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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.

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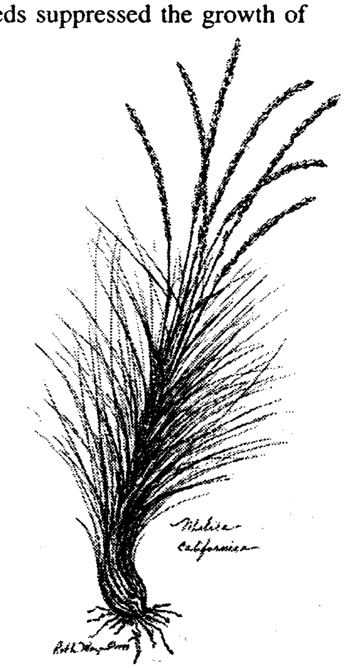

Introduction

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

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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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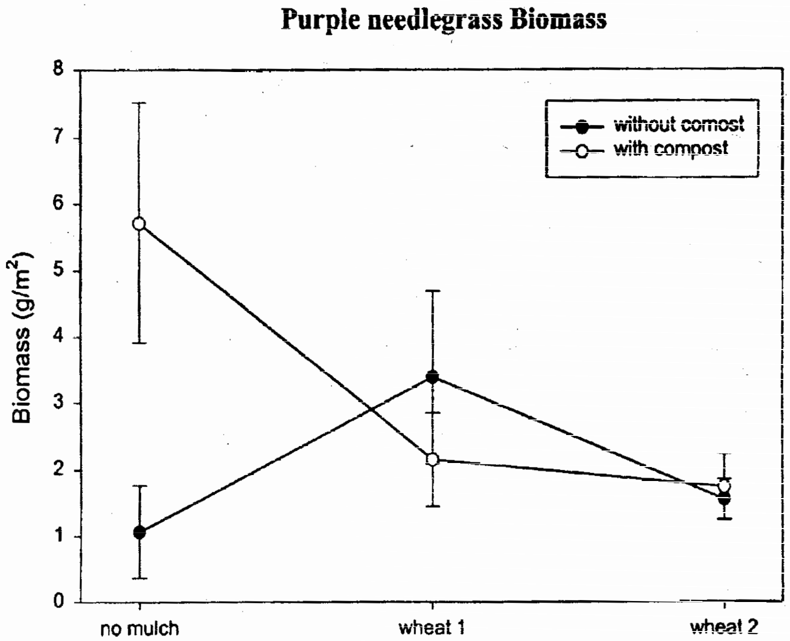

Figure 1. Biomass produced by purple needlegrass with different mulch treatments depended upon compost application (mean + 1 standard error of the mean). Wheat 1 = 3,375 kg/ha (3,000 lb/acre), wheat 2 = 5.625 kg/ha (5,000 lb/acre).

= 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/m^2)	N	Density (plants/m^2)	N	Density (plants/m^2)
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

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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/m²)
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/m².

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/m²)
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/m²)
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

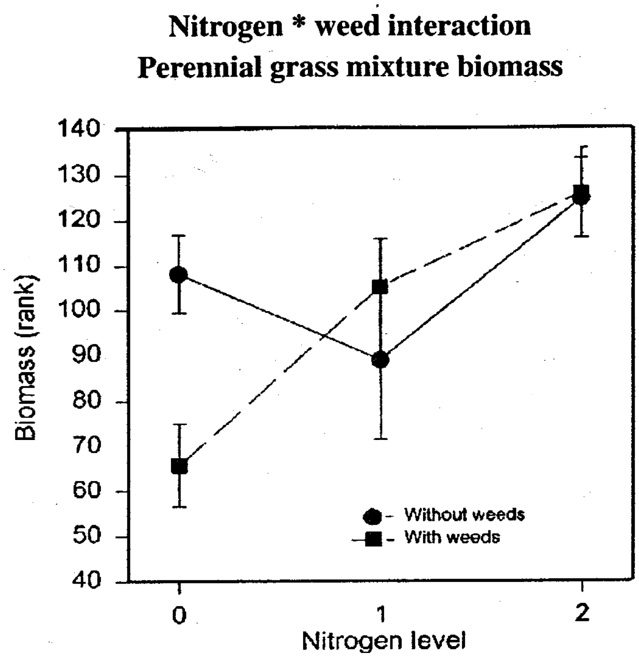

Figure 2. Response of perennial grass biomass to nitrogen fertilizer depended upon the presence or absence of weeds. Fertilizer appears to compensate for the competitive effect of weeds (mean + 1 standard error of the mean).

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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