Final Report - Jul 2004

Report to the Shipley Skinner Grant Committee
Robert D. Cox
and
Edith Allen

Introduction

In Riverside County, coastal sage scrub (CSS) is a highly diverse vegetation type, and is considered either suitable or requisite habitat for over 200 plants and animals currently endangered, threatened, or of "special concern" (O'Leary 1989, Skinner and Pavlik 1994, DiSimone 1995). Although it is difficult to estimate the area originally occupied by CSS, there is general agreement that it is currently much reduced from its former extent, and that what little is left is often in poor condition (Westman 1981, Minnich and Dezzani 1998, Allen et al. 2000, Bowler 2000). In addition, those CSS areas now in good condition are likely to undergo degradation in the future due to a combination of many threats, including urbanization, disturbance, fire, nitrogen deposition, and invasion by exotic annuals (Minnich and Dezzani 1998). In recent years, concern has grown over CSS decline and associated loss of biodiversity (Bowler 2000). These concerns, combined with political and policy imperatives, have made preservation of CSS vegetation a high priority for land managers (Rubinoff 2001).

The generally poor condition of remaining CSS areas and the high threat of future degradation indicate that the continued existence of both CSS vegetation and the species that inhabit it may depend not only on conservation and preservation efforts, but also on enhancement and restoration of CSS vegetation (Allen et al. 2000). Ecological restoration is "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed" (SER 2002). As an applied science, restoration ecology has separate aims from basic ecology, but may also be an ideal platform for investigating many of the ideas central to basic ecology (Dobson et al. 1997, Palmer et al. 1997), such as seedbank storing of plant communities and the interplay between perennial, annual, native and exotic species. This study investigates these two issues as they relate to CSS areas of the Shipley Reserve.

The Importance of Background Community

Competition is cited as a major obstacle to restoration success (Monsen and McArthur 1995, Allen et al. 2000), as well as a factor influencing structure and composition in native communities (Grime 1977, Tilman 1982, Keddy 1990, Greiner La Peyre et al. 2001). It is generally accepted that control of exotic grasses is necessary when attempting to reestablish native perennials (Monsen and McArthur 1995, Eliason and Allen 1997, Allen et al. 2000). In many CSS areas, however, both exotic grasses and exotic forbs have replaced native species (Minnich and Dezzani 1998, Bowler 2000), and it is unknown how exotic forbs may influence establishment of native species. Whether native species emerge better in exotic grasses or exotic forbs is unknown, but understanding the relationships between exotic grasses, exotic forbs, and native species is very important, as we currently know of no practical method for reducing exotic forbs without also reducing native species. A greater understanding of this issue will aid managers of CSS areas in planning and successfully completing restoration projects.

Seedbanks

The composition of seeds in the soil is related to composition and seed production of the aboveground vegetation through time, and how long each seed persists in the soil (van der Valk and Pederson 1989). Many mediterranean-style ecosystems are characterized by persistent seedbanks (Parker and Kelly 1989), and these seedbanks are important components of their plant communities, representing a record of previous plants at the site (Henderson et al. 1988, Coffin and Lauenroth 1989). Thus, it is possible that even when native species are absent above ground in areas formerly dominated by CSS, their long-lived seeds may persist in soils beneath grass-dominated communities.

The presence or absence of a desirable seedbank has ramifications for restoration efforts at the site, since it is possible that persistent seed banks may be exploited and managed for conservation or restoration purposes (Keddy et al. 1989, van der Valk and Pederson 1989). Seedbank differences between CSS and adjacent grassland are of particular interest because such differences may lend insight into how these areas may respond to future disturbance, climatic events, and restoration efforts. If native seeds are present in the soil, managers could focus restoration strategies on promoting germination and establishment of species already represented as seeds in the soil. If areas prove to have few native seeds in the soil, such as areas that were historically cropped or frequently burned (Cione et al. 2002), additional seeds may be supplied. Alternatively, restoration efforts might be most effective if focused in areas where soil-stored seeds are more abundant, thus providing higher native diversity with lower restoration costs.

Methods

Background Community

This experiment was established at the Shipley Multi-species Habitat Reserve in areas now dominated by exotic annual grasses, and adjacent to extant CSS. The experiment consisted of a 4 X 2 factorial design replicated in 10 blocks (fig. 1). Blocks were located throughout the Shipley Reserve: 7 in the Crown Valley area and 3 in the Lopez Canyon area. Native species emergence was monitored at two levels of seeding (seeds added and seeds not added), and at 4 categories of background community: 1) exotic grass only, 2) exotic forbs only, 3) nothing (plot completely removed of all species), and 4) all species. Each plot was weeded by hand to exclude all plants except those indicated.

Treatments were assigned randomly to the $0.5m^2$ experimental units. Although the grant supported work done during the growing season of 2003-2004, this experiment was also completed during the previous growing season, (i.e. 2002-2003). Weeding was accomplished during the fall of 2002 and 2003 for each year's plots, and native species were seeded on February 7, 2003 and on January 1, 2004. Species seeded and their respective seeding rates (in pure live seed per m^2) are listed in table 1.

Table 1. Species and amounts seeded, in pls per meter. Lessingia filaginifolia was seeded only in 2003. Seeds were not available in 2004.

Species	**pls/m²**
Eriogonum fasciculatum foliosum	94.8
Artemisia californica	121.9
Gutierrezia californica	15
Lessingia filaginifolia (not seeded in 2004)	1.15
Castilleja exserta	203.5
Lasthenia californica	167.4
Lupinus bicolor	6.9
Lupinus sparsiflorus	13.5
Dichelostemma capitatum	3.25

Data collected included cover of all species and number of all seeded species emerging in the plots. For analysis, native species were grouped, as were seeded species. The first growing season of each year was analyzed together, while the second growing season of plots established in 2002 was analyzed separately. Cover data was arcsine transformed, and seedling data was square-root transformed, and then analyzed by ANOVA using JMP to test native species cover, seeded species cover, and the number of seedlings of seeded species within each type of background community: "everything" (plot not weeded), "nothing" (all exotic species removed), "exotic grass" (exotic forbs removed), and "exotic forb" (exotic grasses removed).

Seedbanks

Seedling emergence is recommended over flotation or sieving techniques to quantify germinable seedbank composition and density at the community level (Simpson 1989). This portion of the study began by taking 60 soil samples from each of 3 areas on the reserve: two areas in the Crown Valley portion of the reserve (areas 1 and 2) and 1 area in the "Lopez Canyon" portion (area 3). Within each area, 30 samples were taken from a polygon dominated by exotic grasses, and 30 from an adjacent polygon dominated by native shrubs. Within each polygon, five 7m lines were randomly selected along a 20m transect, and six randomly located soil samples were taken along each line. Soil samples were collected in early October 2003, using a 10cm-diameter soil corer inserted 7cm into the soil. Each sample was air dried, and then stored at about 4°C for 5 months. In late October 2003, wildfires burned approximately 4,000 acres on the Shipley-Skinner reserve, including the Lopez Canyon area (1 grass- and 1 shrub-dominated polygon) from which soil samples were previously collected. Following the fire, these sites were resampled in the same manner, to allow inference between burned and unburned soils. On March 13 2004, all soil samples were spread on Styrofoam food service trays in the greenhouse. Each sample was kept moist, and the emerging seedlings were identified and removed.

Data was analyzed by ANOVA using JMP to compare grass-dominated and shrub-dominated areas, and to compare burned versus unburned areas. Since only one site (site 3) burned, the unburned sites were analyzed together, and then site 3 (burned and unburned) was analyzed separately to evaluate the effects of wildfire on soil seedbanks.

Results

Background Community

Native species' cover in the first growing season showed significant effects of year, block, and background community. Seeding did not significantly increase cover of native species in the first growing season. In 2003, cover of native species was nearly 25%, while less than 5% in 2004. Figure 2 displays results for the background community effect. Plots dominated with exotic grasses had approximately 1/3 the cover of native species as plots dominated by exotic forbs.

Cover of seeded species after the first growing season was significantly affected by year, block, and seeding. Background community had no significant effect on cover of seeded species. Year and block showed a significant interaction (fig. 3). Plots seeded in 2003 had significantly more cover of seeded species than plots seeded in 2004, driven by 4 particularly high-producing blocks. Plots that received native seeds had a small, but significantly greater percentage of cover of seeded species than plots that received no native seeds (fig. 4).

Year, block, seeding, and background community also significantly affected the number of seedlings of seeded species. Significant interactions of year*block, year*seeding, and year*background community show that in every case, 2003 had a much greater number of seedlings than 2004. In this analysis, the interaction of seeding*background community (fig. 5) was also significant, and seeded plots which were removed of all exotic species had approximately 2/3 more seedlings than other plots.

After the second growing season, cover of native species was significantly affected by block and background community (fig. 6) only. Plots dominated by exotic grass had significantly less cover of native species than plots with no exotic species.

Cover of seeded species and number of seedlings were both affected by block, seeding, and background community. The two-way interactions of seeding*background community were also significant (fig. 7 and 8, respectively). Once again, seeded plots that were weeded of all exotic species provided much greater cover of seeded species and number of seedlings.

Seedbanks

When evaluating soil-stored seeds of both exotic grasses (fig. 9) and native species (fig. 10) across unburned sites, the only significant effect was that of location. Location 3, with approximately 7000 seeds of exotic grasses and 500 seeds of native forbs per m^2, had many more seeds than locations 1 and 2. Exotic forb seeds showed no significant effect of location, but were significantly greater (nearly 4 times) in grass-dominated soils as compared to shrub-dominated soils fig. 11).

When comparing the burned versus the unburned sites, ANOVA revealed several significant effects. Exotic grasses had about 7000 seeds per sample in unburned areas, while burned areas had less than 150 exotic grass seeds per m^2 (fig. 12). Exotic forbs again had approximately twice as many seeds in samples collected from grass-dominated areas as from shrub-dominated areas(fig. 13). Finally, native forbs had over 500 seeds per m^2 in unburned soils, while burned soils had less than 200 seeds per m^2 (fig. 14).

Discussion

It is no surprise that restoration experiments are often greatly influenced by the year in which they occur. Such an effect may be due to precipitation or some other combination of climatic variables. During the growing seasons of this study (2002-2003 and 2003-2004), precipitation was relatively similar (fig. 15 and 16). A major difference between the two years, however, was slightly lower precipitation during the critical late-winter season of February and March, 2004. In the background community study, every category (native species, seeded species, and number of seedlings) was significantly greater during the first growing season. The higher cover of native and seeded species, as well as the greater numbers of seedlings during the first growing season, may be at least in part due to differences in precipitation between the two years, although more study would be necessary to quantify the relationship.

Once the effects of year are taken into account, however, several points are clear. Seeding of native species is much more successful when all exotic species have been removed; exotic grasses and forbs showed similar inhibitions of seeded species (see fig. 5, 7, 8). On the other hand, native species overall (as opposed to those that were seeded) did have greater cover in areas dominated by exotic forbs than in areas dominated by exotic grass during the first growing season (fig. 2). During the second growing season, exotic forb-dominated areas displayed a small increase in native species cover, but the increase was not significant (fig. 6). It is apparent that exotic grasses exert a powerful effect on the ability of native species, whether artificially seeded or naturally present in the soil, to establish at a site. This study also provides evidence for the idea that exotic forbs may inhibit establishment of seeded species in a manner similar to exotic grasses.

Such inhibition of native species by exotic grasses and forbs is especially troubling when the seedbank analysis is considered. Analysis of seedbanks at the Shipley Reserve provides evidence for remarkably low numbers of native seeds in CSS areas of the reserve. Egerton-Warburton and Allen (unpublished data) reported only 50 seeds per m^2 in a similar area of the Skinner Reserve. In our analysis, native seed density ranged from approximately 150 seeds per m^2 to over 500 seeds per m^2. Burned and unburned areas followed a similar pattern: less than 200 seeds per m^2 in burned areas, and just over 500 in unburned areas. These numbers are encouraging as to the absolute presence of native species in the seedbank throughout the reserve, but when taken in context with the density of exotic grass and forb seeds, troubling conclusions are inescapable. Exotic grass seeds at all unburned locations exceeded 3000 seeds per m^2, and approached 7000 at location 3. Exotic forb seeds also had high density in grass-dominated locations (more than 2000 per m^2), though density in shrub-dominated areas was more similar to native seeds (approximately 500 seeds per m^2).

Among unburned seedbanks, the effect of location across the landscape was most important (fig. 9 and 10) in determining the numbers of seeds of exotic grasses and native species present in the seedbank. Others have also shown that many seedbanks correspond poorly to the existing vegetation on a site (Coffin and Lauenroth 1989, Gilfedder and Kirkpatrick 1993), and exhibit a high degree of spatial variability (Henderson et al. 1988). This study shows that exotic grasses are found in high densities in both CSS- and exotic grass- dominated locations at the reserve, and suggests that areas of the reserve currently dominated by stands of CSS are also heavily invaded by exotic grasses, and may be very vulnerable to degradation and even loss of native components.

When comparing burned and unburned seedbanks, the strong effect of wildfire on native soils is evident. In this study, fire greatly reduced overall densities of both exotic grasses and native species (fig. 12, 14), but did not significantly affect density of exotic forbs, which showed significant effects only in grass-dominated soils, whether comparing between sites or between burned and unburned sites (fig. 13). This suggests that while fire may beneficially reduce the density of viable exotic grass seeds in soils at the reserve, in may also reduce densities of native seeds, while having little effect on exotic forb seeds, thus allowing such exotic forbs to further inhibit establishment of native species.

Literature Cited

Allen, E.B., S.A. Eliason, V.J. Marquez, G.P. Schultz, N.K. Storms, C.D. Stylinski, T.A. Zink, and M.F. Allen. 2000. What are the limits to restoration of coastal sage scrub in southern California? pp. 253-262. *In:* J.E. Keeley, M. Baer-Keeley, and C.J. Fotheringham (eds). 2000. 2nd interface between ecology and land development in California. USGS Open File Report 0062.

Bowler, P.A. 2000. Ecological restoration of coastal sage scrub and its potential role in habitat conservation plants. Environmental Management 26(supp):S85-S86.

Cioni, N.K., P.E. Padgett, and E.B. Allen. 2002. Restoration of a native shrubland impacted by exotic grasses, frequent fire, and nitrogen deposition in southern California. Restoration Ecology 10:376-384.

Coffin, D.P, and W.K. Lauenroth. 1989. Spatial and temporal variation in the seed bank of a semiarid grassland. American Journal of Botany 76:53-58.

DiSimone, S. 1995. California's coastal sage scrub. Fremontia 23:3-8.

Dobson, A.P., A.D. Bradshaw, and A.J.M. Baker. 1997. Hopes for the future: restoration ecology and conservation biology. Science 277:515-522.

Eliason, S.A. and E.B. Allen. 1997. Exotic grass competition in suppressing native shrubland re-establishment. Restoration Ecology 5:245-255.

Gilfedder, L, and J.B. Kirkpatrick. 1993. Germinable soil seed and competitive relationships between a rare native species and exotics in a semi-natural pasture in the midlands, Tasmania. Biological Conservation 64:113-119.

Greiner La Peyre, M.K., J.B. Grace, E. Hahn, and I.A. Mendelssohn. 2001. The importance of competition in regulating plant species abundance across a salinity gradient. Ecology 82:62-69.

Grime, J.P. 1977. Evidence for the existence of three primary strategies in plants and its relevance to ecological theory. The American Naturalist. 111:1169-1194.

Henderson, C.B., K.E. Peterson, and R.A. Redak. 1988. Spatial and temporal patterns in the seed bank and vegetation of a desert grassland community. Journal of Ecology 76:717-728.

Keddy, P.A., I.C. Wisheu, B. Shipley, and C. Gaudet. 1989. Seed banks and vegetation management for conservation: toward predictive community ecology. Pp. 347-366 *In:*

M.A. Leck, V.T. Parker, and R. L. Simpson (eds). 1989. Ecology of Soil Seedbanks. Academic Press, San Diego, California.

Keddy, P.A. 1990. Competitive hierarchies and centrifugal organization in plant communities. pp. 266-290 *In:* J.B. Grace and D. Tilman (eds). 1990. Perspectives on plant competition. Academic Press, San Diego, Ca.

Minnich, R.A. and R.J. Dezzani. 1998. Historical decline of coastal sage scrub in the Riverside-Perris plain, California. Western Birds 29:366-391.

Monsen, S.B. and E.D. McArthur. 1995. Implications of early intermountain range and watershed restoration practices. P. 16-25. *In*: B.A. Roundy, D. E. McArthur, J.S. Haley and D. K. Mann, compilers. Proceedings—wildland shrub and arid land restoration symposium. USDA Forest Serv. Gen. Tech. Rep. INT-GTR-315, Intermountain Research Station, Ogden, Ut.

O'Leary, J.F. 1989. California coastal sage scrub; General characteristics and future prospects. Crossosoma 15:4-5

Palmer, M.A., R.F. Ambrose, and N.L. Poff. 1997. Ecological theory and community restoration ecology. Restoration Ecology 5:291-300.

Parker, V.T. and V.R. Kelly. 1989. Seed banks in California chaparral and other mediterranean climate shrublands. Pp. 231-255 *In:* M.A. Leck, V.T. Parker, and R. L. Simpson (eds). 1989. Ecology of Soil Seedbanks. Academic Press, San Diego, California.

Rubinoff, D. 2001. Evaluating the California gnatcatcher as an umbrella species for conservation of Southern California coastal sage scrub. Conservation Biology 15(5): 1374-1783.

SER (Society for Ecological Restoration) science and policy working group. 2002. The SER primer on ecological restoration. www.ser.org/.

Simpson, R.L. 1989. Seedbanks: General concepts and methodological issues. Pp. 3- 8 *In:* M.A. Leck, V.T. Parker, and R. L. Simpson (eds). 1989. Ecology of Soil Seedbanks. Academic Press, San Diego, California.

Skinner, M.W. and B.M. Pavlik. 1994. CNPS inventory of rare and endangered vascular plants of California. California Native Plant Society, Sacramento, CA.

Tilman, D. 1982. Resource competition and community structure. Princeton University Press. Princeton, N.J.

van der Valk, A.G. and R.L Pederson. 1989. Seed banks and the management and restoration of natural vegetation. Pp. 329-346 *In:* M.A. Leck, V.T. Parker, and R. L.

Simpson (eds). 1989. Ecology of Soil Seedbanks. Academic Press, San Diego, California.

Westman, W.E. 1981. Diversity relations and succession in California coastal sage scrub. Ecology 62:170-184.

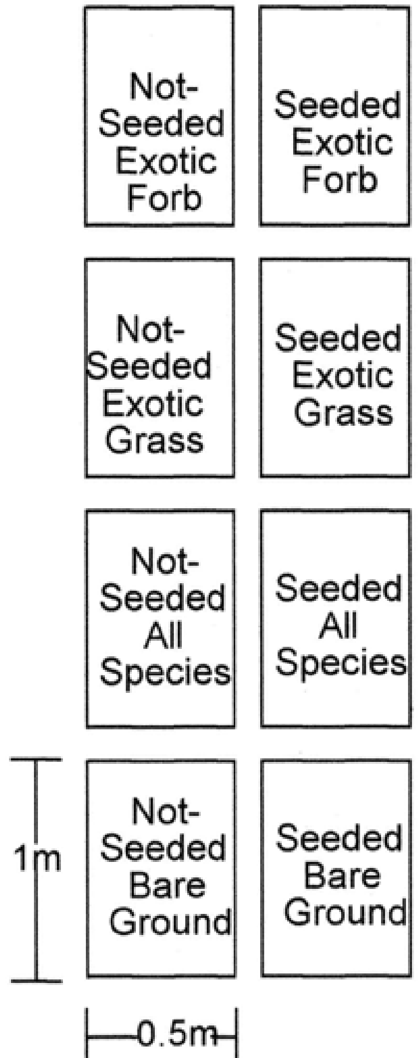

Figure 1. Sample layout of background community plots. Plots were weeded to exclude all plants except those indicated. All treatments were assigned randomly.

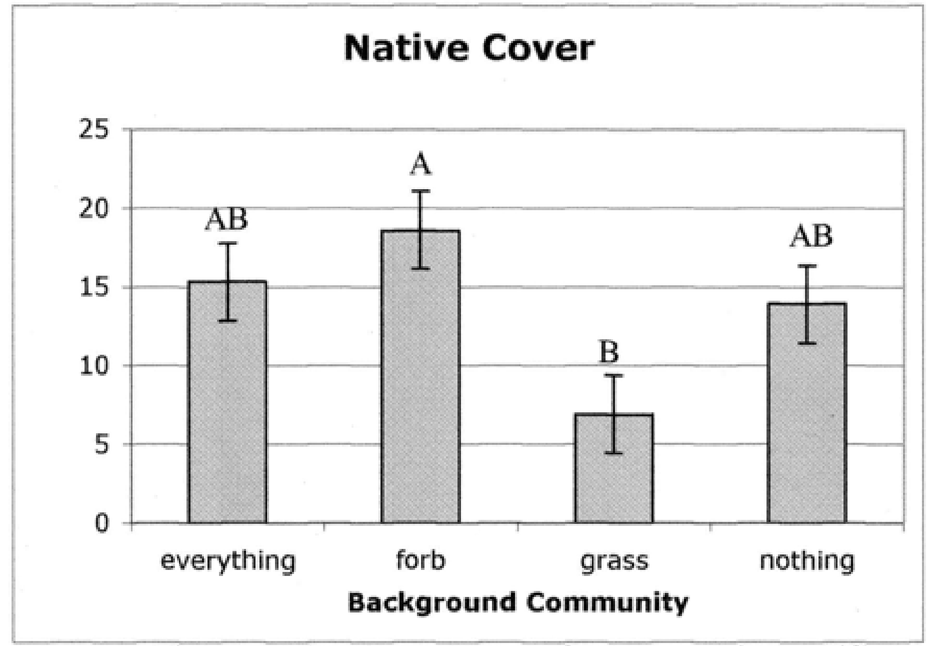

Figure 2. First growing season cover of native species in different types of background community. Bars not displaying the same letters are significantly different. Error bars represent standard error.

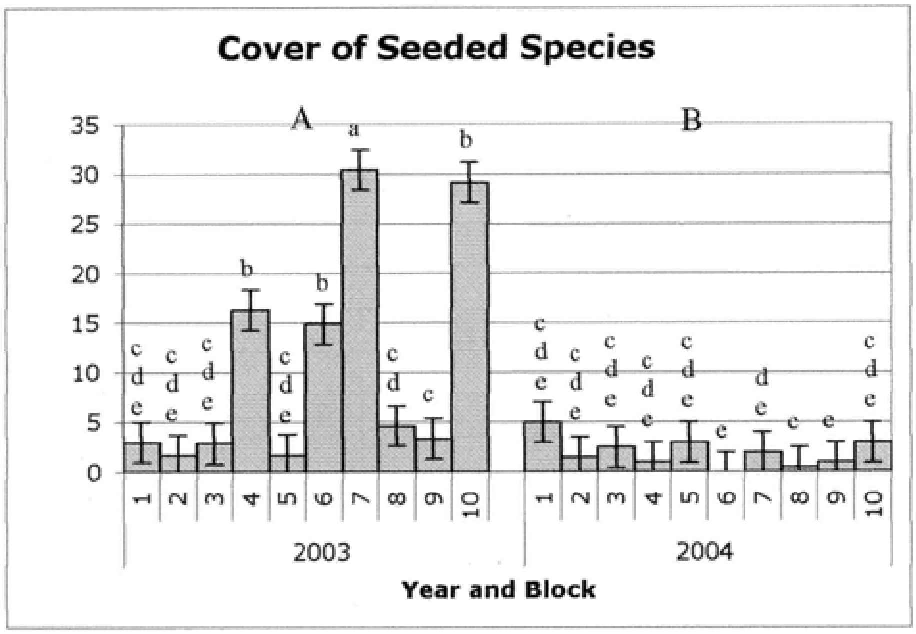

Figure 3. First growing season cover of seeded species in each block (1-10) each year. Bars not displaying the same letters are significantly different. Capital letters represent differences between years, and lower-case letters represent differences between blocks. Error bars represent standard error.

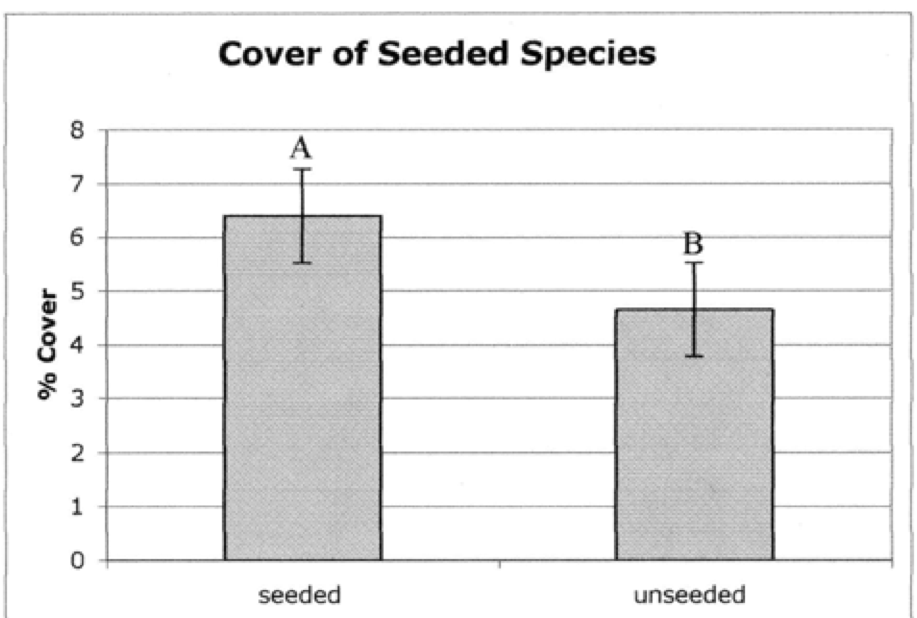

Figure 4. First growing season cover of seeded species in seeded and unseeded areas. Bars not displaying the same letters are significantly different. Error bars represent standard error.

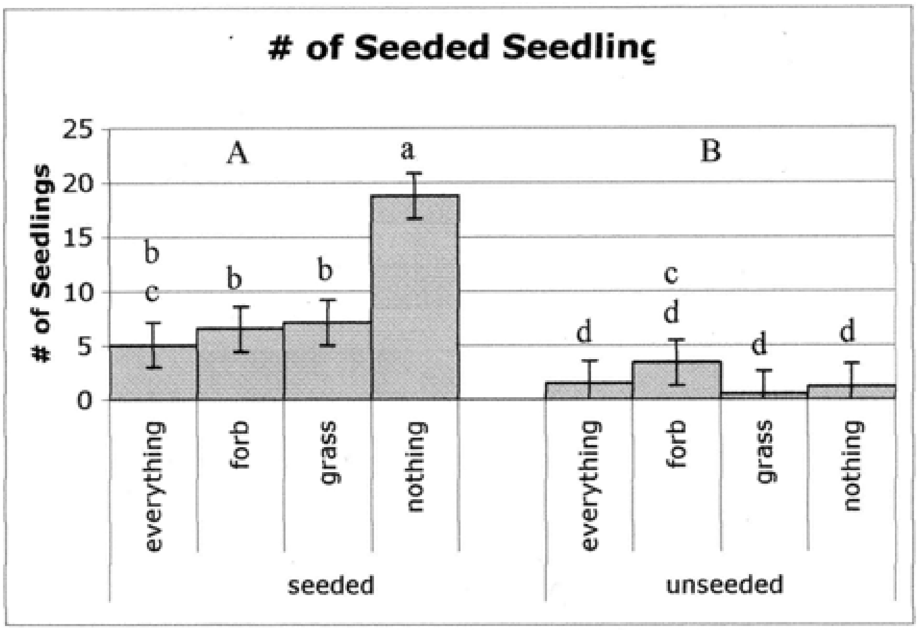

Figure 5. First growing season number of seedlings in different background communities and seeded and unseeded areas. Bars not displaying the same letters are significantly different. Capital letters represent different between seeded and unseeded areas, and lower-case letters represent differences between background community types. Error bars represent standard error.

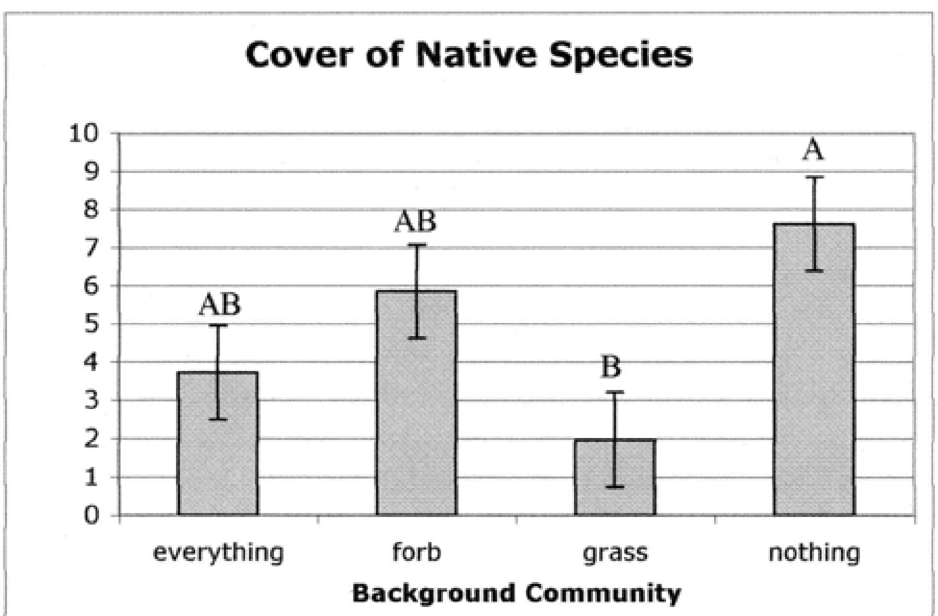

Figure 6. Second growing season cover of native species in different background communities. Bars not displaying the same letters are significantly different. Error bars represent standard error.

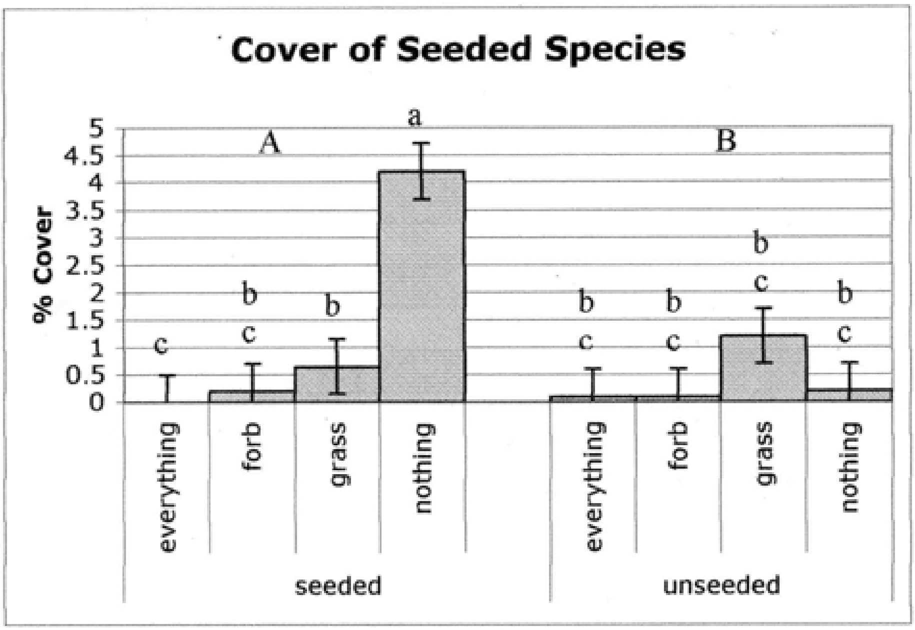

Figure 7. Second growing season cover of seeded species in different background communities and seeded and unseeded areas. Bars not displaying the same letters are significantly different. Capital letters represent differences between seeded and unseeded areas, and lower-case letters represent differences between background community types. Error bars represent standard error.

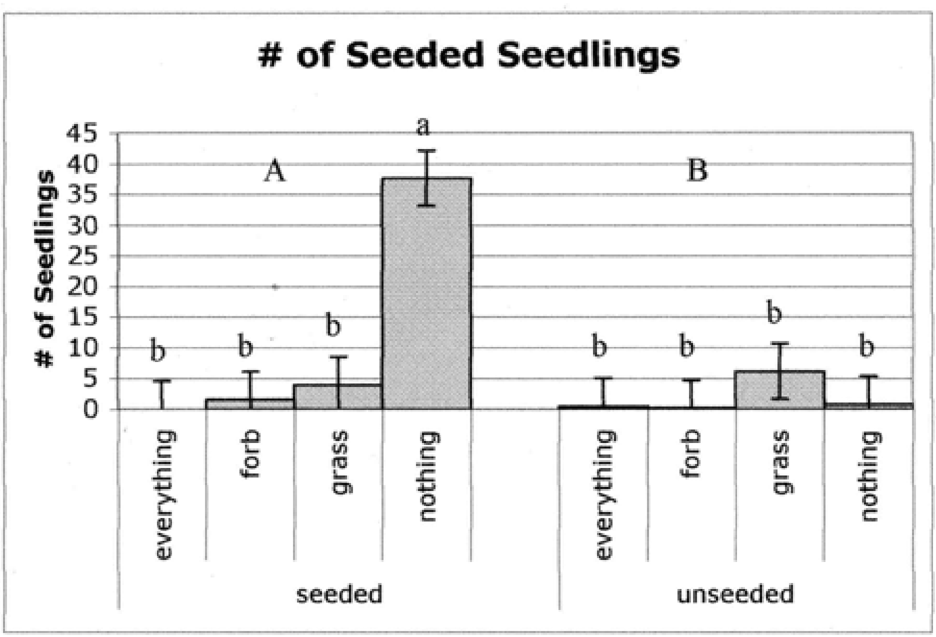

Figure 8. Second growing season number of seedlings in different background communities and seeded and unseeded areas. Bars not displaying the same letters are significantly different. Capital letters represent differences between seeded and unseeded areas, and lower-case letters represent differences between background community types. Error bars represent standard error.

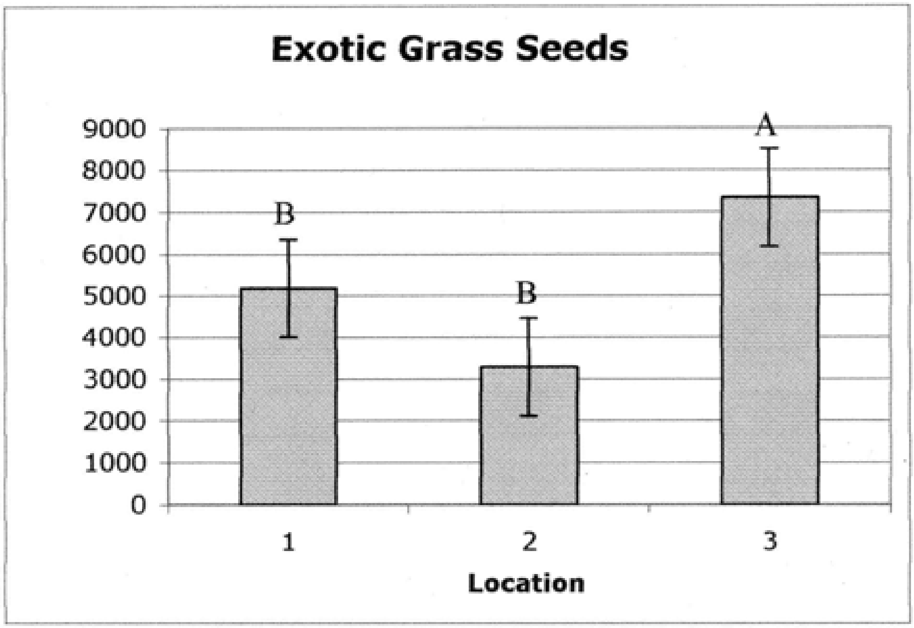

Figure 9. Number of exotic grass seeds in different locations. Bars not displaying the same letters are significantly different. Error bars represent standard error.

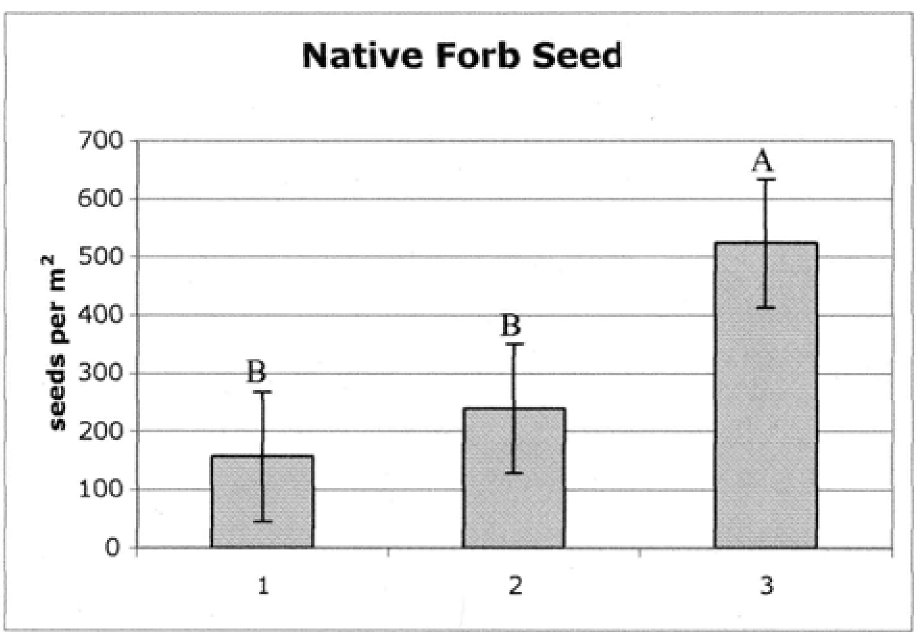

Figure 10. Number of seeds of native species in different locations. Bars not displaying the same letters are significantly different. Error bars represent standard error.

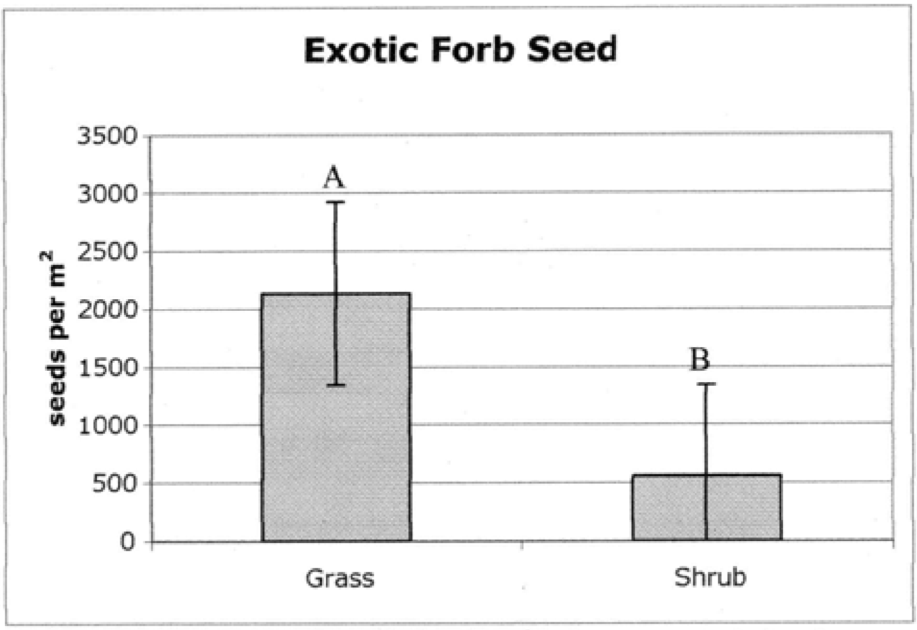

Figure 11. Number of exotic forb seeds in grass and shrub-dominated soils. Bars not displaying the same letters are significantly different. Error bars represent standard error.

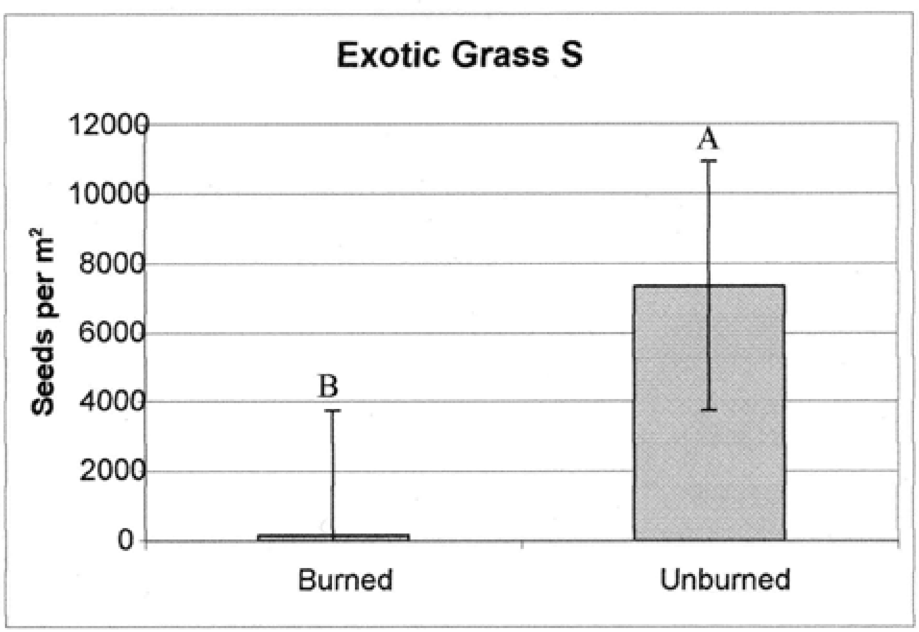

Figure 12. Number of exotic grass seeds in burned and unburned soils at location 3. Bars not displaying the same letters are significantly different. Error bars represent standard error.

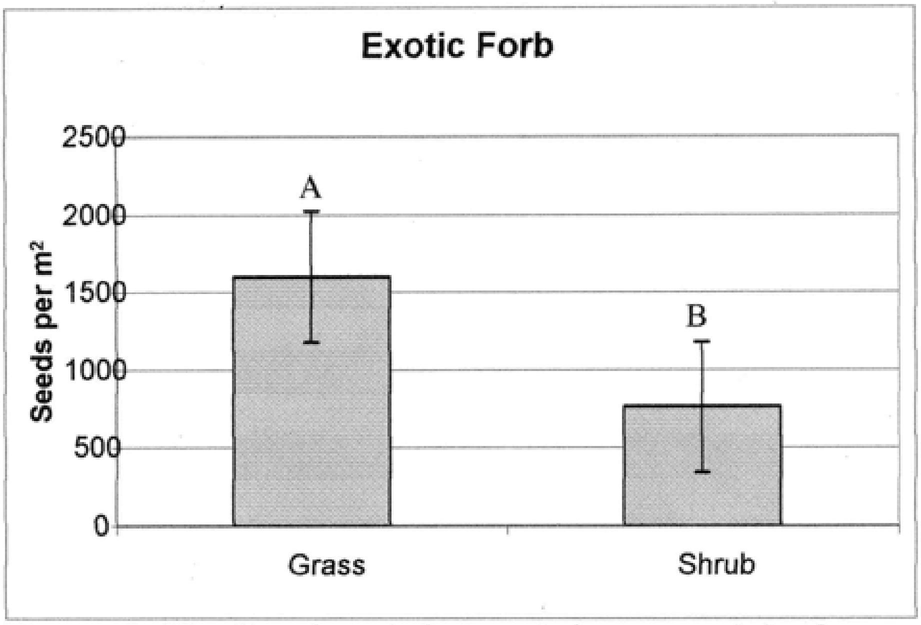

Figure 13. Number of exotic forb seeds in grass and shrub-dominated soils at location 3. Bars not displaying the same letters are significantly different. Error bars represent standard errors.

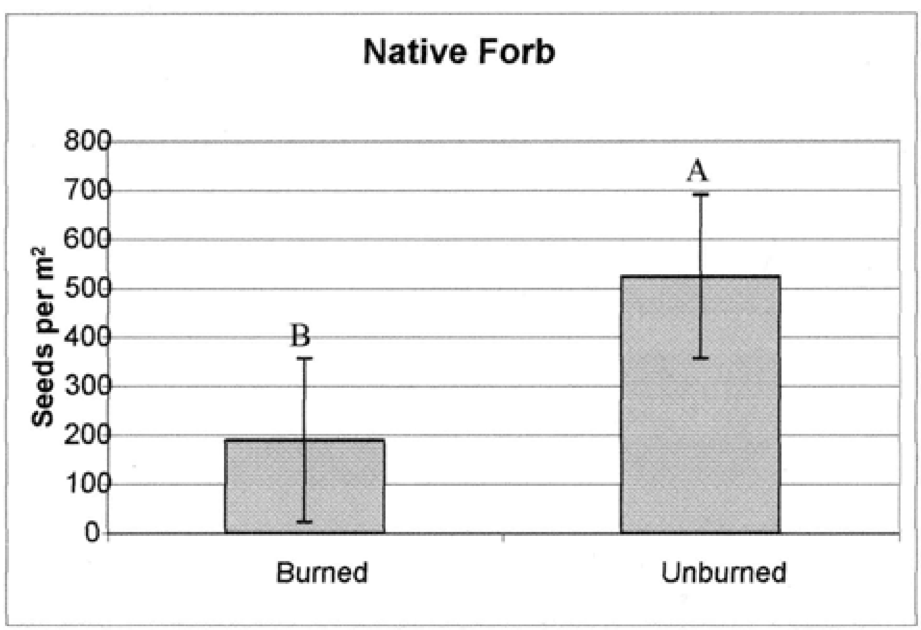

Figure 14. Number of seeds of native species in burned and unburned soils at location 3. Bars not displaying the same letters are significantly different. Error bars represent standard error.

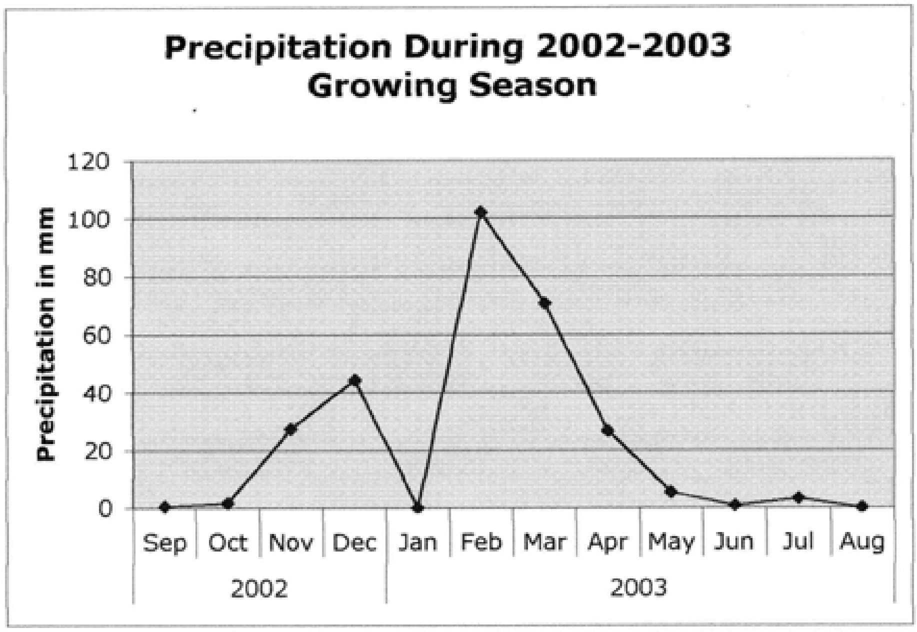

Figure 15. Precipitation in Riverside during the 2002-2003 growing season.

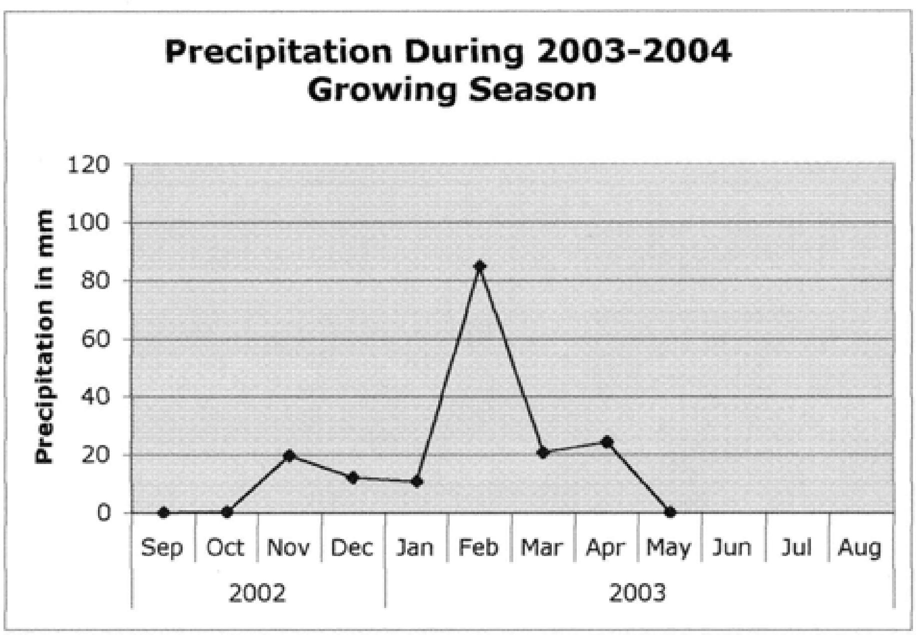

Figure 16. Precipitation in Riverside during the 2003-2004 growing season.