# INFLUENCE OF PRECIPITATION TIMING ON SAGEBRUSH/BUNCHGRASS VEGETATION

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## SUMMARY

The objective of this study has been to monitor the effects of altered precipitation patterns on plant community dynamics in the sagebrush steppe. Plant community response to altered precipitation patterns were assessed by monitoring plant species cover and density, biomass production, phenological development, and root growth. Five rainout shelters, 100 x 40 ft, were used to control season and amount of precipitation. Precipitation under the shelters was applied by an overhead sprinkler system. Precipitation treatments under each shelter are labeled "winter", "spring", "current". An ambient or control treatment is located outside each shelter replication and receives natural precipitation. Under the shelters, each treatment received a total of about 8 inches of moisture per year. Ambient-treatment precipitation amounts and patterns vary by year. Plant community dynamics and ground cover were influenced by the precipitation treatments in several specific areas. All shelter treatments tended to have greater plant cover than the ambient treatment Annual forbs were the most responsive to different treatments. Annual forb density and cover have been consistently lower in the spring treatment compared to the other treatments in all years. Bareground tended to be greater in ambient and spring treatments than in winter and control treatments since May, 1996. The phenology of all the species monitored were effected by the different precipitation treatments (data not shown). The most dramatic effects occurred with herbaceous species where phenology was delayed by the spring treatment (all years) when compared to the other treatments. Sagebrush phenology has been delayed in the Spring treatment through floral shoot development. However, by the ephemeral leaf drop stage there have been few differences in sagebrush phenology among the treatments. In all treatments, root activity appears to be correlated to soil moisture conditions particularly in the upper (10-20 cm) soil profile. During periods of higher moisture availability root activity increases. Although there has been a lack of any consistent treatment effects it does appear that the Spring treatment may be allocating more resources to below ground structures.

## INTRODUCTION

The development and distribution of terrestrial ecosystems are strongly influenced by climate conditions (Emmanuel et al. 1985). Geologic, fossil, and historical records provide evidence that climate is not static; in the past climate has frequently changed, thus effecting the evolution of Earth's ecosystems. In our own region, the Great Basin of the western United States, there have been several shifts in temperature levels and precipitation amounts since the end of the last glacial period 10,000 years ago (Morrison 1964, Mehringer and Wigand 1990, Thompson 1990) . Alternating wet and dry periods have caused changes in plant community composition, production, cover, and distribution, and have effected soil development and movement throughout the Great Basin.

There is concern that human activities that result in the release of greenhouse gases ($CO_2$, methane, CFCs, ozone, and $NO_2$) and other atmospheric pollutants, are altering not only the direction but the rate of climate change (USGCRP, 1997). The increase in atmospheric $CO_2$ is a main area of concern. During the past 100,000 years, global $CO_2$ concentrations have fluctuated between 200 and 300 ppm. Since the beginning of the Industrial Revolution, $CO_2$ concentrations have risen dramatically. Carbon dioxide concentrations increased from 280 ppm in the late 1800s, to a present level of 360 ppm (USGCRP, 1997). It is predicted that the rise in $CO_2$ concentration will lead to increases in global temperatures of between 0.4 to 3.5° C by 2100 (Idso and Balling 1991). Changes in temperatures are expected to alter the amount and distribution of precipitation on a regional basis. Even without climate changes there is tremendous year-to-year variation that influences management decisions. In the Great Basin, altered precipitation patterns have the potential to cause major changes in vegetation, soils, biodiversity, and consequently effect the economic and recreational uses of these lands.

The purpose of this study was to assess the effects of altered precipitation patterns on plant composition and productivity in a sagebrush steppe community. Plant community response to altered precipitation patterns were evaluated by monitoring plant species cover and density, biomass production, phenological development, seed production, and root growth.

## METHODS

### Study Area and Experimental Design

The study is being conducted on the Northern Great Basin Experimental Range in southeastern Oregon, 67 km west of Burns. The experimental range is located on the northern fringe of the Great Basin and is characterized by shrub steppe vegetation represented by sagebrush/bunchgrass and western juniper plant communities.

The study site was dominated by Wyoming big sagebrush, Thurber's needlegrass, bluebunch wheatgrass, and Sandberg's bluegrass. Elevation at the site is 1380 m and the ground is fairly level (0 to 1-percent slope). Soils were well drained and underlain by a duripan between 15 to 20 inches. Soils on the site were classed as a Vil-Decantl Variant-Ratto complex (Lentz and Simonson 1990).

The experimental design was a randomized complete block with four treatments, each replicated five times. Five rainout shelters, 100 x 40 ft, were used to control season and amount of precipitation. Shelters were constructed in 1994. Shelters were open on the sides and covered with light-transparent fiberglass. Light transmission under the shelters is 50 percent of ambient, which was not enough of a reduction to limit plant growth. Precipitation under the shelters was applied by an overhead sprinkler system. Precipitation treatments under each shelter were winter, spring, current (Table 1). An ambient or control treatment was located outside each shelter replication and received natural precipitation. Treatment plots were 32 x 40 ft in size, and include a 6-ft buffer strip on all sides. Each treatment under the shelters received a total of about 8 in of moisture per year. Ambient treatment precipitation amounts and patterns varied by year.

### Vegetation Measurements

Shrub cover was estimated by the line intercept method using three 25-ft transects in each treatment plot. Transects were spaced 6 ft apart. Density of shrubs was determined by counting all rooted plants in 25 x 6 ft belt transects. Cover and density of herbaceous plants were determined using 2.2-$ft^2$ quadrants placed at 1-m intervals along each line transect (8 quadrants per transect). Cover of herbaceous plants, mosses and cryptogamic crusts, litter, rock, and bareground were estimated visually. Density of herbaceous plants, mosses, and cryptogams were determined by counting all individuals in the quadrant.

Herbaceous standing crop biomass was estimated in February 1998. In each treatment replicate 5, 10-$ft^2$ plots were clipped for herbaceous biomass. Plants were separated by group (i.e., perennial grasses, perennial forbs, annual grasses etc.). In all treatment replicates, standing herbaceous biomass was clipped from the entire 32 x 40 $ft^2$ plots. This was done to remove standing dead material and facilitate estimation of 1998 production year biomass.

Plant phenology has been monitored over the past three growing seasons (1995, 1996, 1997). Plant groups monitored were shrubs (Wyoming big sagebrush), perennial grasses (Thurber's needlegrass and squirreltail), annual forbs (blue-eyed Mary, and perennial forbs (pale agoseris, western hawksbeard, and tapertip hawksbeard) in the family Compositae. Three plants of each species were monitored in each shelter plot (15 plants per treatment). Phenology data was collected on a weekly-to-biweekly schedule in 1995 and 1996, and on a weekly basis in 1997.

Root counts were collected biweekly using a root periscope during the 1995, 1996, and 1997 growing seasons (approx. March through October). In 1996, root counts were not done between the third week in July and early September because of equipment breakage and repair. Root counts were performed at 10, 20, 30, and 40 cm depths in root-access tubes. Two root tubes were placed in each treatment plot (10 tubes per treatment).

## RESULTS

### Community Dynamics

Plant community dynamics and ground cover were influenced by the precipitation treatments in several specific areas. All shelter treatments tended to have greater plant cover than the ambient treatment (Table 2). Annual forbs were the most responsive to the different treatments. Annual forb density and cover have been consistently lower ($p < 0.05$) in the spring treatment compared to the other treatments in all years (Tables 2 and 3). Perennial grass density and perennial forb cover and density did not exhibit any consistent differences among treatments in 1995, 1996, and 1997. In 1997, treatment differences were found to be significant for perennial grass cover. In 1997, cover of perennial grasses was significantly lower in the ambient treatment compared to the other treatments (Table 2). Bareground tended to be greater in ambient and spring treatments than in winter and control treatments since May,1996. Cryptogamic crust density and cover was generally lower under the shelters than in the ambient plots. Although there are treatment differences, the cover and density of sagebrush within each treatment has not changed appreciably since the beginning of the study in 1994 (Tables 2 and 3). Standing crop biomass was not significantly different between treatments, but it was clearly lower in the ambient treatment (Fig.1). For herbaceous biomass (Fig. 1), 99 percent of the total was composed of perennial grasses, with the other functional groups (perennial forbs and annual grasses and forbs) contributing only a trace.

## Phenology

The phenology of all the species monitored was affected by the different precipitation treatments (data not shown). The most dramatic effects occurred with herbaceous species where phenology was delayed in the spring treatment (all years) when compared to the other treatments. Sagebrush phenology was delayed in the spring treatment through floral-shoot development. However, by the ephemeral leaf-drop stage few treatment differences were observed in sagebrush phenology. In 1997, several results stood out. There was no emergence of the annual forb blue-eyed Mary in the spring treatment. Some forbs not specifically monitored for phenology did grow and develop seed in the spring treatment in July and August of 1997. These species were desert alyssum and tansey mustard. The perennial forb group had the greatest success in passing through all phenological stages to seed development and scatter in the winter treatment. In the other treatments fewer perennial forbs developed flower heads and set seed, particularly in the spring treatment. In the winter treatment the perennial grasses, needlegrass and squirreltail, tended to be phenologically ahead of the treatments. However, with a few individual exceptions, perennial grasses in all the treatments developed viable seed.

## Roots

In 1995 and 1996, there were no significant treatment differences in total root counts (10-40 cm) (Fig. 2). In these same years, there was a tendency for higher root activity in the spring treatment compared to other treatments after the end of May. In 1997, this trend continued except that the higher rooting activity in the spring treatment did not begin until late June. For all treatments, root activity was greatest at the 10 cm depth ($p < 0.01$). Root activity declined significantly with depth ($p < 0.01$). All treatments had increased root activity between March and late May in 1996 and 1997 ($p < 0.01$). In 1997, root activity declined in early June in ambient, control, and winter treatments, but continued to increase in the spring treatment until early July. In the fall of 1997, a flush of root growth occurred in response to moisture inputs.

# DISCUSSION

## Community Dynamics and Phenology

The forbs, particularly annuals, were favored by a winter precipitation regime and least favored by a spring moisture pattern. Total forb cover and density, and phenological development were generally lower in the spring treatment than the other treatments. The lack of *Collinsia* emergence and growth in the spring treatment in 1997 was probably due to inadequate seed germination conditions (i.e., soil moisture). Fauna that depend on annual and perennial forb production may be adversely affected by an increased spring moisture regime.

The forb component in all treatments displayed wide year-to-year shifts in cover and density. These year-to-year changes in the forb component were likely tied to climatic variables (soil moisture and temperature interactions), which influence the breaking of seed or plant dormancy (Baskin and Baskin 1985), seed germination, and plant establishment.

The higher cover of litter and perennial grass cover under the shelter treatments compared to the ambient was interesting. Part of the reason for this result is that litter breakdown under the shelters appears to be less than in the ambient treatment. Litter under ambient conditions was more exposed and tended to bleach out and be more easily decomposed during the winter months. Snow tended to push vegetation down so that it contacted the soil surface quicker in the ambient treatment. Grass litter under the shelters did not change color, retained a rich golden hue, and often remained standing for several years. Bunchgrasses under the shelters retained much standing litter, which was difficult to separate out from new growth, thus our higher cover estimates. The greater amounts of standing litter is also the reason for the higher biomass values for the treatments under the shelters compared to the ambient. These results demonstrate the importance of exposure to sunlight and other weather events (snow, hail) in assisting in the breakdown of vegetation litter in the sagebrush steppe ecosystem.

**Roots**

In all treatments, root activity appeared to be correlated to soil moisture conditions particularly in the upper (10 to 20 cm) soil profile. During periods of higher moisture availability root activity increased. As soil moisture declined later into the growing season, root activity decreased. The spring treatment maintained root growth later into the season compared to the other treatments, which we attribute to the later precipitation pattern of this treatment. The higher rooting activity in the upper profile was not surprising because soil nutrients were most readily available from 0 to10 cm.

Although there was a lack of any consistent treatment effects, it does appear that the spring treatment may be allocating more resources to belowground structures. Spring treatment root counts were similar to the other treatments during the spring months. By the summer season root counts in the spring treatment were higher than the other treatments. When we harvest roots as planned later in the study, the measurement of root mass and lengths will provide us a better indication of belowground resource allocation in the individual treatments.

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Table 1. Water year (Oct-Sept) schedule for shelter treatments (winter, spring, current). Precipitation amounts totaled 8 inches in the 1995-96 and 1996-97 water years. Values are percentage of total applied in a given month.

| | Treatment | | |
|---|---|---|---|
| Month | Spring | Current | Winter |
| October | 10% | 10% | 10% |
| November | | | |
| December | | | |
| January | | 50% | 80% |
| February | | | |
| March | 10% | | |
| April | | | |
| May | | 30% | 5% |
| June | 80% | | 5% |
| July | | 5% | |
| August | | | |
| September | | 5% | |

Table 2. Plant cover (%) during two sampling dates of 1995, 1996, and 1997 for the four precipitation treatments. Different lower case letters indicate significant differences between treatments within sampling date.

| | Sagebrush | Litter | Bareground | Cryptogam | Perennial Grass | Total Forb | Perennial Forb | Annual Forb |
|---|---|---|---|---|---|---|---|---|
| | (%) | (%) | (%) | (%) | (%) | (%) | (%) | (%) |
| May '95 | | | | | | | | |
| Ambient | 7 | 22.1 b | 48.9 c | 2.3 a | 14.2 a | 12.4 a | 4.6 | 7.5 b |
| Control | 11.4 | 24.4 ab | 51.9 b | 1.9 a | 15.3 a | 7.0 b | 3.7 | 3.1 c |
| Spring | 6 | 25.9 a | 60.0 a | 0.6 b | 9.9 b | 4.0 c | 3.2 | 0.8 d |
| Winter | 8.8 | 21.9 b | 50.6 a | 0.3 b | 13.3 a | 14.4 a | 4.4 | 9.7 a |
| July '95 | | | | | | | | |
| Ambient | | 26.1 b | 54.3 | 1.6 a | 9.3 b | 2.7 c | 2.3 | 0.4 c |
| Control | | 29.3 a | 51.8 | 1.1 a | 14.1 a | 4.0 c | 2.5 | 1.5 b |
| Spring | | 25.7 b | 57.6 | 0.4 b | 12.0 a | 4.4 c | 2.8 | 1.6 b |
| Winter | | 27.6 ab | 54.5 | 0.7 ab | 11.4 ab | 6.0 a | 1.7 | 4.3 a |
| June '96 | | | | | | | | |
| Ambient | 7.8 | 19.2 | 51.9 a | 3.6 a | 18.1 b | 7.8 c | 6.0 | 1.8 c |
| Control | 12.5 | 20.0 | 43.3 b | 1.5 ab | 23.9 a | 11.9 ab | 7.7 | 4.2 b |
| Spring | 7.7 | 18.4 | 50.5 a | 1.2 ab | 20.0 b | 9.7 bc | 8.4 | 2.3 c |
| Winter | 11.3 | 20.2 | 43.5 b | 0.6 b | 21.6 ab | 14.7 a | 8.2 | 6.5 a |
| August '96 | | | | | | | | |
| Ambient | 7.3 b | 26.2 b | 54.3 a | 1.6 a | 15.3 | 2.7 | 2.3 | 0.4 c |
| Control | 13.6 a | 34.8 a | 43.0 b | 0.2 b | 18.8 | 3.6 | 2.5 | 1.1 ab |
| Spring | 9.0 a | 28.2 b | 50.9 a | 0.4 b | 16.0 | 4.7 | 3.8 | 0.9 b |
| Winter | 7.1 b | 34.7 a | 42.1 b | 0.4 b | 18.5 | 4.8 | 3.3 | 1.5 a |
| May '97 | | | | | | | | |
| Ambient | 6.8 b | 15.8 c | 61.6 a | 2.5 a | 14.8 b | 4.5 c | 3.8 b | 0.7 b |
| Control | 9.5 a | 26.8 a | 41.9 c | 0.7 b | 24.7 a | 5.6 b | 4.7 a | 0.8 b |
| Spring | 7.9 b | 20.6 b | 52.4 b | 0.4 b | 22.2 a | 4.0 c | 3.8 b | 0.2 c |
| Winter | 10.5 a | 25.2 ab | 40.8 c | 0.4 b | 26.2 a | 6.2 a | 4.8 a | 1.4 a |
| July '97 | | | | | | | | |
| Ambient | 6.7 b | 18.1 a | 67.2 a | 1.0 a | 11.3 b | 1.5 c | 1.3 b | 0.2 b |
| Control | 9.2 a | 24.8 a | 52.8 b | 0.4 b | 19.1 a | 2.8 b | 2.1 ab | 0.7 a |
| Spring | 8.3 a | 18.6 a | 59.1 ab | 0.4 b | 18.1 a | 3.6 a | 3.4 a | 0.2 b |
| Winter | 9.3 a | 26.8 a | 52.3 b | 0.1 b | 17.7 a | 3.0 ab | 2.4 ab | 0.6 a |

Table 3. Plant density (#/m^2) during two sampling dates of 1995, 1996, and 1997 for the four precipitation treatments. Different lower case letters indicate significant differences between treatments within sampling date.

| | Sagebrush | Cryptogam | Perennial Grass | Total Forb | Perennial Forb | Annual Forb |
|---|---|---|---|---|---|---|
| | (#/m^2) | (#/m^2) | (#/m^2) | (#/m^2) | (#/m^2) | (#/m^2) |
| May '95 | | | | | | |
| Ambient | 0.9 | 2.2 a | 28.4 c | 594 a | 19.4 b | 574 a |
| Control | 0.7 | 1.4 b | 30.5 a | 337 c | 22.4 a | 334 c |
| Spring | 0.6 | 0.6 c | 24.5 b | 89 d | 18.4 b | 70 d |
| Winter | 0.5 | 0.7 c | 26.3 d | 469 b | 19.4 b | 450 b |
| July '95 | | | | | | |
| Ambient | | 2.0 a | 25.9 b | 500 a | 11.7 c | 488 a |
| Control | | 1.2 a | 31.3 a | 293 c | 18.9 a | 274 c |
| Spring | | 0.5 b | 29.4 a | 191 d | 18.1 ab | 173 d |
| Winter | | 0.7 b | 23.8 b | 434 b | 12.9 bc | 421 b |
| June '96 | | | | | | |
| Ambient | 0.9 a | 10.5 a | 27.0 | 173 b | 16.6 | 156 b |
| Control | 0.6 b | 8.6 ab | 29.1 | 376 a | 18.9 | 357 a |
| Spring | 0.5 b | 9.6 ab | 26.8 | 174 b | 15.9 | 158 b |
| Winter | 0.5 b | 9.4 b | 25.1 | 375 a | 17.5 | 357 a |
| August '96 | | | | | | |
| Ambient | 1.1 a | 9.3 a | 23.2 | 112 b | 10.8 | 101 d |
| Control | 0.6 b | 1.7 b | 24.0 | 272 a | 9.1 | 262 b |
| Spring | 0.6 b | 4.3 b | 24.4 | 169 b | 12.0 | 169 c |
| Winter | 0.4 b | 5.1 ab | 23.3 | 381 a | 9.8 | 371 a |
| May '97 | | | | | | |
| Ambient | 0.9 a | 8.7 a | 25.1 b | 145 a | 27.0 a | 118 a |
| Control | 0.5 b | 3.8 b | 33.1 a | 94 bc | 23.8 ab | 170 bc |
| Spring | 0.6 b | 4.2 b | 27.4 b | 50 c | 18.2 b | 31 c |
| Winter | 0.5 b | 8.3 a | 35.0 a | 132 ab | 23.9 ab | 108 ab |
| July '97 | | | | | | |
| Ambient | 0.9 a | 4.0 a | 26.5 b | 67 b | 17.4 | 49 b |
| Control | 0.5 b | 2.1 b | 26.1 b | 114 a | 14.5 | 100 a |
| Spring | 0.6 b | 6.2 b | 29.1 a | 56 b | 18.5 | 37 b |
| Winter | 0.5 b | 3.1 a | 30.6 a | 126 a | 17.5 | 109 a |

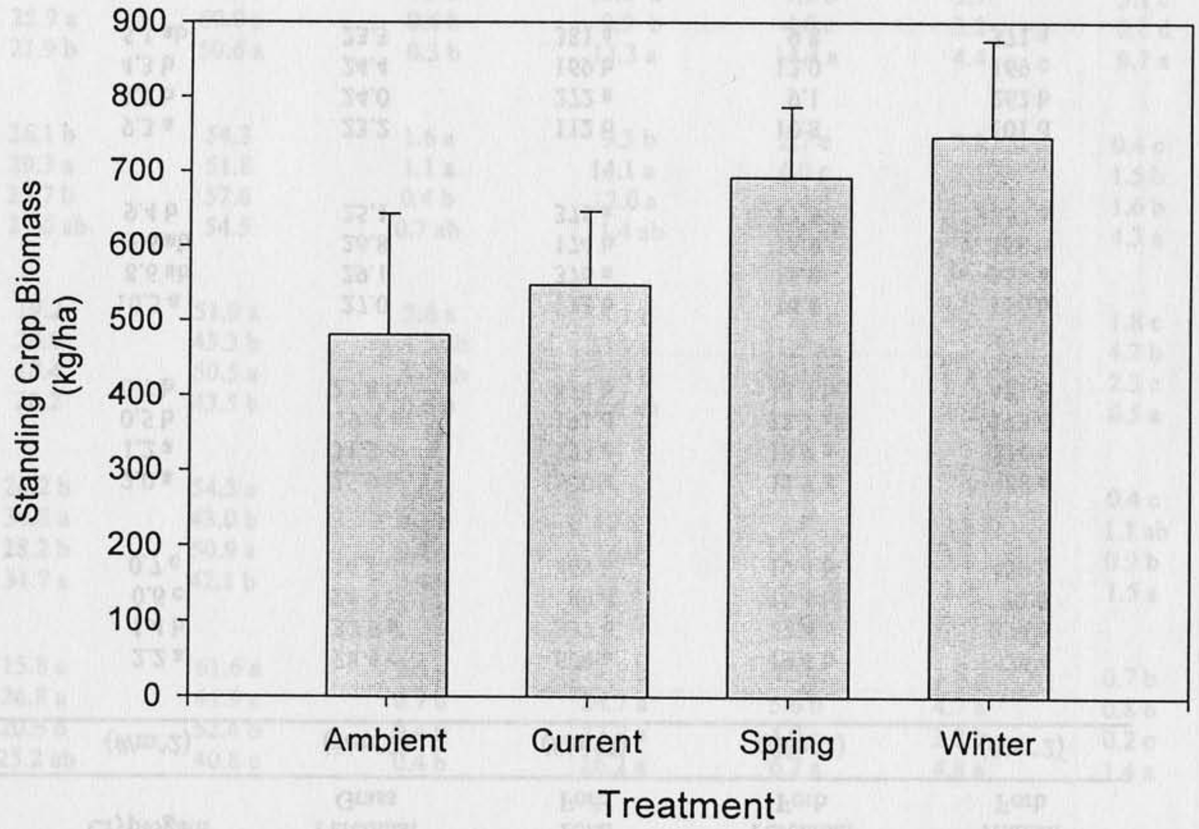


Figure 1. Standing crop herbaceous biomass (kg/ha) in February 1998 for the precipitation treatments.

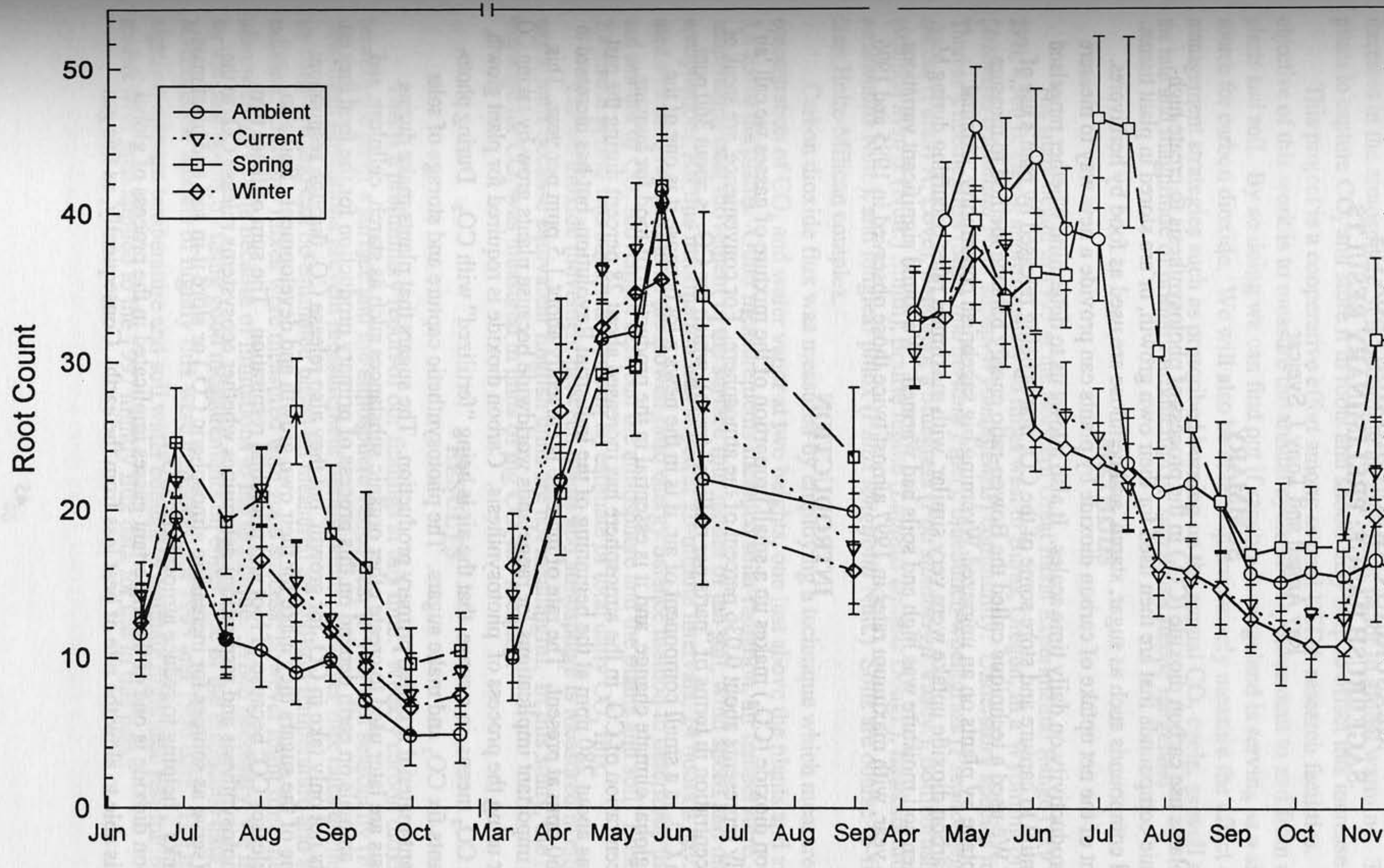


Figure 2. Rooting activity of plants in the precipitation treatments. Root counts are sums of root intersects with minrhizotron tubes at 5, 10, 20, 30, and 40 cm soil depth.