GRASSLANDS

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The effects of soil amendments and mulches on establishment of California native perennial grasses: a summary of selected results

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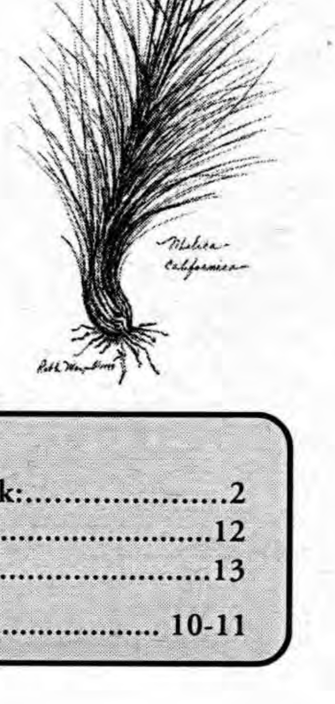
Editors note: Complete details of the results of this experiment will be available by July 2000 in a final report to the California Department of Transportation and can be obtained through their publications office at that time.

Abstract

Increased understanding of the relative efficacy of cultural practices such as fertilization and mulch application may improve our ability to establish native perennial grasses in restoration and erosion control projects. There are potential trade-offs for many of these practices. For example, fertilizing may improve growth of weeds to a greater extent than seeded perennial grasses, which could result in increased competition for resources and poorer perennial grass performance. Applying mulch may improve perennial grass seedling emergence, but weeds introduced in the straw may reduce perennial grass growth. We studied the effects of different types of straw mulch, compost and slow-release nitrogen fertilizer on the establishment and growth of California native perennial grasses. The mixture of perennial grasses, California melic (*Melica californica*), purple needlegrass (*Nassella pulchra*) and pine bluegrass (*Poa secunda* ssp. *secunda*), responded to interactions between nutrient availability, weeds and volunteers of the mulch species. The mixture of grasses exhibited the best nutrient status (%N and C:N) and growth with rice (*Oriza sativa*) straw mulch. These indices showed that the mixture performed most poorly with blue wildrye (*Elymus glaucus*) straw mulch; performance with wheat (*Triticum aestivum*) mulch was intermediate. The responses of individual species to mulch treatments varied. Success of the perennial grasses may have been primarily influenced by weeds and volunteers of the mulch species that grew from the straw. Rice straw mulch had the lowest and blue wildrye mulch had the highest abundance of weeds and volunteers from mulch. Differences in decomposition rates or allelopathic effects of the straws, or both may have also contributed to the effects we detected. The addition of compost benefitted weeds, but not the perennial grasses overall, although the responses of individual species varied. Competition from weeds suppressed the growth of perennial grasses, but this negative effect was eliminated by the addition of nitrogen fertilizer. In summary, perennial grass performance was best with rice straw, was improved by the addition of nitrogen fertilizer in the presence of weeds and was not greatly affected by the addition of compost.



Introduction

The appropriate cultural practices to apply in revegetation projects using native perennial grasses are still being developed. Many

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IN THIS ISSUE:

The California Native Grass Association is a membership organization that brings together diverse interests to "develop, promote, preserve, and restore" native grasses and grassland ecosystems in California. Members include conservationists, restoration practicioners, botanists, resource managers, horticulturalists, agency representatives, farmers, ranchers, homeowners, seed producers, scientists, consultants, students, and native plant enthusiasts.

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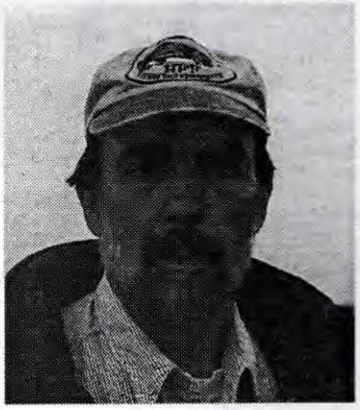
FROM THE PRESIDENT'S DESK



Spring ahead!

John Anderson, CNGA president

First, let me congratulate and welcome our newly-elected boardmembers: Sheila Barry from Alameda County, Sid Johnson from McCloud, and Mary McClanahan from the Fresno area. Each of them brings new expertise to the organization and I know CNGA will be stronger for their contributions (You can read more about Shiela, Sid, and Mary on page 13).

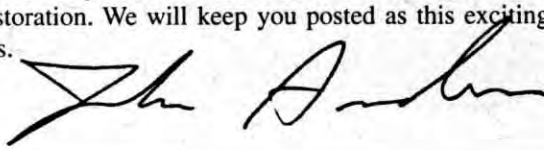
Our individual membership now exceeds 500, an all time high. Additionally, our corporate membership is growing energetically, giving us the financial stability to expand our programs and run the organization more effectively. I'd like to welcome the following companies who recently joined our bunchgrass circle, including: Conservaseed, Pacific Coast Seed, Rana Creek Habitat Restoration, Albright Seed Company, California Straw Works, Mark Seeding Services, Sierra View Landscape Inc., Zentner & Zentner, and the City of Davis. Many thanks also to our newest life members: Jane Anderson, Rene di Rosa, and Jim Hanson.

Through our individual and corporate supporters, CNGA was able to ring in the new century with an ambitous program agenda. We held a one-day restoration workshop in January for the East Bay Municipal Utilities District in Oakland. We are following up with a second day and a half program for EBMUD on April 10-11 at Pardee Conference Center and a third restoration workshop on May 11 in conjunction with our annual meeting (see pages 10-13 for information).

As a volunteer organization, CNGA relies on its members to help build the organization and its programs. We have an excellent updated promotional brochure, which we encourage you to hand out individually or at events attended by practitioners and decision-makers. To obtain a stack of brochures, contact Mary Kate McKenna at our CNGA address or phone (left).. You can also get more directly involved by volunteering for one of our committees. New committees that have been or will be established this year include an annual meeting committee, a workshop committee, an education committee, a conservation program committee, and a short-term by-laws committee.

The annual meeting committee has been busy for months already putting together what we know will be a most enriching and enjoyable program (see pages 10-11 for registration information). This year's meeting, focusing on the diversity of California's grasslands, is being co-sponsored by the Department of Biological Sciences at Cal State San Luis Obisbo, thanks to the gracious support of department chair V.L. Holland.

CNGA's new conservation program committee has been drafting an ambitious proposal to establish a major California Grasslands Initiative in partnership with other restoration and conservation organizations. If funded, it will dramatically escalate CNGA's mission in grassland conservation and restoration. We will keep you posted as this exciting new project develops.



CNGA remembers Dr. Ledyard Stebbins

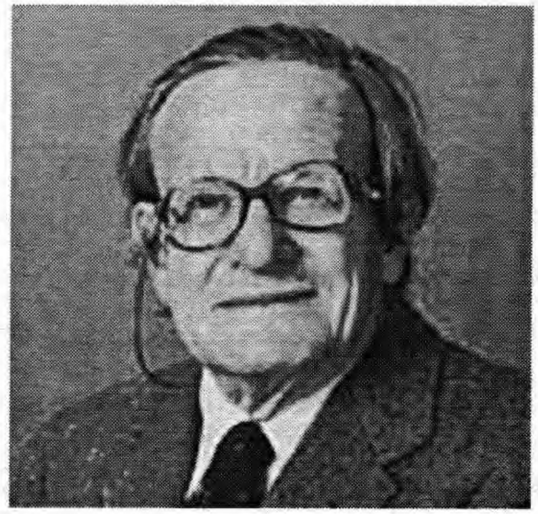
Dr. G. Ledyard Stebbins, widely considered the founding father of evolutionary botany, died of cancer at this home in Davis, California on January 19, 2000. He was 94.

"He was certainly the world's leading expert on plant evolution," said Francisco Ayala, Bren Professor of Ecology at UC Irvine and Stebbins' long time friend and colleague.

Dr. Stebbins became a professor of genetics at UC Davis in 1950, just after he published *Variation and Evolution in Plants.* It was one of four texts considered to be the classics that formulate the modern theory of evolution, Ayala said. Dr. Stebbins is credited with establishing the theory of plant evolution. Central to his contribution was to demonstrate that while plants and animals are both subject to evolutionary forces, plants have certain characteristics that require understanding the species concept in a different way.

A frequent contributor to *Grasslands* during the past two years, Dr. Stebbins will be remembered fondly by CNGA members and students of native grasses and grasslands throughout the state. His series of articles in *Grasslands* (see box, right), which he compiled and submitted with the assistance of Craig Dremann, described the distribution and genetic relationships among species of common genera including *Stipa*, *Elymus*, *Bromus*, and *Melica*. Drawing on his decades of experience with the California flora, his articles are characterized not only by detailed scientific information, but by his own personal observations and reflections.

In the article below, written just before his death, Dr. Stebbins and Craig Dremman give an overview of the geographic distribution of 140 of California's native grasses. Because Dr. Stebbins died before he was able to approve any changes in the article, it appears here as submitted, edited only for form and space restrictions, not content.



Dr. Stebbins' articles in *Grasslands*

- The evolution of seed hulls and chromosomes in the Stipoid grasses, Vol 8(3) Summer 1998.
- *Elymus glaucus*: a collection of polyploid cryptic species, Vol 8 (4) Fall 1998.
- The genus *Bromus* in California, Vol 9 (1) Winter 1999.
- The genus *Melica* in California, Vol 9 (2) Spring 1999.
- One hundred and forty of California's native grasses, Vol 9(1) Winter 2000

A complete listing of Dr. Stebbins' publications is available on the web at: www.ecoseeds.com/stebbins.html.

One hundred and forty of California's native grasses

by G. Ledyard Stebbins and Craig Dremann

Introduction

California has one of the richest floras in the world for its geographic size. This diversity generally holds true for the grass family (Poaceae) as well as other plant families. This article is intended to give an overview of the native grasses in California.

The grass family is one of the three largest among flowering plants in California, being approached only by the sunflower family (Asteraceae) and the bean family (Fabaceae). Moreover, many grass genera are not only large but also consist of widely distributed species, totaling about 300 species in California, as treated *in The Jepson Manual: Higher Plants of California* (Hickman 1993)

The Jepson Manual's ecological and geographical subdivisions of California, for simplicity and convenience here, have been lumped together into six regions: (1) the San Francisco Bay and Monterey bay areas; (2) the Great Valley, surrounding inner coast ranges and the Sierra foothills; (3) the Northwest coast of California up to 5,000 ft. (1500m.); (4) altitudes above 5,000 ft. in the North Coast ranges, the Cascades, chiefly Mts. Shasta and Lassen, the Sierra Nevada, and the higher Transverse ranges, San Gabriel and San Bernardino Mountains of southern California; (5) southwestern California including the coast from San Luis Obispo south to the Mexican border and eastward to the deserts; and (6) the Mojave and Colorado deserts and the desert mountains rising from them. The Northeastern portion of the State, which is an extension of the Great Basin flora, is not covered in this article.

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The San Francisco Bay And Monterey Bay Area

This area contains most of northern California's educational facilities and the greatest bulk of our northern population. Its climate is cool and temperate without persistent snow or frost so that many frost-sensitive grasses can inhabit it. The moisture regime consists of a gradient from the fog bound coast to the warm interior. Its grasslands include the salt-tolerant marshes surrounding the bays which are dominated by cord grass (*Spartina foliosa*). In some areas, including parts of the upper bay and Sacramento River delta, there are almost pure stands of saltgrass (*Distichlis spicata*).

The open slopes above these salt marshes were once covered with grasses that included many of the most common genera in the state as a whole, forming prairies between the oak woodlands of the valley floors.

Most distinctive are California oatgrass (*Danthonia californica*), California brome (*Bromus carinatus*), several fescue grasses (*Festuca californica, F. elmeri, F. idahoensis, F. subuliflora*) and bluegrasses (*Poa douglasii, P. howellii, P. kelloggii, P. secunda ssp. secunda, P. tenerrima, P. unilateralis*). Others are *Phalaris californica* and the foothill and purple needlegrasses (*Nassella lepida* and *N. pulchra*).

In addition, the oak and conifer forest areas of the Bay region contain other brome grasses (*Bromus laevipes, B. vulgaris*), melic grasses (*Melica harfordii, M. subulata, M. torreyana*) and the vanilla-scented sweetgrass (*Hierochloe occidentalis*), which is generally found only among the redwoods. Finally, a species confined to the San Francisco region (with perhaps additional localities in the northwest) is a rather rare grass of the moist coastal forests, California bottlebrush grass (*Elymus californicus*).

The Central Valley, Inner Coast Ranges And Sierra Foothills

The second region is the Central Valley and the inner coast ranges abutting it on the west and the Sierra foothills to the east. In this region the grasslands are now almost completely taken over by annual grasses introduced from Europe.

Some foothill areas are occupied by California melic (*Melica californica*), and in the inner coast ranges nodding needlegrass (*Nassella cernua*), the low-rainfall loving relative of the widespread *Nassella pulchra*, dominates. You can also find the three-awn (*Aristida divaricata*), a perennial whose flowering parts when dry are so prickly that they are completely avoided by livestock.

Two relictual areas should be mentioned. The first is a sparse stand of one-sided bluegrass (*Poa secunda* ssp. *secunda*) on the low hills west of the valley in the vicinity of Caliente. The probable reason why these populations of *Poa* have been preserved is that their leaves wither and dry even in the springtime before the flowering stalks are mature.

Another relictual area is on the shore of Lake Berryessa in an area known as Quail Ridge Reserve. Here there is an extensive stand of *Nassella pulchra*, native *Bromus* and *Koeleria*. This area is on a private road that is narrow and rough, so that visiting it is inadvisable except in the company of its chief preservationist, Frank Maurer. Quail Ridge is protected from grazers since it is separated from the other grazing areas south of Lake Berryessa by State Highway 128, and cattle have no way of crossing this highway!

Turning to the floor of the Central Valley, it now has been almost filled by intensive cultivation for raising species of vegetable crops as well as fruit tree orchards, vineyards, and in the southern San Joaquin valley, fields of cotton. This is the present condition of the central section that is mentioned in the writings of John Muir as having excellent grassy areas with stalks so high that they reached the belly of his horse while riding across it. However a beautiful spot still exists between Fairfield and Rio Vista, along State Highway 12, on both sides of the road to Bird's Landing, where you can see some of the finest examples of purple needlegrass prairie in California. In a number of other areas the valley floor contains stands of the sod grass creeping wildrye (*Leymus triticoides*), which is also present in most of the coastal areas near San Francisco and Monterey.

The Northwestern Coast Grassland Areas

North of the San Francisco region and extending to the Oregon border near Crescent City and the Klamath River is the most species rich grassland area in the state. It contains all of the genera that are also present in the San Francisco area, both native and introduced.

The species that is most frequent here is California brome (*Bromus carinatus*). It extends throughout this area and ascends to the montane area above 5000 feet (1300 meters). At altitudes between 1000 and 1500 feet (300-500 meters) is *Bromus marginatus*, a close relative which has been separated from *B. carinatus* by Pavlick (1995).

The most conspicuous of the fescues are *Festuca elmeri*, *F. rubra* and *F. subuliflora*. The seaward slopes of the area contain extensive stands of California oatgrass (*Danthonia californica*) plus the introduced Autralian species *D. pilosa*.

Particularly conspicuous are several grasses that crown the coastal bluffs in many areas, as well as the landward side of intervening beaches. Genera that you might find along the shore are species of reed grasses: *Calamagrostis nutkaensis, C. bolanderi, C. foliosa,* and *C. ophiditis*.

Even more conspicuous are species of the genus *Leymus*, particularly *L. mollis* which has extensive creeping stems. It has hybridized with *Leymus triticoides* to such an extent that some of its hybrids have been given specific names (*L. multiflorus, L. vancouverensis*). The fact that these hybrids can reproduce vegetatively by means of their prostrate stems, or rhizomes, is responsible for the great confusion in this group that makes almost impossible the separation of the parental

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species, hybrids, and hybrid derivatives.

In the genus *Melica* the species that are prominent in the northwest region are *M. aristata, M. bulbosa, M. californica, M. geyeri, M. harfordii, M. spectabilis, M. torreyana* and *M. subulata.*

The wetter grasslands of this area are dominated by tufted hairgrass (*Deschampsia cespitosa*) which has one of the widest elevational distribution of any grass in the state, with its two subspecies occupying most of the wetter areas in California, even up to 12,500 feet (3900 meters) in the high Sierra.

The genus *Poa* is remarkable for a number of its species that are restricted to the northwest. These are *Poa kelloggii, P. napensis, P. piperi,* and *P. rhizomata*. More widespread are *P. confinis* and *P. macrantha* that extend northward to British Colombia and *P. secunda,* which is found in both the San Francisco area and the high montane region to the north.

A genus that is closely related to *Poa* and is prominent at or near the seacoast in the northwest region is alkali grass (*Puccinellia)* which extends northward to Alaska. The fertile scales or lemmas of some species of Poa, such as *Poa secunda* are very much like those of *Puccinellia*. The scales of *Puccinellia* species are more strongly nerved than *Poa.* However, the principle distinction between the two genera is the tendency of *Puccinellia* to favor semi-saline conditions near the sea coast, or, if in the interior, alkali regions.

Among the needlegrasses (genus *Achnatherum*) the most prominent northwest coast species are *A. lemmonii* and *A. occidentalis*.

California's Higher Mountains

The higher mountains of our state, including the Cascade Range, particularly Mts. Shasta and Lassen, the high Sierra and the San Gabriel and San Bernardino mountains of southern California have many species of grasses in common. The most extensive grassland meadows occur only a little above middle altitude, that is from 7,000 to 9,500 feet (2000-2500 meters). Above that altitude, species of sedge (*Carex*) are more abundant than are any grasses.

Nevertheless, if you climb Mt. Whitney, which is the highest point in the lower 48 states, and look for the highest climbing plant species on its summit, you will only see two species, the blue flowered Sky Pilot (*Polemonium eximium*) and short-leaved fescue (*Festuca brachyphylla*). However, a species of squirreltail (*Elymus elymoides*) occurs at an altitude almost as great. In addition, grassy meadows above 9,000 feet (3,000 m) are dominated either by Brewer's reed grass (*Calamagrostis breweri*) or by King's ricegrass (*Ptilagrostis kingii*).

Other grasses that occur at altitudes between 5,000 and 10,000 feet (1600 and 3000 meters) are *Bromus carinatus, B. ciliatus, B. suksdorfii, Festuca kingii, F. minutiflora, F. saximontana*, mountain bunchgrass (*F. viridula*), and various species of bluegrass (*Poa bolanderi, P. cusickii, P. fendleriana, P. glauca, P. keckii, P. leptocoma, P. lettermanii, P. pattersonii, P. pringlei, P. secunda, P. stebbinsii,* and *P. wheeleri*).

Other species in the high region are *Agrostis* (*A. humilis, A. idahoensis, A. pallens, A. scabra, A. thurberiana, A. variabilis*), *Calamagrostis* (*C. breweri, C. canadensis, C. purpurascens, C. stricta*), *Danthonia* (*D. intermedia, D. unispicata*), *Deschampsia cespitosa*, and *Melica* (*M. aristata, M. bulbosa, M. fugax, M. spectabilis, and M. stricta*).

Two genera that are rare in California below 6000 feet (2000 meters) are *Muhlenbergia* and *Achnatherum*. The most common species of *Muhlenbergia* are *M. andina, M. asperifolia, M. filiformis, M. jonesii, M. minutissima, M. montana, M. richardsonis* and *M. rigens.*

The genus *Achnatherum* in California is a special case. Formerly recognized as *Stipa*, these species are more closely related to species of the southern hemisphere, particularly Australia, than to *Stipa* the entire distribution of which occurs in northern Eurasia, according to the new division of the Stipeae by Mary Barkworth.

In general, species of *Achnatherum* are not found mixed with other grass genera in meadows or streambanks but are predominant in dry, rocky areas. The following are abundant in the Sierra Nevada: *Achnatherum hymenoides, A. lettermannii, A. nelsonii, A. nevadensis, A. occidentalis, A. pinetorum, A. thurberianum,* and *A. webberi*. An additional three species are marginal in the high altitude region. *Achnatherum stillmanii* occurs in the northwest Sierra Nevada up to 5,000 feet (1550 meters). *A. speciosum* extends from the Mojave desert west to the Sierra up to 6,500 feet (2200 m), and *A. parishii* is confined to the southern Sierra Nevada and the Transverse Ranges between 2,800 and 8,000 feet (900-2700 meters). Another species, formerly placed in Stipa but now recognized as its own genus, is *Hesperostipa comata*. Its principle range is east of California but it does climb the eastern slopes of the Sierra Nevada to a height of 10,000 feet (3500 meters).

Southwest California Grasses

Southern California's grasses can be divided into two groups: 1) coastal and coastal mountain species, and 2) the

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high elevation and southernmost range for the northern species.

The coastal and coastal mountain species consist of the southern most extension of *Nassella pulchra, N. cernua*, and *N. lepida*, plus two endemic needlegrasses, *Achnatherum coronatum* and the rare *A. diegoensis* which is found only in San Diego County and on the islands off the coast.

Some of the common northern grasses reach their southern range here: *Bromus carinatus, Danthonia californica, Elymus glaucus, Melica californica* and *Poa secunda*. *Leymus condensatus*, a robust plant that can be found from Santa Barbara to the Ventura/Los Angeles county line, is one of the most common natives along the coast.

The Mojave desert and Colorado River areas share many of the same species, but the Colorado River area has species not found in the Mojave. Both areas share Indian rice grass (*Oryzopsis hymenoides*) and desert stipa (*Achnatherum speciosum*). You can still see large areas of Indian rice grass between the towns of Mojave and California City, and desert stipa is being used in landscaping in shopping malls.

Alkali-loving grasses, like *Spartina foliosa, Spartina gracilis*, and *Distichlis spicata*, are found in alkali-soils, usually where water accumulates in lower areas. One of California's rarest grasses *Puccinellia parishii*, only grows around one alkali spring in the Lucerne Valley. Another rare endemic species that has no close relatives in California or elsewhere, *Swallenia alexandrae*, is confined to the desert sand dunes in Eureka valley, north of Death Valley.

The Galletta grasses, *Pleuraphis jamesii* and *Pleuraphis rigida*, are mostly Mojave grasses that spread vegetatively. Individual plants can form enormous rings of *P. rigida* up to 10 feet (3 meters) across, and are probably of great age.

Species of the genus *Melica* are usually forest or woodland grasses, but *Melica frutescens* is an unusual isolated member of the genus found out in the desert.

A group of grasses confined to the Colorado River area from Anza Borrego State Park eastward are the little-known three-awns: *Aristida californica, Aristida purpurea*, and *Aristada ternipes*; and the Grama grasses: *Bouteloua eriopoda* and *Bouteloua trifida*.

The Interior Southern California Desert Mountains

This area contains some of California's rarest grasses. *Blepharidachne kingii* is found in the desert mountains at 3,000-6,000 feet (1,000-2,000 meters) in pinyon/juniper forests. *Muhlenbergia fragilis* and *Munroa squarrosa* are only found in the Clark and New York Mountains. *Muhlenbergia pauciflora* and *Scleropogon brevifolium* are only found in the New York Mountains.

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currently used methods provide a great deal of promise, but their efficacy individually and in combination need to be tested. Applying soil amendments that will immobilize nitrogen and release it slowly can be a valuable tool in successful revegetation and restoration of plant communities (Morgan 1994; Zink and Allen 1998). The practice may provide an advantage for slower growing native perennial species in competition with fast growing, weedy species that benefit from high nitrogen conditions (Chapin 1980; Jackson et al. 1988; Hart et al. 1993; Davidson et al. 1990; Claassen and Marler 1998; Zink and Allen 1998)(but also see Wilson and Gerry 1995 and Reever Morghan and Seastedt 1999).

The use of soil amendments that provide small amounts of nitrogen over long periods of time can also encourage the establishment and persistence of vegetation on severely degraded sites (Claassen and Hogan 1998, Brown et al. 1998). Claassen and Marler 1998 showed that slow-growing perennial grasses can benefit from limited nutrient availability when competing with fast-growing species.

The application of straw mulch is a common practice in revegetation. The benefits of surface mulch for establishing plants from seed have been well demonstrated (Clary 1983; Gupta et al. 1984; Phillips and Phillips 1984; Kwon et al. 1995; Abrecht et al. 1996; Bautista et al. 1996; Byard et al. 1996; Cavero 1996; Rahman et al. 1997). Surface mulch application also has well-known erosion control benefits (Osborn 1954; Kay 1978; Clary 1983; Bautista et al. 1996). Applying mulches to the soil surface can result in increased immobilization of nitrogen similar to incorporation of soil amendments with high C:N (carbon to nitrogen ratio) (Zink and Allen 1998, Holland and Coleman 1987).

Straw mulch is typically applied to erosion control plantings after road construction at a rate of 4,500 kg/ha (4,000 lbs/acre) (Haynes personal communication, Kay 1978). Wheat and barley straws have been the most easily obtained and most widely used straw mulch in the past. However, there are now several alternatives to wheat and barley straw available. Rice straw is abundant since burning of rice fields post-harvest has been reduced in the Central Valley of California. Use of rice straw for erosion control would provide a valuable market for this agricultural by-product and, indirectly help improve air quality through reduced burning. Rice straw may also be preferable to wheat or barley straw for revegetation because it and its associated weed flora are adapted to flooded conditions. As recognized by Clary (1983), these wetland plants may compete significantly less with species seeded for erosion control than wheat, barley and their associated dryland weeds because they are less likely to survive under typical revegetation conditions.

However, at least one revegetation specialist has reported poor performance of native perennial grasses when rice straw mulch is applied after seeding (Scott Stewart personal communication). Because of its high silica content, rice decomposes less quickly than other types of straw. This may result in reduced nitrogen immobilization, resulting in relatively greater nitrogen availability under rice straw mulch than other types of straw mulch that decompose more readily. The slower decomposition of rice straw may protect the soil surface for a longer period of time than other types of straw mulch. Rice straw also has greater loft than other types of straws, resulting in a thicker layer for a given amount of rice. Because of this, it is typically specified at the lower rate of 3,375 - 3,940 kg/ha (3,000 - 3,500 lbs/acre) than other types of straw (John Haynes personal communication).

Now that native perennial grass seed is being produced commercially, straws of these species have become available for erosion control projects. One of the benefits of using native grass straw is that volunteers of the straw species can contribute to the stand of desirable vegetation. It is also possible that native grasses have evolved to grow best under the vegetation of their own species or other native species. They may benefit from the particular light, nutrient and chemical environment created by native grass straws, but this hypothesis has not been investigated. Native grasses, when used as straw mulch, have the disadvantage of being upland species like wheat and barley. The weed flora contained in their straws is more likely to be adapted to erosion control planting sites and may compete significantly with the seeded species, although Clary (1983) noted that native grass straw may help minimize weed problems.

In this experiment, we investigated the effects of (1) soil amendments including low nitrogen availability compost and slow release synthetic nitrogen fertilizer and (2) straw mulch application including application rate and straw type on the establishment and growth of a seeded mixture of California native perennial grasses and resident vegetation. We designed the experiment to gain insight into the degree to which weeds and seeded species benefitted from these cultural practices in order to develop recommendations that will maximize benefits to the seeded species and minimize those to weeds.

Methods

Site description and precipitation

The experiment was conducted in Yolo County, California on Corning gravelly loam soil from fall 1997 through spring 1998. The experiment was planted on beds (150 cm wide) that had been harrowed to as equally fine soil structure as possible and to a depth of 10 cm. The wet-season of 1998 was very long and the total amount of precipitation was 123% of the 30 year average (Owenby and Ezell 1992). The longest periods without rain between November and June were 13 days in December and 9 days in January-February. Otherwise, only 1 to 3 days passed between storms. Conditions were very favorable for perennial grass establishment.

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Soil amendments

All plots were amended with available phosphate (1.90 %), soluble potassium phosphate (3.34 %), sulfur (3.34 %), and magnesium (1.67 %) in order to ensure that these nutrients would not be limiting. The compost treatments were as follows:

(1) No compost or nitrogen added (hereafter control without amendments).

(2) Compost (hereafter compost alone).

(3) Low nitrogen treatment with 0.97 % slow release nitrogen fertilizer, from equal weights of isobutylidene diurea (IBDU) and urea-formaldehyde (15.48 kg N/ha 13.73 lb N/acre) added with compost (hereafter low nitrogen).

(4) 1.92 % slow release nitrogen fertilizer from equal amounts of IBDU and urea-formaldehyde (31.43 kg N/ha, 27.89 lb N/acre) added with compost (hereafter high nitrogen).

Compost (municipal greenwaste product from Hydropost, Organics International, Irvine, CA, U.S.A.) was applied by hand at a rate of 91.4 m^3/ha (48.4 yrd^3 per acre) and rototilled into soil to the depth of 2.54-10 cm (1-4 inches). The compost itself contained approximately 1.65 % N (Claassen and Hogan 1998), so contributed no more than 878 kg N/ha (782 lbN/acre), although no more than about 128 kg N/ha (114 lb N/acre) would probably become available to plants.

Seeding

A mixture of three species of California native perennial grasses was seeded on October 16, 1997 using a wildflower broadcast seeder (Truax Company, Inc., 3609 Vera Cruz Avenue North, Minneapolis, Minnesota 55422), followed with chains to cover the seed and a ring roller to compact the soil. The species included were California melic (*Melica californica* Scribner) (151 pure live seeds/m^2,14 seeds/ft^2) (from Fisk Creek in the Cache Creek watershed), purple needlegrass (*Nassella pulchra* [A. Hitchc.] Barkworth) (54 pure live seeds/m^2, 5 seeds/ft^2) (from the Stone Ranch, Yolo County, CA), and pine bluegrass (*Poa secunda* ssp. *secunda* J.S. Presl.) (872 pure live seeds/m^2, 81 seeds/ft^2) (from Fisk Creek).

Mulch

Straw of wheat (*Triticum aestivum* L.), rice (*Oryza sativa* L.), and the California native perennial grass blue wildrye (*Elymus glaucus* Buckley) was applied at two different levels, 3,375 kg/ha (3,000 lbs/acre) and 5,625 kg/ha (5,000 lbs/acre) to each of the nitrogen fertilizer treatment plots. Only wheat straw at two levels was applied to the control without amendments. The standard prescription for straw is 4,500 kg/ha (4,000 lb/acre). We first applied mulch on October 21-22, 1997 and sprinkler irrigated beginning October 23, 1997. Irrigation was discontinued when the wet-season began in November. Because of high winds that partially removed straw, all straw was raked from the plots and reapplied October 28, 1997.

Weed control

Weeds were removed from half of each compost, nitrogen, and mulch treatment combination. The weeded areas were sprayed with the broadleaf specific herbicide Banvel February 28, 1998 at 1.0 a.i. kg/ha (0.91 a.i. lb/acre). Species that were not seeded or were not volunteers from the mulch species in each plot were removed from the weeded areas by hand April 7-8 and May 15, 1998.

Monitoring

Monitoring of the experiment began May 5, 1998. A 0.1 m^2 circular ring was place in the center of each 2.3 m^2 plot (1.5 m X 1.5 m, 5 ft X 5 ft). We recorded the dominant weeds and clipped the aboveground biomass of weeds and mulch species. The number of seedlings of each of the seeded species rooted within the ring were counted. Three individuals of each of the seeded species were measured to make non-destructive estimates of biomass.

Data analysis

The effects of nitrogen fertilizer were evaluated in analyses that included the plots to which compost and mulches were applied (excluding the control without amendments). Plots that received compost with and without wheat mulch (without nitrogen fertilizer) were compared to plots without compost with and without wheat mulch (without nitrogen fertilizer) to evaluate the effects of compost.

RESULTS

Compost effects and interactions with wheat straw mulch

To evaluate these effects, we compared plots that received wheat straw mulch or no mulch with compost (no nitrogen fertilizer) to plots that received wheat straw mulch or no mulch without compost (no nitrogen fertilizer). We found that the density and biomass of the perennial grass mixture were not affected by addition of compost ($p = 0.54$ and 0.22, respectively). When the densities of the three species of perennial grass were analyzed individually, none were affected by the addition of compost ($p > 0.05$). Compost had no effect on pine bluegrass and California melic biomass, however, the response of purple needlegrass to compost depended on whether or not mulch was present ($p = 0.02$). Purple needlegrass biomass was greater with compost than without it when no mulch was applied, but there was little difference between the two compost treatments with either wheat straw level; mulch appeared to eliminate the benefit of compost for purple needlegrass (Figure 1). We did not detect an effect of weeds on purple needlegrass biomass ($p = 0.39$), but California melic produced more biomass when weeds were removed (*p*

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Purple needlegrass Biomass

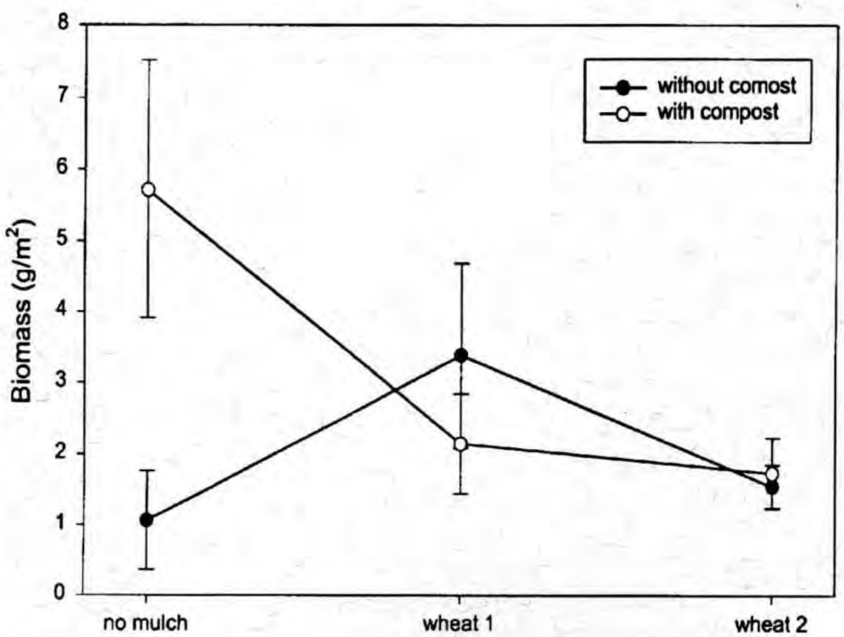

Figure 1. Biomass produced by purple needlegrass with different mulch treatments depended upon compost application (mean + 1 standard error of the mean). Wheat 1 = 3,375 kg/ha (3,000 lb/acre), wheat 2 = 5.625 kg/ha (5,000 lb/acre).

= 0.04) and pine bluegrass demonstrated a similar, but non-significant, tendency ($p = 0.06$). Weed biomass was greater in the treatment with compost (333.6 ± 66.3 g/m^2) than the treatment without compost (143.0 ± 29.5 g/m^2) ($p = 0.008$).

Nitrogen, mulch and weed effects

Mixture of perennial grasses and individual species

To evaluate these effects, we analyzed the plots that received compost, varying levels of nitrogen fertilizer and the different mulch treatments. We found no effects of fertilizer, mulch or weeds on the density of perennial grasses ($p = 0.64$, 0.69 and 0.17, respectively). However, there was a significant interaction between mulch and weeds ($p = 0.02$) because the perennial grasses responded differently to the presence of weeds in different mulch treatments. These varied responses canceled each other out so that there was no overall effect of either mulch or weeds when averages were calculated.

When individual species for the same group of treatments were evaluated, California melic was the only species that responded to mulch, although the response was marginally insignificant ($p = 0.05$). Densities of California melic tended to be higher in the presence of mulch at any level compared to the no mulch control ($p = 0.0004$). The densities of the individual species did not respond to nitrogen level ($p = 0.75$, 0.67 and 0.68 for pine bluegrass, California melic and purple needlegrass, respectively). However, there was a significant interaction between mulch and nitrogen level for purple needlegrass ($p = 0.01$), indicating that the response of purple needlegrass density to nitrogen depended upon which straw mulch had been applied. Pine bluegrass and California melic densities were affected by weeds ($p =$ 0.02 and 0.0009, respectively); pine bluegrass densities were higher without weeds and California melic densities were higher with weeds (Table 1). We detected no effect of weeds on purple needlegrass densities ($p < 0.05$).

When all mulch types and amounts were compared, including the control without mulch, there was a strong effect of mulch treatment on the biomass of the perennial grass mixture ($p = 0.0004$) (Table 2). Surprisingly, when perennial grass biomass in the control without mulch was compared to the average biomass of plots with mulch, biomass of plots with the low level of mulch, and biomass of plots with the high level of mulch, there were no significant differences ($p = 0.17$, 0.24 and 0.17, respectively). Rather, the differences existed between the types of mulch and the amounts applied because, on average, mulch did not change the biomass of perennial grasses compared to the control without mulch. Perennial grasses produced the most biomass in rice straw treatments compared to the average of the other mulch treatments (i.e. the average perennial grass biomass of the rice treatments was greater than the average of the other mulch treatments,

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Table 1. Densities of individual perennial grass species in different weed treaments. Values are means ± standard error of the mean. Weed treatment means within species followed by an asterisk are significant different based on planned linear contrasts (P<0.05); N = number of plots included in the analysis

Treatment	California melic		Purple needlegrass		Pine bluegrass	
	N	Density (plants/m²)	N	Density (plants/m²)	N	Density (plants/m²)
With weeds	102	47.7 ± 3.3*	102	12.2 ± 1.2	102	25.18 ±1.02*
Without weeds	105	59.2 ± 3.2	105	14.5 ± 1.5	105	21.72 ± 1.17

California Native Grass Association

2000 Annual Meeting Friday, May 12, 2000

Cosponsored by The Department of Biological Sciences, Cal Poly San Luis Obispo
Embassy Suites San Luis Obispo

Grassland Ecosystems of California: Diversity, Preservation, and Management

Technical Session: Friday May 12th - 8:00 am – 5:00 pm

Diversity:

- Grasses of the Central Coast; a Biogeographical Perspective
- California's Coastal Prairies

Preservation:

- Function of Grasslands as Habitat for Herps
- Birds and Grassland Conservation

Management:

- Long Term Fire Planning in Grassland Systems
- Fire Effects on Grasslands in the Lassen Foothills
- Use of Functional Grass Banks in Grassland Conservation
- Livestock Grazing and Management of California Grasslands

Panel Discussion: Grassland Conservation and Restoration in California: Establishing a Mission for the Future

Friday, May 12th 5:00 – 7:00 pm

Join us at the Embassy Suites Atrium for a Post-Meeting Social sponsored by *Native Grass Seed Producers*
Hors d'oeuvres, Hosted Bar

Other CNGA Sponsored Activities

Thursday May 11

Grass ID Workshop, Dept of Biological Sciences, Cal Poly SLO, 8:00 am – 4:00 pm

A not to be missed opportunity to train under Dr. Travis Columbus of the Santa Ana Botanic Garden. Dr. Columbus will instruct in the use of the taxonomic grass keys in the Jepson Manual. This lab workshop will take place indoors and will include the use of dissecting microscopes that will allow participants to easily see the fine details of these beautiful plants. All participants must bring a copy of the Jepson Manual for use during the workshop. A continental breakfast and lunch are provided.

Techniques and Strategies for Using Native Grasses and Graminoids in Restoration Projects
Embassy Suites, 8:00 am – 5:00 pm

This practical how-to workshop for restoration practitioners, land managers, agency representatives, consultants, researchers, and students presented by CNGA's grassland restoration experts. The workshop agenda includes:

- Native grass morphology and response to fire, grazing, and other management techniques
- Wildland seed collection – determining when seed is ripe and harvesting techniques
- Restoration site evaluation –soils, weed seed bank, etc.
- Selection of appropriate species and species mixes
- Seeding and plug planting rates and techniques
- Erosion control techniques
- Evaluating seed tests and how to read a seed label
- Post-planting management – mowing, fire, grazing, selective herbicide use, haying, and more.

A comprehensive training binder and continental breakfast and lunch are provided to each participant

Saturday May 13

Tour of Las Flores Ranch and Buffalo Barbecue
S&S Seeds, Los Alamos: 11:00 am –4:00 pm

This trip will visit the S&S Seeds growing grounds near Los Alamos, CA. The drive time from the conference center is approximately one hour. Victor W. Schaff will lead a tour of the 50+-production field and the research and increase plots of California native annual and perennial grasses and wildflowers. Many of the species are being grown for increase under the California Crop Improvements Wildland Certification Program. There will be a talk explaining the Wildland Certification program for source identified seeds. Also on site you will be able to observe a completed erosion control practice and subsequent revegetation. S&S Seeds will host a Buffalo Barbecue lunch. You may be able to get a close up view of a bison herd on the ranch

Thursday, May 11th 3:00 – 5:00 pm
Saturday, May 13th 8:00 – 9:30 am

Poly Canyon Serpentine Reserve Tour
Cal Poly SLO

Poly Canyon is home to a wide diversity of plant communities composed of species encountered throughout the central coast. The canyon lies in the northeastern end of Cal Poly's campus and is the watershed for Brizziolari Creek, which flows southwesterly down the steep slopes of Cuesta Ridge and through the canyon. As one hikes up the canyon along Brizziolari Creek, initially very steep slopes will be encountered on either side of the creek forming a small gorge. As the journey continues further, the canyon begins to open up, offering spectacular views.

Maps for self guided tours of restoration sites and grasslands will be available
Updated information will be available on our web-site: http://www.cnga.org

California Native Grass Association
2000 Annual Meeting

Cosponsored by the Department of Biological Sciences, Cal Poly San Luis Obispo

Registration Form

To register, complete a separate form for each registrant. Please PRINT.

Name:

Affiliation:

Address:

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Phone, Day and Evening E-Mail Address

Conference Registration
Early registration deadline is Monday, May 1, 2000

Member:	☐	$100.00			
Student/Senior Member	☐	$ 50.00			
Non-Member	☐	$135.00	*includes 1-year membership*		
Student/Senior Non-Member	☐	$ 70.00	*includes 1-year membership*		
Late and Walk-In Registration	☐	$125.00 *(Member)*		☐	$60.00 *(Student)*

Vendor Display:

Commercial	☐	$100.00 per table *(includes conference/meals for 2 Exhibitors per table)*
Non-Profit	☐	$ 30.00 per table *(includes same as above)*

Workshop/Tour Choices

Grass ID Workshop	☐	$125.00 *(Member)*	☐	$50.00 *(Student)*
Restoration Workshop	☐	$175.00 *(Member)*	☐	$75.00 *(Student)*
Poly Canyon Serpentine Reserve Tour –		May 11 (pm)	☐	$N/C
		May 13 (am)	☐	$N/C
Tour of Las Flores Ranch and Buffalo BBQ			☐	$ 50.00

Total to be enclosed with registration form..$ _________

I will be paying by check: ☐ *Please make check payable to CNGA*

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Quantity	Item Description		Price Each	S/H	Total
	Using Prescribed Fire as a Vegetation Management Tool—Workshop training binder		30.00	5.00	
	Techniques and Strategies for Using Native Grasses and Graminoids in Restoration Projects-- Workshop training binder		40.00	5.00	
	Easy Lawns—A guide to using natives in home landscaping from the Brooklyn Botanical Garden		10.00	2.00	
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	Grasslands: Individual Issue		3.00	1.00	
	Grasslands Back Issues: complete set		30.00	3.50	
	CNGA Apparel	**Size (S, M, L, XL, XXL)**			
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Thank you for your order!

Inside CNGA

CNGA Welcomes New Boardmembers

Three new boardmembers began their two year terms this January, including Sheila Barry, Sid Johnson, and Mary McClanahan. The position of President-elect remains vacant.

Sheila is a watershed management expert and Certified Rangeland Manager from Alameda County. Formerly the Executive Director of the Alameda County Resource Conservation District, she recently accepted a position with UC Cooperative Extension. Shiela is also on the board of the Society of Range Management.

Sid has 30 years of experience as a ranch manager. In 1997 he left a position managing a 120,000 acre bison ranch in Wyoming to take over managemnet of the 5,000 acre Willow Creek Ranch in McCloud, CA. Restoration and ecosystem management are high priorities at Willow Creek and we look forward to learning from Sid's practical experience in that area.

Mary has a degree in range science and worked with the U.S. Forest Service monitoring grazing before an 11 year position as a reclamation specialist at a consulting firm. Mary is finishing up a degree in restoration ecology at Fresno State and plans to pursue a restoration career in the San Joaquin Valley and surrounding foothills.

Upcoming CNGA Restoration Workshops

• **April 10-11** at the East Bay Municipal Utility District's Pardee Conference Center. Workshop is for EBMUD employess, but limited additional spots are available. Contact Mary Kate for details.

• **May 11** at the Embassy Suites Hotel, in conjunction with CNGA's May 12 Annual Meeting. See page 10-11 for details.

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Table 2. Biomass of perennial grasses for each mulch treatment. Straw was applied at 3,375 kg/ha (3000 lbs/acre) for level 1 and 5625 kg/ha (5000 lbs/acre) for level 2

Mulch type	N	Biomass (g/m^2)
0	28	22.4 ± 3.8
Blue wildrye 1	28	20.9 ± 5.0
Blue wildrye 2	30	14.6 ± 1.7
Rice 1	29	35.7 ± 7.6
Rice 2	29	27.1 ± 3.6
Wheat 1	30	15.7 ± 1.7
Wheat 2	30	14.8 ± 1.1

excluding the control without mulch) ($p = 0.0001$). This was also true when the perennial grass biomass of the low level of rice straw was compared to the average of the low levels of wheat and blue wildrye straw ($p = 0.0001$) and when the perennial grass biomass of high level of rice straw was compared to the average of the high levels of wheat and blue wildrye straw ($p = 0.0005$). Perennial grasses produced significantly less biomass in the blue wildrye mulch treatment compared to the average of the other mulch treatments ($p = 0.0007$). This was also true when perennial grass biomass of the low level of blue wildrye mulch was compared to the average of the low levels of rice and wheat mulch ($p = 0.009$) and when the perennial grass biomass of the high level of blue wildrye mulch was compared to the average of the high levels of rice and wheat mulch ($p = 0.02$). Mean biomass of the seeded perennial grass mixture across all treatments was 28.5 ± 7.0 g/m^2.

Perennial grass biomass increased with increasing nitrogen fertilizer levels ($p = 0.04$). However, the response of perennial grasses to nitrogen fertilizer levels depended upon the presence of weeds, indicated by a significant nitrogen fertilizer by weed interaction ($p = 0.02$). In treatments receiving compost without nitrogen fertilizer, perennial grasses produced more biomass in the absence of weeds. When nitrogen fertilizer was added, biomass of perennial grasses was similar with and without weeds (Figure 2).

Weeds

The amount of weed biomass produced depended upon the mulch treatment ($p = 0.04$) (Table 3). The biomass of weeds was lower in the no mulch treatment than the high level mulch treatments ($p = 0.02$). The same but insignificant trend was detected for the no mulch treatment and the average across all mulch treatments ($p = 0.07$). Weed biomass was significantly lower in the rice mulch treatments than the average of the other types of mulch ($p = 0.04$). There was no difference in weed biomass between the low level of rice straw compared to the average of the low levels of wheat and blue wildrye straw treatments ($p = 0.42$), but there was significantly less weed biomass produced in the high level rice straw plots compared to the average of the high levels of other straw mulches ($p = 0.04$). Weed biomass was marginally non-significantly greater for the average of all blue wildrye straw treatments compared to the average of all wheat and rice straw treatments ($p = 0.05$).

Mulch species

We evaluated the biomass production by mulch species in their respective treatment plots (i.e. wheat, rice and blue wildrye plants that volunteered from seed in the straw). Different amounts of biomass were produced by the three mulch species ($p = 0.0001$) (Table 4). No rice plants grew in the rice mulch plots, whereas a moderate amount of wheat and blue wildrye grew in their respective mulch treatments. The high level of rice mulch had significantly less mulch biomass (i.e. rice) than the average of the other high level mulch treatments had of their respective mulch species (the average

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Table 3. Biomass of weeds for mulch treatments. Straw was applied at 3,375 kg/ha (3,000 lbs/acre) for level 1 and 5,625 kg/ha (5,000 lbs/acre) for level 2.

Mulch type	N	Weed Biomass (g/m^2)
0	29	381.8 ± 74.1
Blue wildrye 1	29	368.8 ± 74.9
Blue wildrye 2	30	296.7 ± 63.6
Rice 1	30	324.5 ± 62.1
Rice 2	29	287.5 ± 70.0
Wheat 1	30	307.9 ± 61.4
Wheat 2	30	316.2 ± 65.6

Table 4. Biomass of volunteer plants from the respective mulch types for mulch treatments. Straw was applied at 3.375 kg/ha (3,000 lbs/acre) for level 1 and 5,625 kg/ha (5,000 lbs/acre for level 2.

Mulch type	N	Mulch Biomass (g/m^2)
0	29	0
Blue wildrye 1	29	41.1 ± 6.7
Blue wildrye 2	30	88.9 ± 15.3
Rice 1	28	0
Rice 2	29	0
Wheat 1	28	95.2 ± 15.4
Wheat 2	30	82.9 ± 22.9

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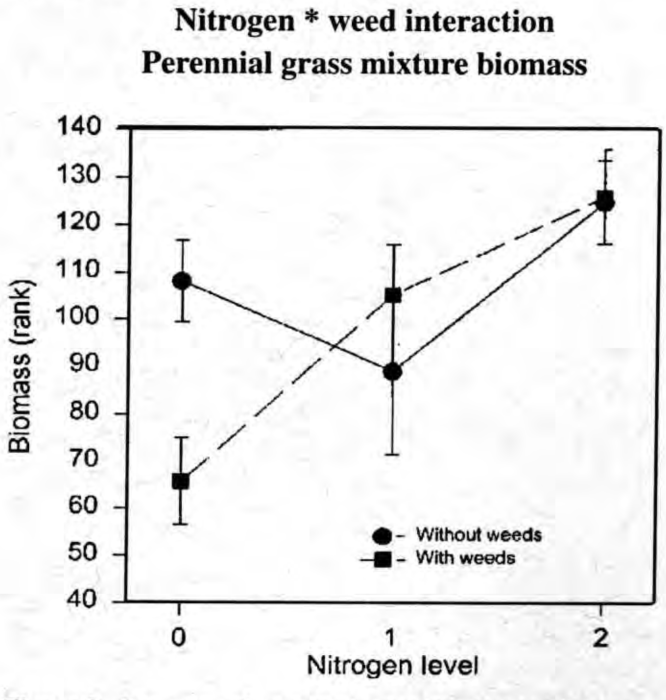

Figure 2. Response of perennial grass biomass to nitrogen fertilizer depended upon the presence or absence of weeds. Fertilizer appears to compensate for the competitive effect of weeds (mean + 1 standard error of the mean).

mulch volunteer biomass of high level wheat and blue wildrye) ($p = 0.0001$). The high level of blue wildrye straw produced more biomass of blue wildrye than the average of the high level treatments of other mulch types produced of their respective mulch species (i.e. the average mulch volunteer biomass in high level rice and wheat) ($p = 0.0001$). Mean biomass of blue wildrye from mulch was 75.0 ± 9.4 g/m^2, more than two and a half times as large as the perennial grass mixture biomass.

Discussion

Effect of compost

Weeds were the only plants that grew larger with compost than without it; purple needlegrass without mulch was the only case of improved growth with compost. Even though the nitrogen in the compost should have been released very slowly, the weeds appeared best able to utilize the available nutrients. The response of purple needlegrass biomass to compost depended upon mulch treatment. It was greater with compost than without compost if mulch was not applied, but similar in both compost treatments when straw mulch was applied. Adding mulch apparently eliminated the benefit of compost. It is unlikely that this result can be attributed to competition from weeds introduced in the mulch because we detected no effect of weeding on purple needlegrass biomass. Purple needlegrass growth was not reduced by the addition of mulch to plots without compost, making allelopathic effects of wheat straw an unlikely explanation for the observed effect. Several alternative explanations are possible, including that (1) volunteer wheat plants from the mulch were removing resources provided by compost, or (2) nutrients from compost were immobilized by microorganisms breaking down the straw mulch, or both.

Effect of mulch presence

Even though applying mulch only benefitted the growth and establishment of California melic, the use of mulch in such plantings should not be abandoned. One reason that we may not have detected a benefit for most species was the climatic conditions of the year. The distribution of rainfall events was very regular and so problems of soil crusting that may have been ameliorated by mulch were not evident. Also, the benefits of mulches to seedling establishment, especially under dry and hot conditions has been shown in many cases (Rahman et al. 1997, Abrecht and Bristow 1996, Townend et al. 1996, Byard et al. 1996, Cavero et al. 1996, Kwon et al. 1995).

It is important to note that plots without mulch had lower weed biomass than those with mulch. This suggests that significant weeds were introduced to the site in the straw. Optimal performance of native grass restoration and revegetation depends on the use of weed-free straw to minimize competition with weedy species.

Application of mulch may also have lead to decreased nutrient availability. Nitrogen may be immobilized by microorganisms decomposing the straw, even though it was not incorporated into the soil (Holland and Coleman 1987, Zink and Allen 1998).

Effects of mulch type

Perennial grasses performed best with rice straw mulch. These findings appear to be the result of interactions between the weeds present in mulches (there was lower weed biomass in rice straw treatments) and volunteers of the mulch species themselves (no rice plants volunteered), which led to reduced competition for resources. Resource availability may also have been affected by the decomposition rates of the different types of straw. Nitrogen from fertilizer may have been immobilized by micro-organisms breaking down the more easily decomposed wheat and blue wildrye straw (Zink and Allen 1998). Because rice is less readily broken down, less nitrogen may have been tied up in microorganisms and more available to the plants in the rice straw treatments.

Perennial grasses performed most poorly with blue wildrye straw mulch treatments. This straw treatment had the greatest weed and mulch species amounts, creating the least favorable conditions for survival and growth of the native perennial grasses, which was reflected in reduced growth.

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Chemicals released by straw mulch that negatively affect perennial grass growth (allelopathic compounds) may also have contributed to the effects we detected. If so, we would have expected poorer biomass production in the straw mulch treatments that contained allelopathic compounds compared to the control without mulch. Only wheat and blue wildrye straws resulted in reduced biomass compared to the control without mulch, indicating the potential for allelopathy. The notion that perennial grass species may be best adapted to conditions created by the litter of other native perennial species was not supported by our results. However, since blue wildrye volunteers from its straw performed so well, it is possible that this species is adapted to the conditions created by its own mulch. Whether this is generally the case should be systematically tested with seed and straw mulch of different native perennial grasses.

The success of blue wildrye volunteers from its straw may not be bad news for revegetation and erosion control with native perennial grasses. Since blue wildrye is a native perennial grass, its success may be desirable. The biomass of blue wildrye was over two and a half times as great as the seeded perennial grass mixture. This shows that it is possible for successful stands of perennial grasses to be established simply by spreading perennial grass straw.

Effects of weeds

Weeds generally had a negative effect on perennial grasses, although these responses often involved interactions with other factors we tested. Generally, perennial grass biomass production was lower in the presence of weeds and revegetation efforts should attempt to minimize weed introduction and success.

Effects of fertilizer

Fertilizer had remarkably little effect on the survival and growth of perennial grasses. Nitrogen fertilizer level was generally only significant in interactions with other factors (i.e. weeds and mulch). We attribute the responses to fertilizer to differences between mulches in the amount of weeds and volunteers of the straw species. The nitrogen added by fertilizer was probably removed by these plants and became unavailable to the perennial grasses. It is also possible that nitrogen was immobilized differentially by straws due to variability in their ease of decomposition, as described above.

Interaction between fertilizer and weeds

Nitrogen fertilizer appeared to compensate for the competitive effects of weeds because perennial grass biomass was greater without weeds when only compost was added and about the same with and without weeds when both nitrogen fertilizer and compost were added. The amount of fertilizer applied at this site, with the particular weed flora and inherent soil fertility, appeared to benefit the perennial grasses without affecting weed biomass significantly. It should be noted that weeds produced more biomass with the addition of compost, but further addition of nitrogen did not increase their growth significantly. Weeds were able to reach their biomass production potential with the amount of nutrients provided by the compost alone.

Interactions between mulch and weeds

The use of nutrients by weeds was the driving force behind the differences we found between mulch treatments. This is evident in the response of pine bluegrass biomass, which tended to be greater with rice straw than other straw types. Weeding made little difference in most mulch treatments, but pine bluegrass biomass increased when weeds were removed from the mulch treatments with the greatest amounts of weeds, i.e. blue wildrye and wheat straws.

Conclusions

The performance of seeded native perennial grasses was determined by complex interactions between nutrient availability and competition from weeds and volunteer plants from the straw mulch. Performance of perennial grasses in rice straw treatments exceeded that in other types of straw mulch by a large margin. Weeds that were introduced in the straw had important negative effects on the perennial grass mixtures. The positive response of perennial grasses to rice straw mulch and poor performance in blue wildrye straw mulch was primarily due to differences in competition from weeds and volunteer mulch species. Slower decomposition rates of rice straw may also have been a factor in this response. In the presence of weeds, perennial grasses benefitted from the addition of slow release nitrogen source with compost while weeds benefitted from the addition of compost alone.

Finally, we make the following recommendations:

1. Rice straw is a good mulch choice because it is likely to have fewer weeds adapted to revegetation sites, rice plants are unlikely to volunteer and it has a slow decomposition rate. All of these factors result in higher nutrient availability for the seeded species.

2. Use native straw when you want to establish the straw species and if the straw is free of weeds.

3. Apply high carbon content and slow nitrogen release fertilizers.

4. Use weed free straw.

5. Study the performance of native perennial grasses with rice and other straw mulches on very low nutrient soils with varying nitrogen levels. In these studies, plant nutrient status and available nutrients in the soil should be measured.

6. Investigate the performance of native perennial grass species with different types of native grass straw mulch to identify patterns of success and more species specific mulch recommendations.

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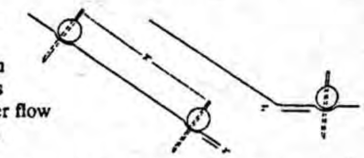

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