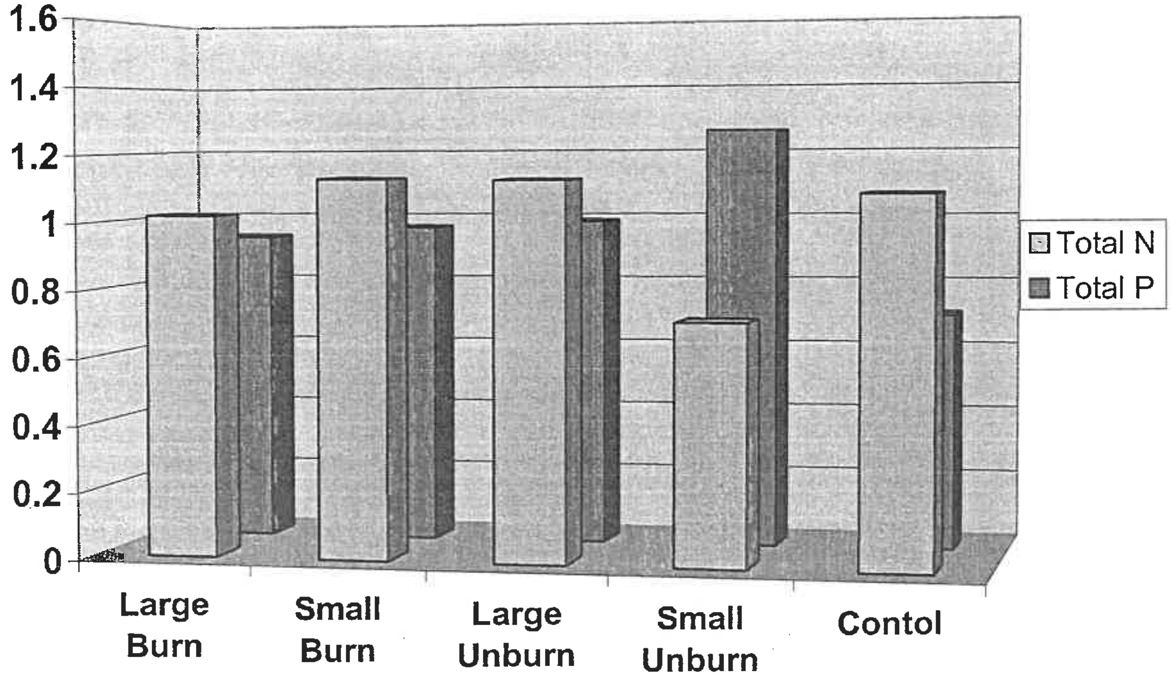

Figure 10: Total N and P for Replicate 6 (g/kg)

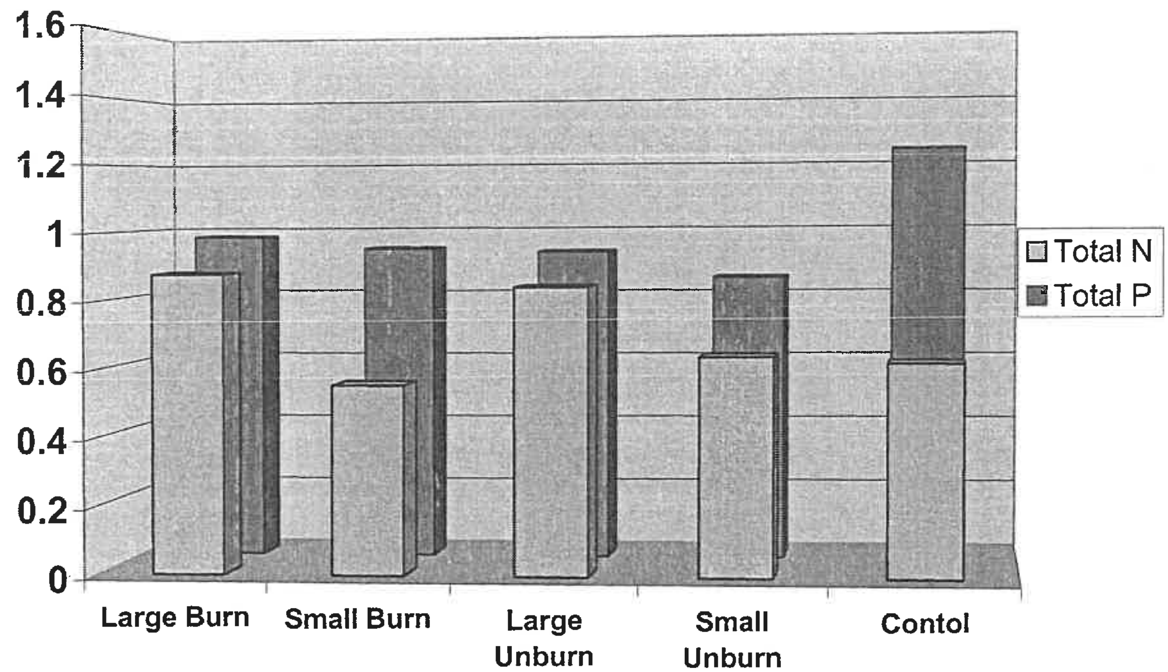

Figure 11: Total N and P for Replicate 4 (g/kg)

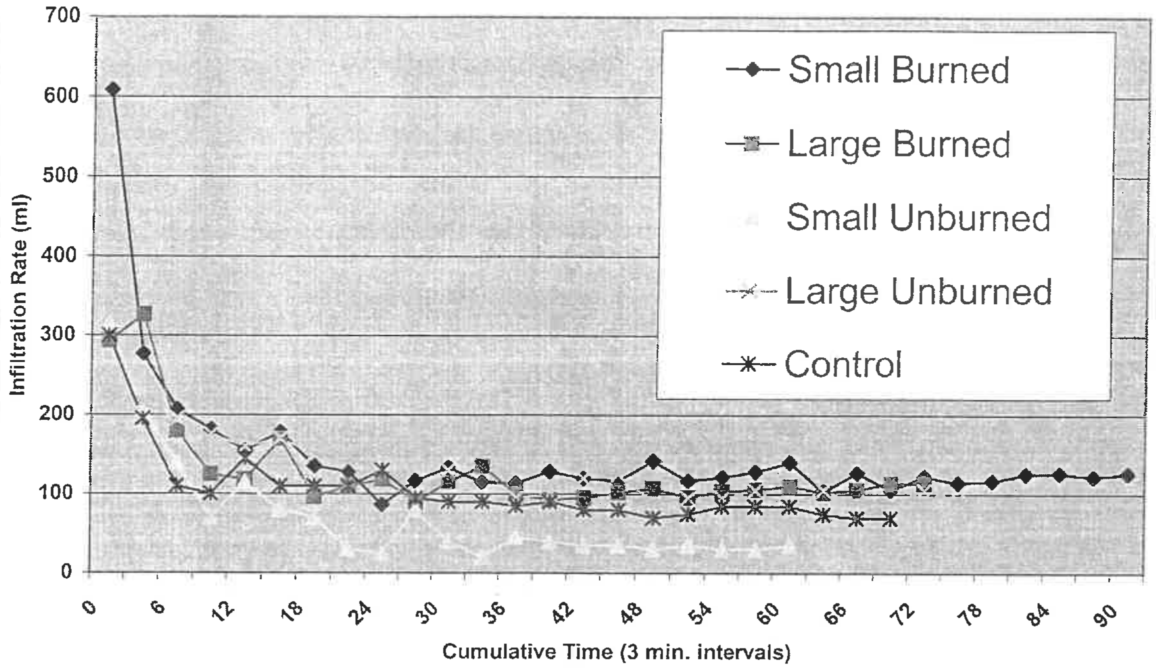

Figure 12: Infiltration Rates Over Time (Replicate 10)

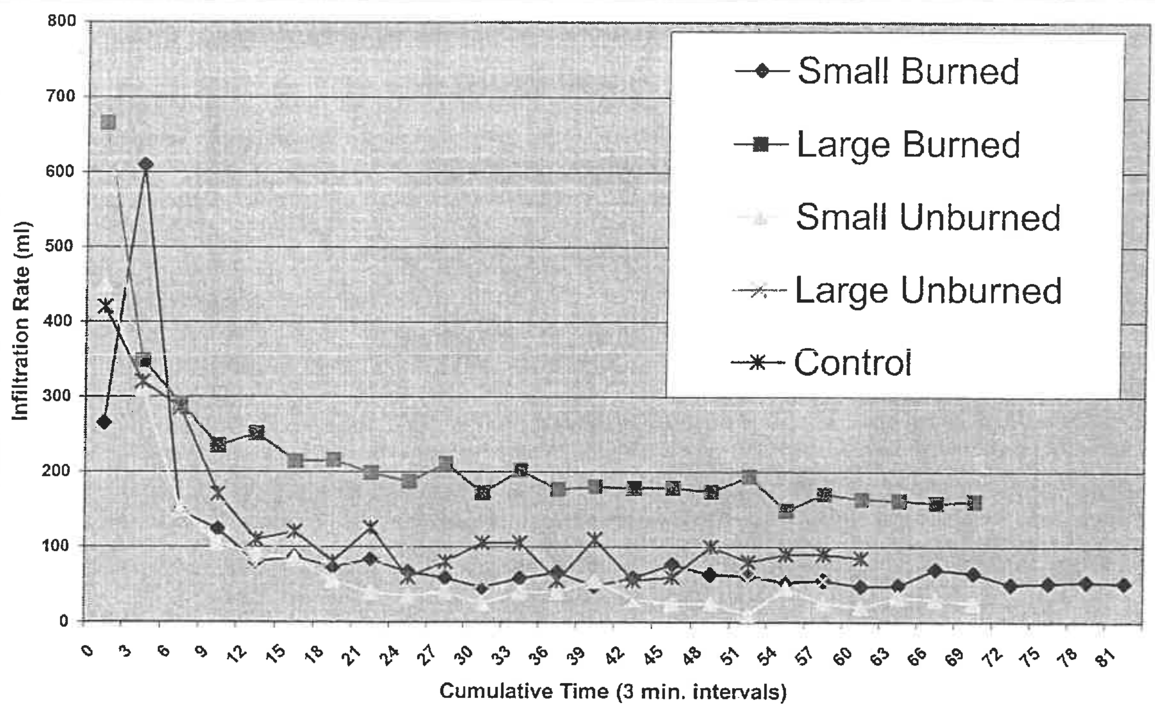

Figure 13: Infiltration Rates Over Time (Replicate 9)

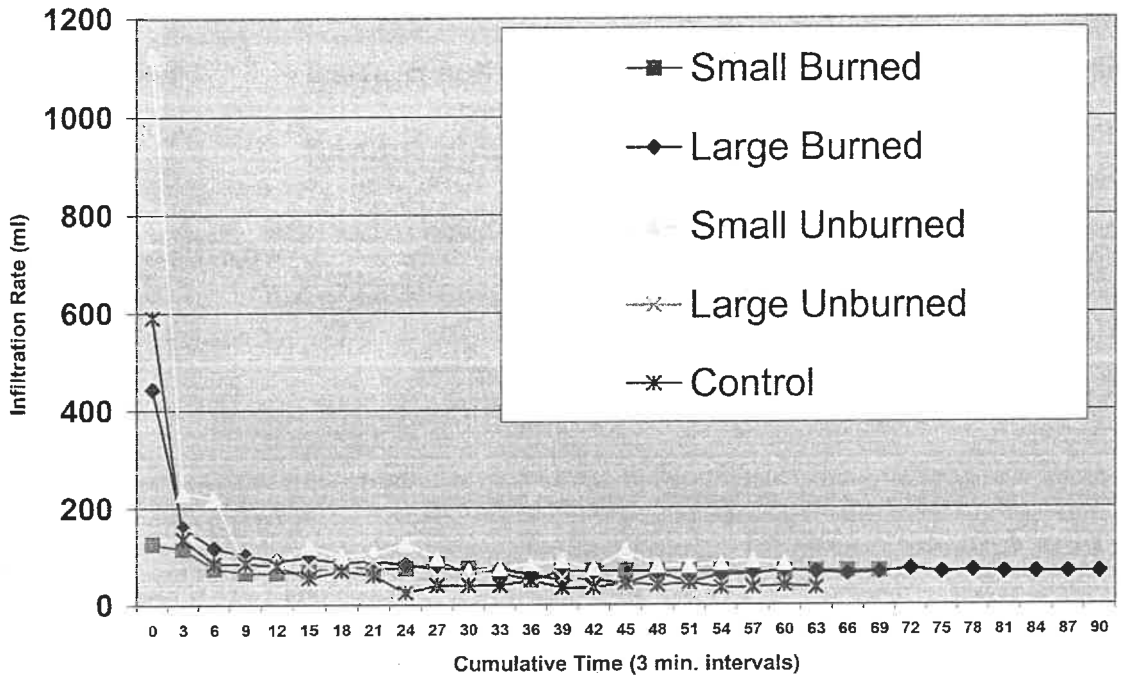

Figure 14: Infiltration Rates Over Time (Replicate 6)

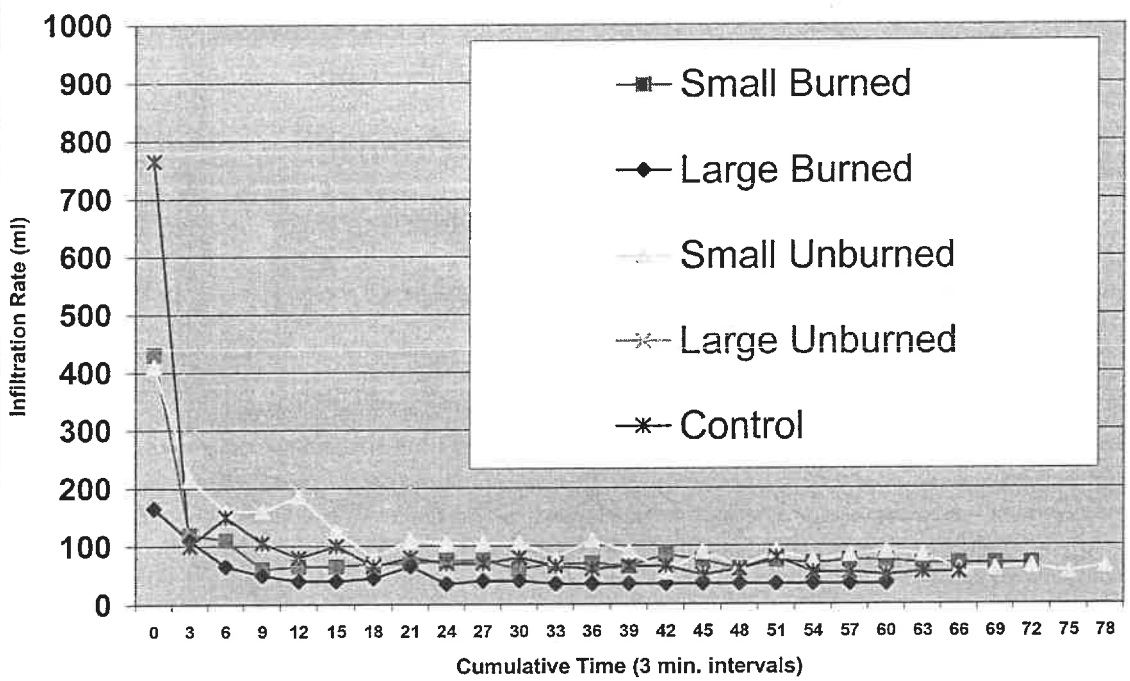

Figure 15: Infiltration Rates Over Time (Replicate 4)