Prescribed Burn and Non-native Plant Density Effects on Soil Characteristics in a California Grassland

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Introduction

The invasion of non-native plants into California grasslands has lead to displacement of rare and endangered species, increased fire hazard and an alteration of important above and belowground ecosystem processes such as nitrogen mineralization. In order to understand the impact non-natives have on these processes and the potential for restoration after invasion, research must study changes in both above and below ground processes whose alteration can lead to significant ecosystem changes. Most soil restoration work has focused on restoring anthropogenically degraded soils to productive qualities related to agricultural production. Few studies have looked at restoration of invaded soil (Lal & Steward 1992). Therefore, it is not known if soils and their processes recover from non-native plant invasions once the invaders have been removed.

California grasslands were historically dominated by perennial grasses and annual forbs, but during the past 250 years over nine million hectares have transitioned into non-native annual grasslands (Biswell 1956; Bartolome et al. 1986; Seabloom et al 2003) due in part to fire suppression (D'Antonio & Vitousek 1992). Approximately 400 non-native species have been introduced to California (McNaughton 1968) with some becoming dominant, such as *Bromus, Vulpia,* and *Avena* species (Hervey 1949; Biswell 1956; Gillespie & Allen 2004).These non-native grasses can limit germination and establishment of native perennial species by altering water availability and overcrowding seedlings (Eliason & Allen 1997; Cione et al. 2002; Seabloom et al. 2003; Moyes et al 2005). Non-native plant species have also been found to alter soil fluxes in carbon, nitrogen and other nutrients, microbial communities, (Ehrenfeld 2003; Yoshida et al. 2004; Siguenza et al. 2006) increase fire intensity and frequency, change above and belowground litter quality and quantity, decrease biodiversity, (Mc Naughton et al 1968, Jones & Woodmansee 1979; Ehrenfeld 2003, Wardle et al. 2004) and decrease carbon storage in grasslands (Seabloom et al. 2003).

Because fires are a natural disturbance that can maintain the native structure and function of grasslands (D' Antonio & Vitousek 1992), prescribed fires are now being used to attempt to control and reduce the cover of non-native plants, specifically grasses. Such burns are timed to coincide with grass phenology such that burns are conducted before seeds drop to the soil (Gillespie & Allen 2004). Because most annual grass seeds have little dormancy, spring burns can reduce seeds by 96% and allow native perennials to replace non-natives annuals (Hervey 1949; Moyes et al. 2005; White et al. 2006). Establishment of native perennial grasses is limited by non-native grass crowding and water use (Eliason & Allen1997; Cione et al 2002). With disturbance, such as spring fire, it may be possible to remove this limitation.

Prescribed fires used for non-native plant control are generally low in intensity and duration, causing short-term alterations of soil properties and microbial communities (Ubeda et al. 2005; D'Ascoli et al. 2005; Guerrero et al 2005; White et al 2006). The resilience of soils following fire depends largely on climate, topography and current vegetation. If plants can recover quickly, most pre-fire soil conditions should also return (Certini 2005; Hart et al. 2005). The resilience of the soil following non-native invasion and their later removal is not known.

Study Objectives

This study examined the effects non-native plants have on soil chemical and biotic factors and the role of two non-native plant control methods, hand removal (weeding) and fire, in the recovery of native plants and soils after the removal of non-native plant species. It tested the hypotheses: **(1)** Non-native plant species alter soils they invade. **(2)** There is a time lag between vegetation restoration and soil quality recovery and a lag between reinvasion of non-native vegetation and realteration of soils. **(3)** Removal of non-natives, by fire or weeding, allows soils to recover to pre-invasion characteristics.

Methods

To test the effect of fire as a non-native plant control, soils and vegetation were sampled from 9 randomly located blocks in four burn units of a chronosequence in 1994, 1997, 2000, 2003, 2004 (fig.1A) during the spring of 2006. Beginning in the summer of 2004 four more sampling locations/ burn units (1984, 1993, 2006, and 2006 weeding) were added to attempt to better describe the overall patterns of change over time since last burned. At that same time, the 2004 burn unit was removed due to differences in soil type that would lead to confounding factors in later data analysis.

To test the effect of hand removal of non-natives, a randomized replicate block design was be used in a unit that last burned in 1997. We used three treatments: removal of non-native grasses, removal of non-native forbs, removal of all non-natives and a control with no plant removal (fig.1B). To test the combined effect of fire and weeding, we have set up nine more plots in the recently burned 2006 unit in which all non-native plants have been weeded out. These plots are paired with the plots already established for the fire treatment in the 2006 unit.

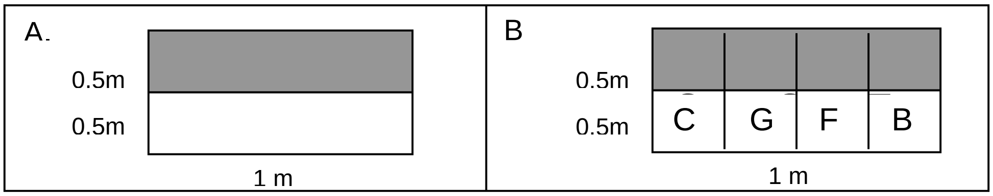

Figure 1. Plot design A will be used in fire chronosequence units and plot design B. will be used in the hand removal block replicate plots of the 1997 burn unit. (C) control, (G) non-native grass removal, (F) non-native forb removal and (B) non-native grass and forb removal. Biomass will be collected from shaded regions. Species percent cover, richness and soil will be collected from white regions.

To analyze treatment effects on plant composition, native and non-native plant species richness and species percent cover was recorded spring and summer of 2006 and again in the spring of 2007. Biomass was collected spring of 2006 and 2007 during plant senescence. In order to test the effect of non-natives and treatments on soils, soil samples at 5 cm depth were taken using a 2cm diameter soil corer. Samples were taken 24 hours after rain event and in the case of no rain in a given phenological stage of the plants, soils were wetted with an average rainfall volume and sampled after 24 hours. These samples were also collected spring and summer of 2006 and spring of 2007. Spring and summer samples from 2006 have been tested for chemical composition (total carbon and nitrogen, NO^-_3, NH^+_4, potassium and phosphorus), and soil bulk density. Spring 2007 soil samples have been sent out for analysis, but results are not available at this time.

This was year one of a three year project to examine change in soil characteristics related to non-native plant presence or absence. It was our intent to sample during plant germination, peak growth and plant senescence, however, due to the drought conditions during the 2006-07 growing season, this was not likely to provide data that differed enough to produce useful results. It is our intention to continue this research over the next two years during which time we will return to our original sampling schedule if weather permits.

Results

Fire Treatments

Spring 2006 Results

Soil chemical composition was analyzed using ANOVA to compare between burn years for total N, total C, Olsen P, NH_4, and NO_3. None of these soil chemistry variables were significantly different between burn years. Bulk density was greatest in the 1997 unit and lowest in the 2000 unit (fig. 2). Plant species richness and ground cover data were also analyzed using ANOVA to compare between burn years. Bare ground was significantly higher in the 2006 burn unit than in all other units (fig 10). Litter cover was significantly higher in the 2000 and 1994 burn units with 2003 burn unit significantly different from all other units and 2005 burn unit having significantly less litter cover than all other units (fig 9). Richness (fig 11), diversity (fig12), evenness (fig 13), and total plant percent cover (fig 3) did not differ between burn years. Biomass was analyzed by nativeness and as forb or grass using ANOVA to determine differences between burn units. Non-native grass biomass was significantly higher in the 2004 and 2000 burn units and lowest in the 2003, 1997 and 1994 units (fig 5). Non-native forb and native grass biomass did not differ between burn years, but native forb biomass was highest in 1994, 1997 and 2003 burn units and lowest in 2000 (fig 6). When biomass was combined into two groups (native and non-native), native biomass was highest in 1994, 1997, and 2003 and lowest in 2000 burn units (fig 7). While non-native biomass was highest in the 2004 and 2000 burn units and lowest in the 1997 burn unit (fig 8).

Spring 2007 Results

Percent cover data were analyzed using ANOVA to test differences between fire treatments. Total plant cover was highest in 1997 and lowest in 2000 burn unit (fig 7). Native plant cover was highest in the 1997 burn unit and lowest in 2006 burn unit; while, non-native percent cover was the opposite (fig 8). Richness was highest in the 1984, 1994 and 1997 burn units while it was equally lower in all other plots(fig 11) Diversity was highest in the 1997 burn unit and lowest in the 2006 unit (fig 12). Bareground was highest in the 2006 weeded burn unit, with 2006 burn unit next highest and all other units equally the lowest in bareground (fig 10). Non-native grass litter cover was highest in the 1993 burn unit and equally lowest in the 1984, 1994, 2006 and 2006 weeded units, while non-native forb litter had highest cover in the 2003 burn unit and was equally the lowest in the 1984, 1993, 1997, 2000, and 2006 burn units (fig 5). Native grass litter cover, on the other hand was equally highest 1984, 1994, 1997, and 2003 burn units (fig 4) and native forb litter cover is highest in the 1997 burn unit and equally lowest in the 1984, 1993, 2000, 2006 and 2006 weeded burn units (fig 6).

Hand Treatment

Spring 2006 Results

These data were obtained before the application of treatments and at the end of plant senescence. Data was analyzed using ANOVA to determine differences between treatments. Percent cover of total plant litter (fig 15), richness, diversity, evenness, native plants, non-native plants and bareground did not differ between the weeding treatments. Non-native grass litter cover was highest in control and all exotic plant removal plots and lowest in the exotic grass removal plots (fig. 17). However, non-native forb litter, native grass litter and native forb litter cover did not differ between weeding treatments. Nor was there significant difference between treatments when native litter is grouped and non-native litters are grouped (fig 16).

Spring 2007 Results

Data were analyzed with ANOVA to test for significant differences between weeding treatments. Bareground was highest in plots with all non-natives removed and lowest in the control plots (fig. 14). Non-native grass litter cover was equally highest in the control and non-native forb removal plots and equally lowest in the non-native grass removal and all non-native removal plots (fig. 17). However, the Non-native forb litter cover was highest in the non-native grass removal plots and lowest in the control and non-native forb removal plots (fig 17). Native grass and native forb litter percent cover was not different between treatments. Nor was the total plant percent cover (fig 15), native plant cover, non-native plant cover, richness, native richness, non-native richness, or diversity. Total native percent cover and non-native percent cover did not significantly differ across treatments (fig 16).

Discussion

The fire treatment data resulted in very scattered and unpredictable results overall. Much of this may be due to late sampling of the spring 2006 data (plants were very far into senescence and some forbs were likely missed) and the severely low rain fall during the 2006-07 growing season. However, some patterns did emerge. Native biomass appears to be generally higher in the oldest units and non-natives generally have the opposite biomass pattern. This may be a negative response of the natives to disturbance or to the presence of the non-natives. However, it is impossible to determine this from the current data. Richness and diversity tended to be higher in the middle aged burn units. This may reflect the increased presence of native species in these plots along with the non-natives. There are no burn units completely free of non-native plant species at Santa Rosa Plateau Preserve, so increases in richness are more likely driven by changes in the native species composition.

During the spring season of 2006, data was collected for the weeding treatment plots to ensure that the plots did not differ before treatments were applied. Because treatments had not been applied, it was expected that plots would show no significant differences between treatments. Results indicated that the plots did not differ between weeding treatments except for the variable of non-native grass cover, which was slightly lower in the plots later treated as non-native grass removal plots.

Because an entire growing season had passed before resampling the weeding treatment plots again in spring 2007, we expected to see a reduction of non-native grasses in both the non-native grass removal plots and the all non-native removal plots. We also expected to see a reduction of non-native forbs in the non-native forb removal plots and in the all non-native removal plots as a result of their manual removal. This was the case for both non-native grasses and non-native forbs. We had further expected to see an increase in native plant cover and diversity in plots treated with all non-native plant removal and the non-native grass removal plots. This, however, did not occur. We believe this result was driven by the severe drought experienced during the 2006-07 growing season. With a normal rainfall, we expect these results will differ. Soil chemical data for all treatments in the spring of 2006 showed no significant difference between treatments, which is what we expected to see. Spring 2007 soil chemistry data is not available at this time, but we expect to have it available by the end of the 2007 summer.

It is our intention to continue this project into the next two years and hope that with more average precipitation, the native plants will respond to the non-native removal treatments. The drought may have prevented us from successfully testing our hypotheses, but we did see some important patterns. It does appear that when non-native species are present in high abundance, native plant species, especially native forbs, are reduced. These results are consistent with our expectation that non-natives would negatively impact the native plant species, but our data can not determine the actual mechanisms of this pattern. Greenhouse experiments will be run in the future to pull out the important mechanisms. We had also hypothesized that there would be a lag time between treatment and recovery of native plants and associated soil conditions. Our data suggest that there may be a period just after the fire treatment where natives are present in only lower abundances. At some medium age of burn unit, the native abundance increases and then declines with passing of time. Non-natives show a fast recovery response to fire treatment, which suggests that for non-natives, a lag time might not be occurring. We can not say whether these patterns are due to fire disturbance, plant competition, soil feedbacks, or drought from the data we currently have. Once soil chemical samples from the spring 2007 sampling date are analyzed, we may have a clearer picture, but this too may be masked by the effect of the drought. At this time, it appears our data are unable to address our hypotheses adequately. With future sampling of the sample plots and the addition of greenhouse experiments, we hope to have more useful conclusions.

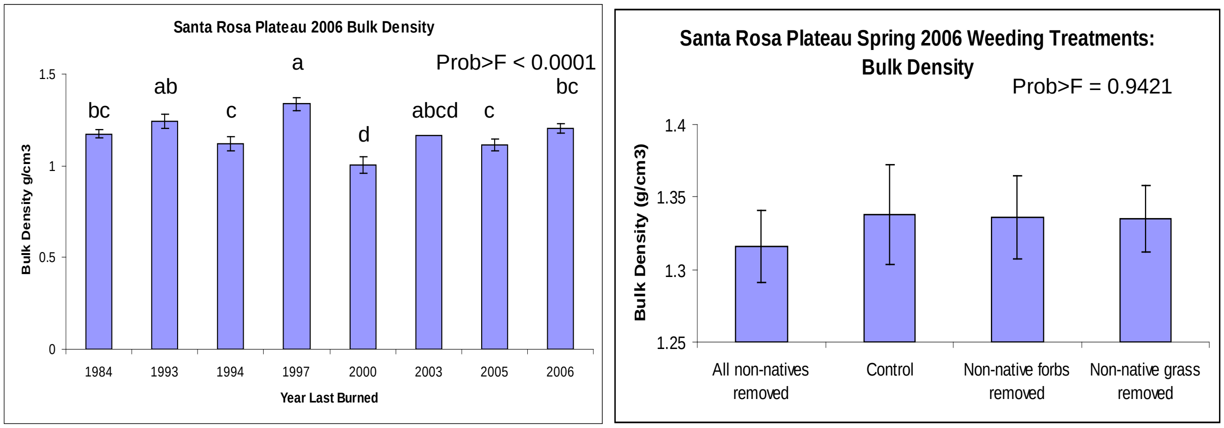

Figure 2. Soil bulk density was taken for all plots during the 2006 season. Soil bulk density was measured in g dry soil per cubic cm.

Figures for fire treatments

Results for spring 2006 **Results for spring 2007**

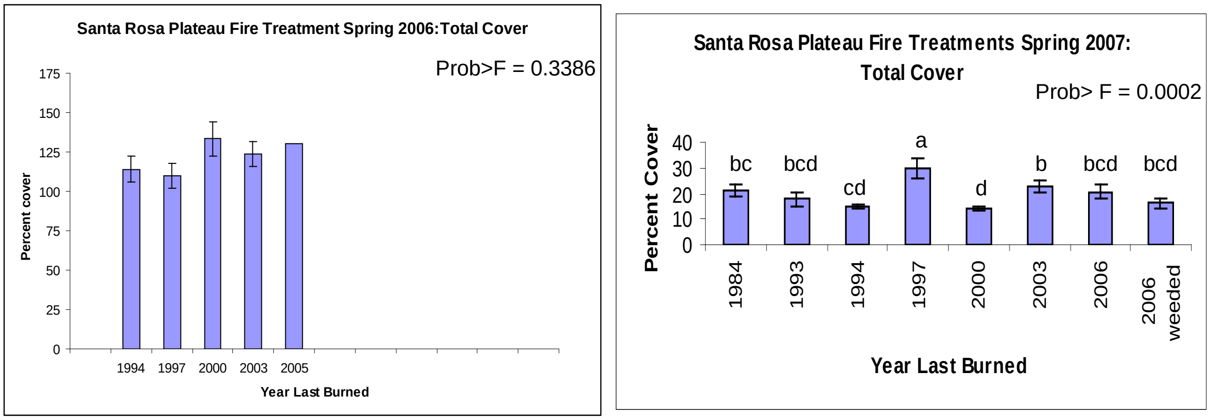

Figure 3. Total plant cover measured in spring 2006 and in spring 2007 as the percent of plot area covered by plant live biomass.

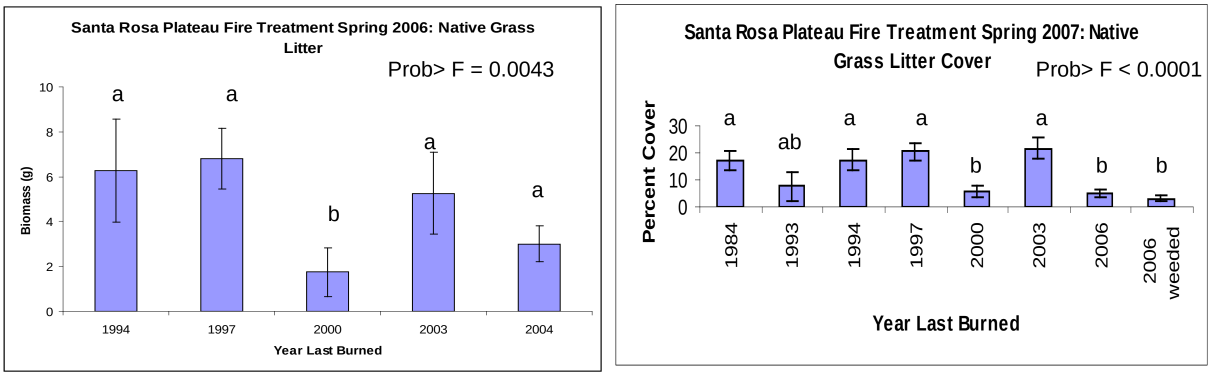

Figure 4. Native grass litter was measured as the percentage of the plots covered by the current years native grass litter.

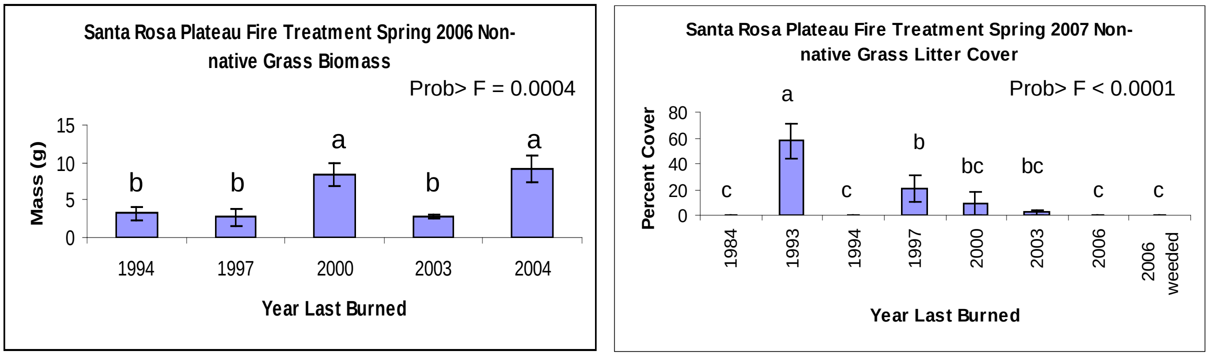

Figure 5. Spring 2006 non-native grass biomass was collected at senescence and non-native grass litter measured as the percentage of the plots covered by non-native grass litter.

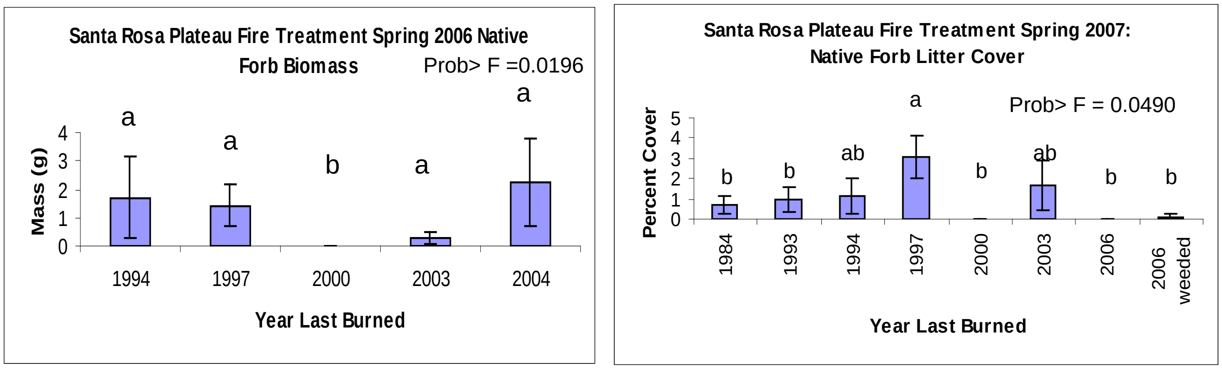

Figure 6. Spring 2006 native forb biomass was collected during plant senescence and native forb litter cover measured as the percentage of the plot covered by native forb litter.

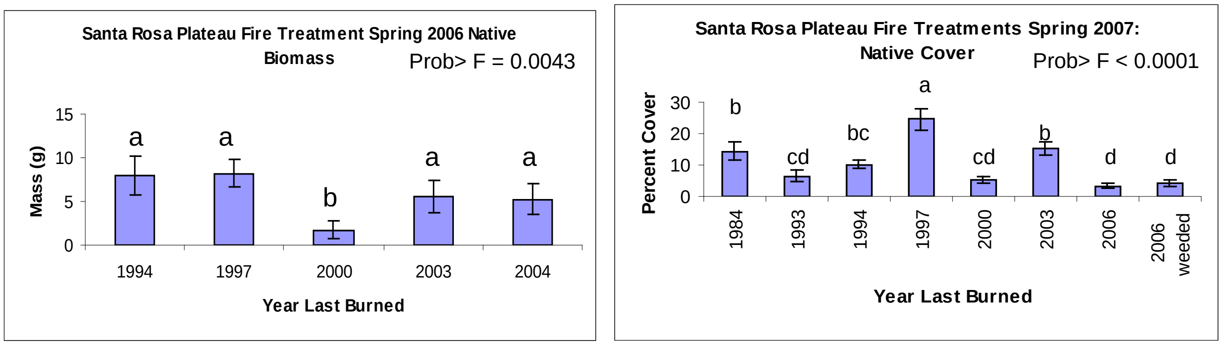

Figure 7. Total native plant biomass measured during the spring of 2006 and 2007.

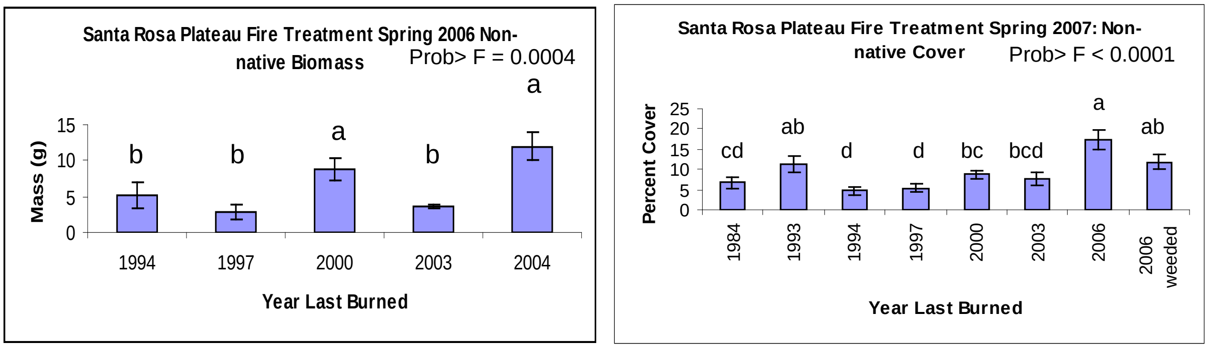

Figure 8. Spring total non-native plant biomass measured during 2006 and 2007.

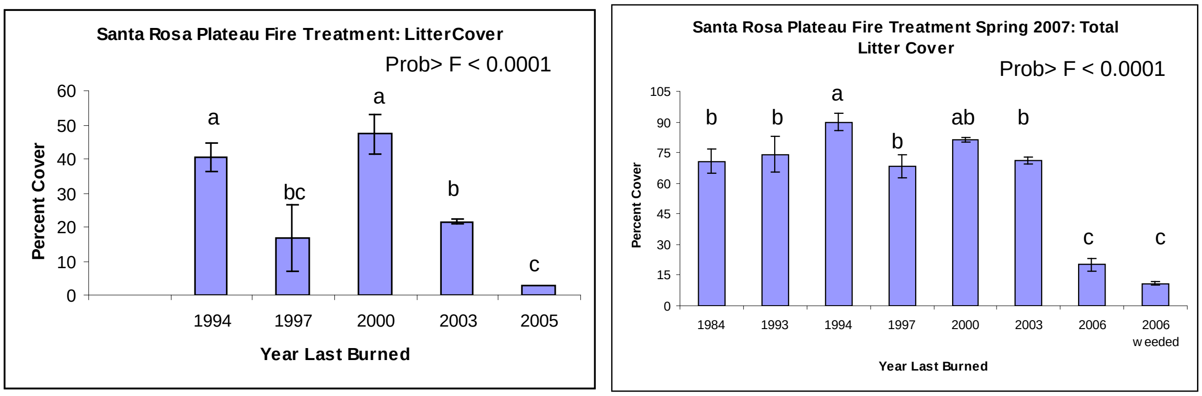

Figure 9. Total percent cover of litter measured during spring 2006 and 2007.

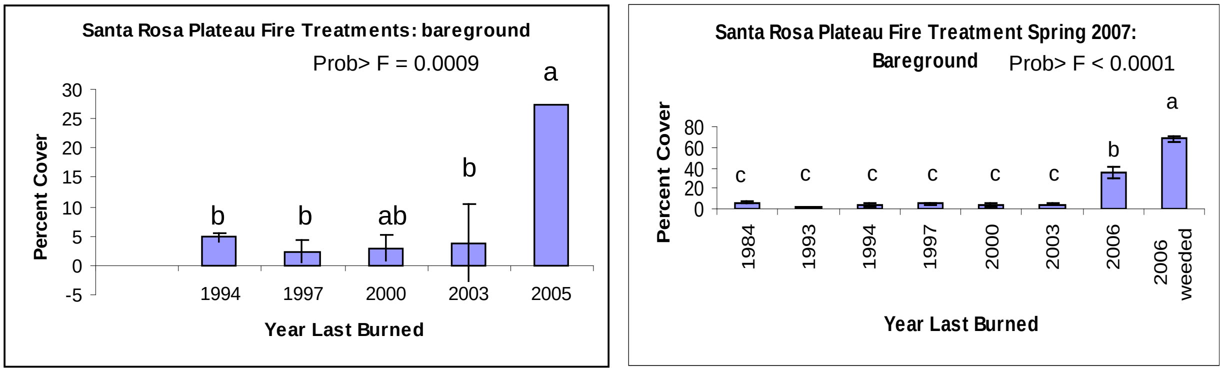

Figure 10. Total bareground percent cover measured during spring 2006 and 2007.

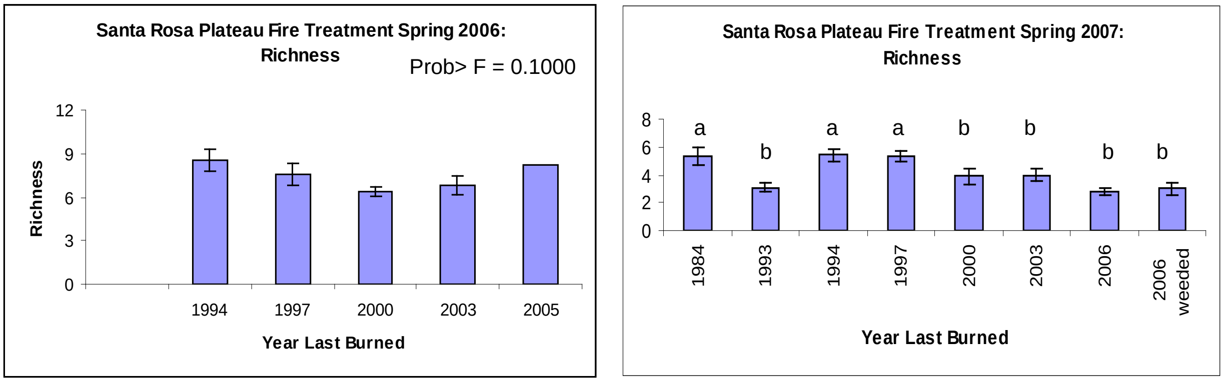

Figure 11. Species Richness in 2006 and 2007 during late spring.

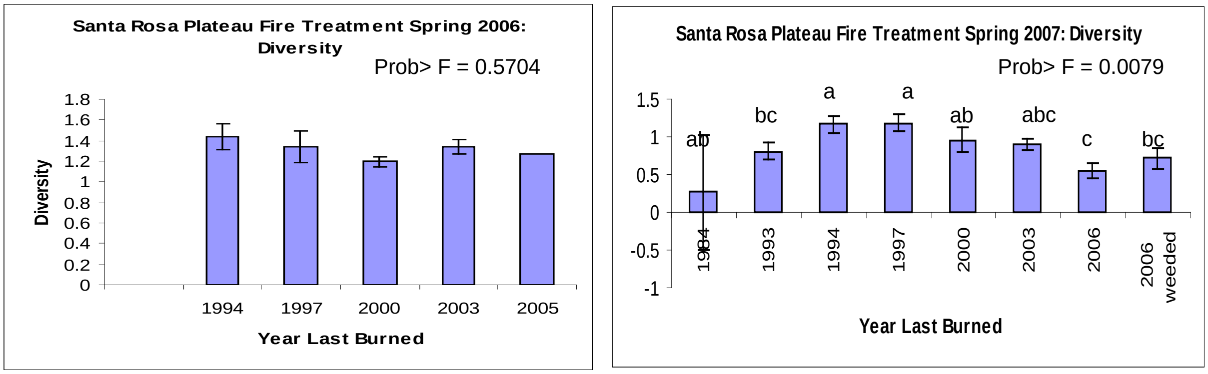

Figure 12. Diversity of plant species of fire treatments spring 2006 and 2007.

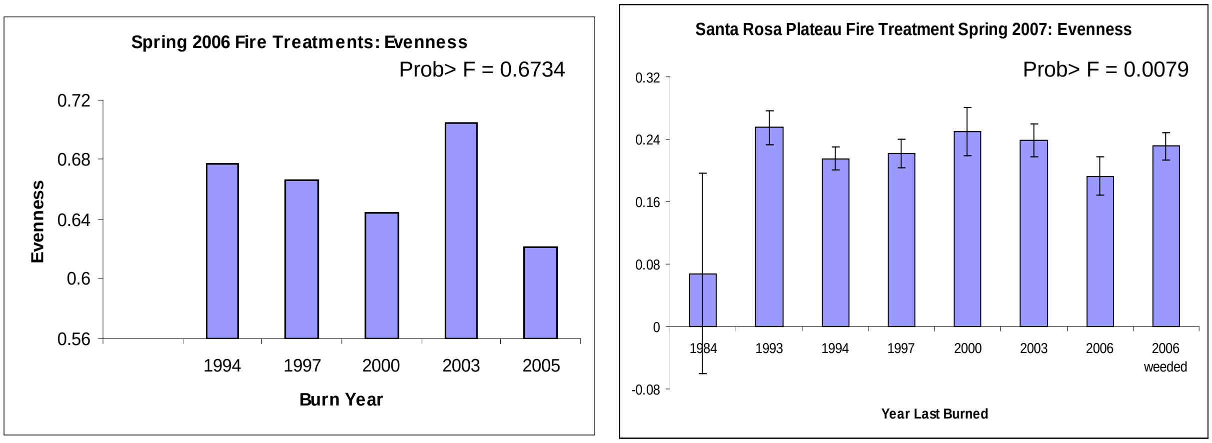

Figure 13. Evenness of plant species for the fire treatments spring 2006 and 2007.

Figures for Hand treatments

Results of spring 2006

Results of spring 2007

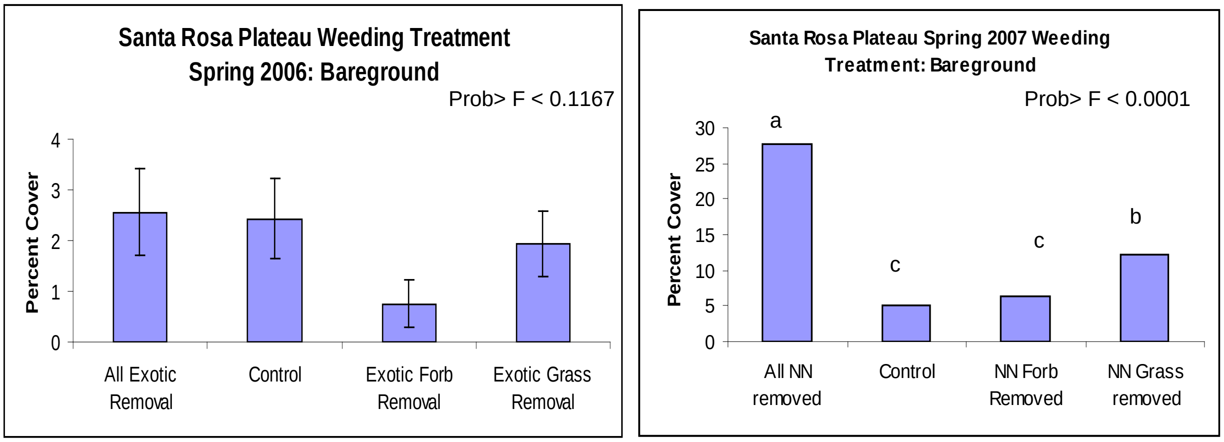

Figure 14. Percent of plots covered by bareground measured during the spring seasons. Differences in bareground are more likely driven by treatments (actual removal of vegetation) than due to plant responses to treatments because the 2006-07 season was a severe drought year with little plant growth.

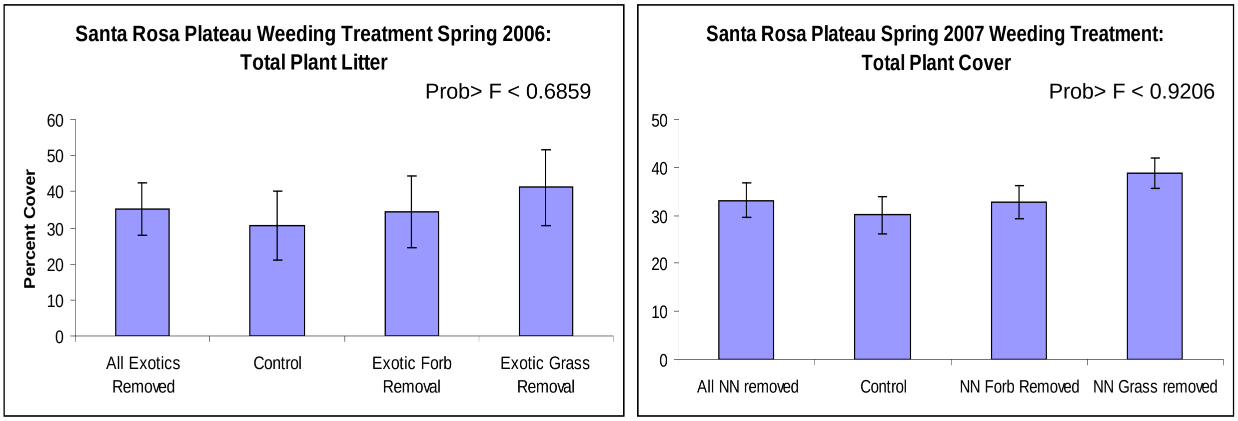

Figure 15. Total plant litter cover of spring 2006 and total percent plant cover for spring 2007. Much of the plants had senesced by the 2006 sampling date and thus was recorded as litter for that current year and thus represents what would have been cover of live biomass if sampled sooner in the season.

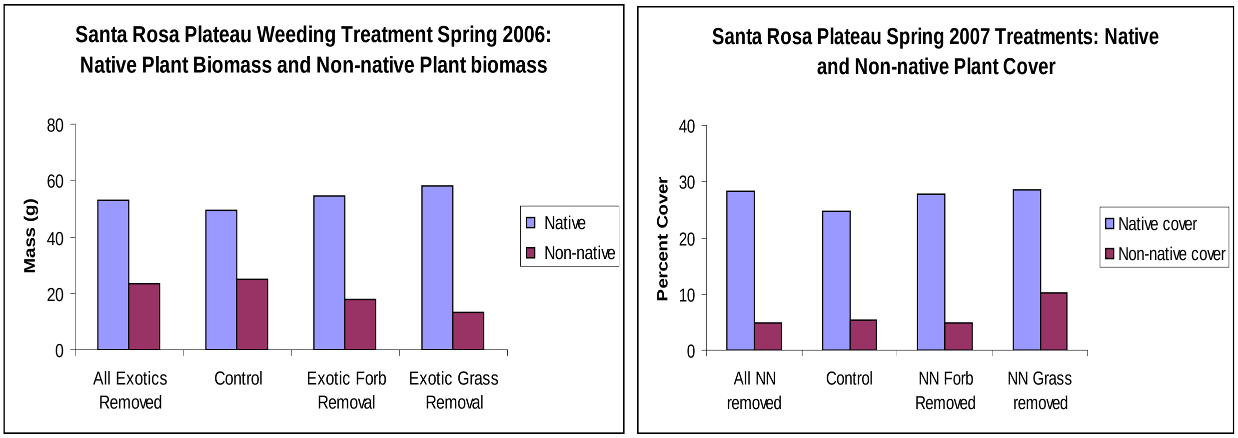

Figure 16. The total native (Prob> F = 0.9501 in 2006 and 0.8002 in 2007) non-native (Prob> F = 0.2482 in 2006 and 0.1977 in 2007) plant biomass and cover were not significantly different across fire or weeding treatments when all species are grouped according to their native or non-native standing.

Significant changes in relative litter cover after weeding treatments

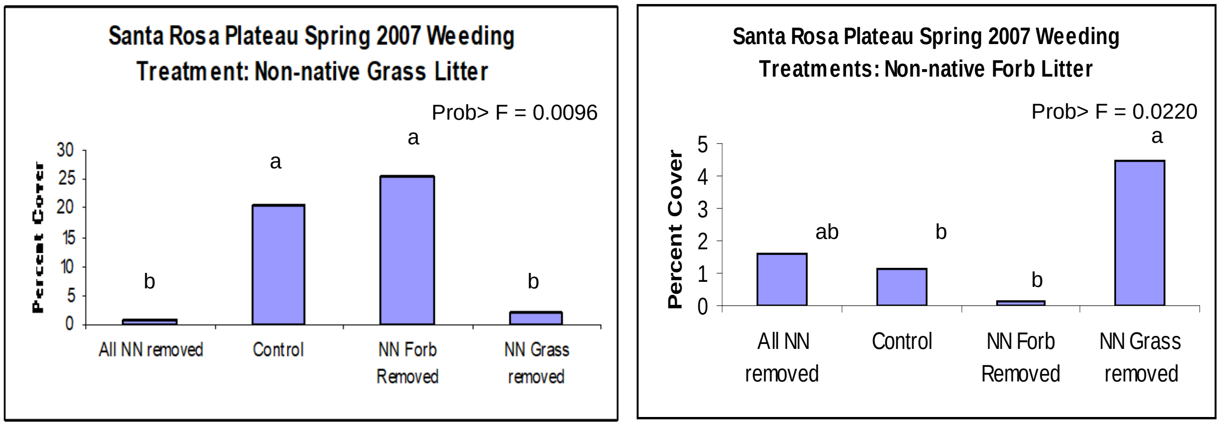

Figure 15 Non-native grass and non-native litter percent cover for weeding treatments in spring 2007. While the total non-native plant cover did not show significant differences between weeding treatments, when data is broken down to functional groups of grass and forbs, differences in cover arise.

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