Restoring Native Perennial Grasses to Rural Roadsides in the Sacramento Valley of California: Establishment and Evaluation

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Abstract

Along rural roadsides of the Sacramento Valley of California, we seeded native and non-native perennial grasses to gauge their potential value in roadside vegetation management programs. In trial I (polycultures), three seeded complexes and a control (resident vegetation only) were tested. Each seeded plant complex included a different mix of perennial grasses seeded into each of several roadside topographic zones. The seeded levels of plant complex were: native perennial grasses 1 (8 species); native perennial grasses 2 (13 species); and non-native perennial grasses (3 species). In trial II, plots were seeded to monocultural plots of 15 accessions of native Californian and three cultivars of non-native perennial grasses. Plots in both trials were seeded during January 1992 and evaluated for three successive years.

In trial I polycultures during 1993, canopy cover by seeded species was not significantly different among the three seeded complexes. The three seeded complexes showed statistically equivalent reduction of canopy cover by resident plant species. Biomass of seeded perennial grasses was greater for non-native perennial grasses than for native perennial grasses 1 or native perennial grasses 2. Total biomass (seeded plus resident species) was greatest for non-native perennial grasses.

In trial II monocultures during 1993, the non-native *Thinopyrum intermedium ssp. trichophorum* (pubescent wheatgrass) attained the greatest height, followed by the native species *Nassella (Stipa) cernua* (nodding needlegrass), *Nassella (Stipa) pulchra* (purple needlegrass), and *Elymus trachycaulus* var. *majus* (slender wheatgrass). By contrast, the non-native *Festuca ovina* (sheep fescue) and the native *Poa secunda* ssp. *secunda* (pine bluegrass) were particularly short. *N. cernua, N. pulchra, E. trachycaulus*, and *T. intermedium* ssp. *trichophorum* showed particularly great canopy cover, whereas particularly low values of canopy cover were obtained for *F. ovina* and *P. secunda* ssp. *secunda*. A highly significant inverse linear relationship was obtained by regression analysis when canopy cover for seeded perennial grasses was used to predict canopy cover for resident plant species ($p <$ 0.0001, $r^2 = 0.297$, slope $= -0.336$, intercept $= 39.442$).

In 1994, the following native perennial grasses showed substantial canopy cover in trial II monocultures and appear promising for use in Sacramento Valley rights-of-way: *Bromus carinatus* (California brome), *Elymus glaucus* (blue wildrye), *E. trachycaulus*, all accessions of *Hordeum brachyantherum* ssp. *brachyantherum* (meadow barley), a prostrate accession of *Hordeum brachyantherum* ssp. *californicum* (California barley), *N. cernua*, and *N. pulchra*. In addition, the non-native *T. intermedium* ssp. *trichophorum* performed well. By contrast, virtual failure of stands was observed for the non-native *F. ovina* and the following native species: *Elymus multisetus* (squirreltail), two accessions of *Festuca idahoensis* (Idaho fescue), *Festuca rubra* (creeping red fescue), and *P. secunda* ssp. *secunda*.

Introduction

In rural California, roadside management schemes emphasize herbicides and tillage to suppress resident vegetation. An alternative approach could involve the establishment and maintenance of native perennial grasses. These grasses may be grown in conjunction with other native flora and may provide habitat for desirable wildlife while potentially reducing the threat of flooding, erosion and siltation, wildfire, and incidence of resident vegetation.

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Perennial sod-forming and bunch grasses were once common in much of California, including the Sacramento Valley and the surrounding foothills (Crampton 1974). However, by the mid-1800s, the native grasses were greatly reduced, presumably by a combination of prolonged drought, overgrazing by feral and domestic cattle, cultivation, and competition from invasive annual grasses and forbs introduced from the Mediterranean area (Dasman 1973; Menke 1989).

There are now opportunities to reestablish portions of the native grasslands, along with increased public interest in native grasses and ecological restoration (Meyer 1989; Anonymous 1990). There are several large producers of California native grass seed, and specialized seeding implements are available for the long-awned native grass seed (Truax, no date).

In several midwestern states, native perennial grasses have been established on rights-of-way (Harrington 1989) and along ditches (Bright 1988). For example, Iowa developed Integrated Roadside Vegetation Management and the Living Roadway Trust Fund to encourage the use of native plants for roadside revegetation throughout the state (Integrated Roadside Vegetation Management, no date). Analogous vegetation management programs are possible in California.

The purpose of this study was to seed and evaluate establishment of non-native and native perennial grasses, including several local accessions, both in polycultures and in monocultures. The work included two trials, one involving polycultures (trial I) and the other, monocultures (trial II). In trial I, different polycultures were established. Each seeded plant complex featured a different mix of grasses seeded to each topographic zone. It is important to assess the collective performance of various species in such polycultures because aesthetic, ecological, and general management considerations dictate that polycultures of various grasses will be used in practical roadside projects. By contrast, in trial II individual species were seeded across all the topographic zones described below. Such monocultures are important to evaluate, because numerous accessions could have roles in various topographic zones. Their variable performance in those zones must be assessed individually, to avoid potentially confounding effects of competition from neighboring seeded perennial grasses. In both polycultures and monocultures, widely used cultivars of non-native perennial grasses can provide valuable benchmark data by which to gauge performance of the natives.

The present research addressed whether local forms of several native perennial grasses can be established and managed on disturbed sites. In light of the likelihood of within-region genetic distinctness of different populations of native grasses such as *Elymus glaucus* (blue wildrye) (Knapp and Rice 1996), we believed that local forms of native perennial grasses should be used if available. Inasmuch as we used several such local forms, the work could be said to concern restoration ecology in a relatively narrow sense. The experimental site was set amid farmlands and was susceptible to run-off, flooding, and the inadvertent effects of herbicide drift and various agricultural production practices. In these important respects, the study reflected real-world conditions rather than rigorous local control by researchers.

Rural roadsides may be viewed as typically comprising several topographic zones (Fig. 1): (1) unimproved shoulder; (2) recovery area; (3) side slope; (4) open-cut ditch (drainage); (5) back slope; (6) back berm; and (7) field edge. These zones present a range of environmental conditions and management options and requirements, and may necessitate the use of a variety of plant materials. Various native perennial grasses have diverse environmental optima and tolerances and differing growth habits, and thus may lend themselves to different topographic zones. In general, it is a reasonable goal to use plant species that lead to reduced total aboveground biomass yet retain high proportions of perennial groundcover. Other things being equal, this should reduce the threat of flooding, wildfire, and soil erosion. Before these experiments, J. H. A. had experience with large-scale roadside plantings and had made detailed observations of the natural habitats of native grasses. Thus, we had some knowledge of the suitability of various perennial grasses to the various topographic zones; our rationales for those assignments in trial I polycultures follow.

Low-statured bunchgrasses (e.g., *Festuca idahoensis* [Idaho fescue], *Poa secunda* ssp. *secunda* [pine bluegrass], and low-growing forms of *Hordeum brachyantherum* ssp. *californicum* [California barley]) are perhaps most suitable for the unimproved shoulder, because they permit maximum visibility by motorists, are unlikely to break up pavement in the adjoining travelled way, and, although they tolerate close mowing, require no mowing in many cases. *Festuca rubra* (creeping red fescue), *Bromus carinatus* (California brome), and lower-growing forms of *E. glaucus* are intermediate in height and are candidates for use in the recovery area, through which motor vehicles occasionally travel. Perennial grasses like *Hordeum brachyantherum* ssp. *brachyantherum* (meadow bar-

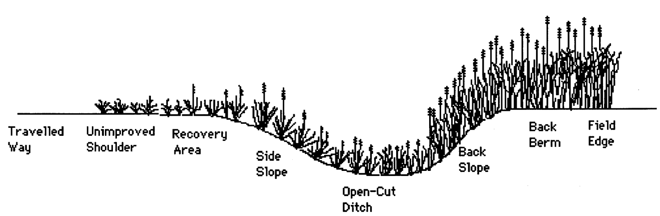

Figure 1. Schematic diagram of roadside topographic zones.

ley), *H. brachyantherum* ssp. *californicum*, *B. carinatus, Melica californica* (California oniongrass), *Nassella (Stipa) pulchra* (purple needlegrass), *Nassella (Stipa) cernua* (nodding needlegrass), and *Elymus multisetus* (squirreltail) are candidates for both the recovery area and the side slope. The moderate biomass production of these grasses makes them unlikely to interfere with motor vehicles that occasionally use the area. Also, these grasses are drought tolerant and thus would adapt to these two zones that may receive less water than do either the unimproved shoulder or the open-cut ditch. *H. brachyantherum* ssp. *brachyantherum* is tolerant of intermittent flooding and has moderate stature. Thus, it would tolerate conditions encountered in most open-cut ditches and be unlikely to block the flow of water. If the open-cut ditch contains water for extended periods, *Eleocharis* spp. (spike-rushes) would be better adapted. For the back slope and back berm, tall-statured grasses, such as *B. carinatus, E. glaucus, Elymus trachycaulus* var. *majus* (slender wheatgrass), and *N. pulchra* appear to be good candidates. If mowing is frequent, these species could also be used on the back slope and in intermittently-flooded ditch beds. The field edge is subject to inadvertent damage by herbicides and agricultural implements. Therefore, the rhizomatous *Leymus triticoides* (creeping wildrye or beardless wildrye) is probably appropriate. This species is tall statured, recovers rapidly from mechanical damage, and is believed by some workers to show resistance to glyphosate, a commonly used broad-spectrum contact herbicide (J. H. Anderson, personal observation).

Methods

Experimental Design

The trials were conducted at Hedgerow Farms, approximately 8 km north of the town of Winters, Yolo County, California. For both trials I and II, there were five experimental blocks involved, with blocks I and II situated on Brentwood silty clay loam (fine, montmorillonitic thermic Typic Xerochrepts [class 1 agricultural soil]), and blocks III and V were on Capay silty clay (fine, montmorillonitic, thermic Typic Haploxererts [class 2 agricultural soil]).

Trial I: Polycultures. In trial I (polycultures), each level of plant complex included a different mix of perennial grasses seeded into each of several roadside topographic zones, based on principles discussed earlier. The organization of trial I is illustrated in Figure 1 and summarized in Appendix 1. Trial I involved three factors: plant complex, block, and topographic zone. Four levels of plant complex were compared: (1) unseeded plots containing resident vegetation (control); (2) commercially available native grasses (native grasses 1, a plant complex with relatively low species richness: eight species) (3) a combination of commercially available and newly collected native grasses (native grasses 2, a plant complex with relatively high species richness: 13 species, including *Hordeum brachyantherum* ssp. *brachyantherum* and *Hordeum brachyantherum* ssp. *californicum*); and (4) non-native perennial grasses (non-native perennial grasses, a plant complex employing three species of commercially available non-native perennial grasses). Plots were arrayed in five randomized complete blocks (block); each plot extended along 7.63 m of roadside and was 7.63–9.15 m wide, extending to the edge of an agricultural field. Thus, each plot comprised all the roadside topographic zones mentioned earlier.

As indicated for trial I in Appendix 1, different mixes were sown into the various topographic zones. Thus, in trial I, the variable topographic zone is confounded with seeded mix. Seed was obtained from a commercial source (Stewart ConservaSeed, Rio Vista, California), local seed increase plots (Hedgerow Farms), or from the wild. Seeding rates ranged from about 10–68 kg/ha for the individual species sown, with precise rates given in Appendix 2. Number of seeds per kg and germination data (provided by ConservaSeed and Hedge-row Farms) are also presented in Appendix 2 and Appendix 3. Seeding rates were relatively high and were intended to promote rapid establishment and homogeneous stands. Relatively high seeding rates are typically used for cold-weather plantings, such as those conducted during 1992.

Trial II: Monocultures. In trial II (monocultures), plots were seeded to 15 native Californian and three non-native accessions of perennial grasses. This trial entailed three factors: grass, block, and topographic zone. The levels of grass, seeding rates, and germination data are summarized in Appendix 3. As in trial I, seeding rates were relatively high to promote rapid establishment and homogeneous stands. Some levels of grass were not replicated because of shortage of seed; these levels were not included in the statistical analyses. There were five randomized incomplete blocks (block). Plots were of dimensions 3.1 m $\times$ 7.63–9.15 m, i.e., a 3.1-m length of roadside. As with trial I, each plot comprised all the roadside topographic zones mentioned earlier. As with trial I, there were also plots of resident vegetation (control) embedded in the design; the management of these is explained in greater detail below; they were used in some but not all of the experimental comparisons.

Cultural Practices

Except where otherwise noted, cultural practices were similar for both trials I and II.

Methods for establishing seeded grasses were as follows. During late November 1991, a grader was used to prepare the seedbed; following rains in late December 1991, glyphosate (Monsanto Corporation, St. Louis, Missouri, 1.17 l a.i./ha) was applied to kill emerged resident vegetation seedlings. Cool-season perennial grass seed was broadcast by hand on January 14, 1992 and immediately incorporated to a depth of approximately 1.25 cm using a tractor-drawn spike-tooth harrow. As mentioned above, the seeded zones and rates are summarized in Appendices 1, 2, and 3. An additional application of glyphosate was made on January 29 (0.59 l a.i./ha) to kill resident vegetation seedlings before the emergence of the perennial grass seedlings. Following January 29, 1992, all weed control measures mentioned, including herbicides and mowing, were withheld from control plots (those assigned to the resident vegetation regime). In late March, all seeded plots in blocks III, IV, and V were sprayed with a mixture of broadleaf herbicides (Buctril [bromoxynil, Rhone Poulenc, Research Triangle Park, North Carolina, 1.40 kg a.i./ha] and rhomene [(4-chloro-2-methylphenoxy) acetic acid [MCPA] Rhone Poulenc, 0.43 kg a.i./ha]). Because broadleaf weed densities did not appear to be high in blocks I and II, these were not treated with the broadleaf herbicide mix.

On April 20, in response to heavy infestations of *Avena fatua* (wild oat), the fieldside zones of blocks I and II were treated by wick application of glyphosate; on April 21, blocks IV and V were so treated. In late April, blocks II and V, which had heavy infestations of *A. fatua*, were mowed with a rotary mower. In early May, blocks I and II were irrigated with overhead sprinklers, and block I was hand weeded to remove *A. fatua* and *Malva rotundifolia* (cheeseweed).

The pre-emergence herbicide Surflan (oryzalin, DowElanco, Indianapolis, Indiana) was applied to all blocks, control plots excluded, on November 5, 1992, at 0.24 kg a.i./ha.

Data Collection

The trials assessed whether different perennial grass polycultures or monocultures would show different rates of establishment, height, canopy cover, and biomass production. Height of roadside vegetation was evaluated, because it may affect competitiveness, threat of flooding (in that tall grass may block ditches and thereby impede drainage), and vision of motorists. Perennial canopy cover was evaluated because it has implications for plant competitiveness, soil erosion, and water infiltration. Biomass production by seeded and resident plant species (assessed here in trial I polycultures) has possible implications for flooding in that greater biomass may increase blockage of ditches and impede drainage and for wildfire in that greater biomass production implies greater fuel load. In both respects, combined biomass produced by seeded and resident species is important to assess.

Trial I: Polycultures. In trial I polycultures during 1992, height (including reproductive structures, if present) was assessed on May 25, with one measurement made in predetermined locations in each of five topographic zones in each plot: unimproved shoulder, side slope, open-cut ditch, back slope, and back berm. In each case, the tallest plant part (including reproductive structures) within 5 cm of the meter stick was measured. Because blocks II and III were mowed in April 1992, to reduce resident vegetation, height was not assessed there during that year. Canopy cover attained by seeded perennial grasses in seeded plots and by resident vegetation in control plots was assessed on June 13, 1992, with one visual estimate of percentage of canopy cover given for each entire plot, without regard to topographic zone. Because of our overriding interest in erosion prevention and suppression of resident vegetation (including agricultural weeds), canopy cover was deemed a much more important index to successful establishment, dominance, and persistence than was plant population density. Therefore, the latter index was neglected in the present evaluations. In the interests of brevity, initial live seed population densities are not given explicitly here for the polycultural plots, but may be calculated from data presented in Appendices 2 and 3.

In trial I polycultures during 1993, height of seeded or resident species (including reproductive structures, if present) was assessed for all levels of plant complex and block on May 25. Measurements were made at three predetermined sites within each of five topographic zones (recovery area, side slope, open-cut ditch, back slope, and back berm). As during 1992, the tallest plant part (including reproductive structures) occurring within 5 cm of the meter stick was measured.

Canopy cover was assessed using the method described by Daubenmire (1959), using a 40×100–cm frame. Block V was evaluated on May 26 and the other levels of block on May 28. By this method, within each experimental plot, the frame was placed in three predetermined sites within each of five topographic zones (recovery area, side slope, open-cut ditch, back slope, and back berm). Thus, 15 measurements were made within each plot. With each placement of the frame, visual assessment was used to assign a canopy cover class. Each canopy cover class was a category representing a range of percentages of cover. Before analyses, each categorical datum was converted to the mean cover percentage for the range represented.

In trial I polycultures, aboveground biomass was assessed on June 8, 1993. Using a quadrat that circumscribed an area of 0.1 m^2, one biomass harvest was made in each plot at one predetermined site in each of the five levels of topographic zone mentioned above. All vegetation was clipped down to a height of about 2.5 cm. Herbage of seeded perennial grasses was separated from that of resident vegetation, and samples of both types were dried for 1 hour at 78°C and thereafter for at least 39 hours at 60°C or 65°C to constant weight. Biomass measurements were then made using an analytical balance.

Trial II: Monocultures. In trial II monocultures during 1992, initial seedling stands were assessed visually for each seeded plot on February 8. Plots were scored as category 4 (high seedling density, mean ca 500/m2), category 3 (intermediate seedling density mean ca 100/m2), category 2 (low seedling density, mean ca 50/m2) or category 1 (extremely low seedling density, mean ca 10/m2). On June 13, we assessed whether seeded perennial grasses had flowered. Methods of assessing height and canopy cover were as mentioned for trial I during 1992.

During 1993, height was assessed on May 22, with one measurement made at a predetermined site in each of six levels of topographic zone in each plot: unimproved shoulder, recovery area, side slope, open-cut ditch, back slope, and back berm. Canopy cover of seeded perennial grasses or resident vegetation was determined on May 23, using the Daubenmire (1959) method used as for trial I above, except that only three levels of topographic zone were evaluated: unimproved shoulder, recovery area, and side slope.

During 1994, canopy cover was determined by whole-plot visual inspection on May 22.

Statistical Analysis and Presentation of Results

Untransformed data from trials I and II were assessed statistically by suitable analysis of variance (ANOVA) models. Because some grasses were dropped from consideration and because sampling methods varied, separate analyses were conducted for data from different years. Because management of resident vegetation was uniform for each level of block, any effects of such management differences are pooled in the effects for block in the ANOVA. In trial II, all accessions of *H. brachyantherum* ssp. *brachyantherum* were pooled for the purposes of the 1993 analyses. The same was done for all accessions of *H. brachyantherum* ssp. *californicum*. Where topographic zone was considered in a statistical analysis, this factor was regarded as a repeated measure of each experimental plot, because level cannot be randomly assigned as in a conventional split-plot design. Post hoc mean separation, where appropriate, was obtained using Fisher's protected least significant difference. In trial II, regression analysis was used to assess the relationship between canopy cover of seeded and resident species. Planned single-degree-of-freedom linear contrasts were used where needed to distinguish among heights attained in various levels of topographic zone.

In the interests of brevity, only results from the 1993 measurements are presented in detail here. Results from 1992 and 1994 are merely summarized in brief in this article, but are available in detail by request from the corresponding author (R. L. Bugg).

Results

Several perennial grasses showed good establishment and persistence both in polycultures (Fig. 2) and in monocultures (Fig. 3). Particularly good performance was observed for the non-native perennial grasses *Dactylis glomerata* (orchard grass) and *Thinopyrrum intermedium* ssp. *trichophorum* (intermediate wheatgrass), and the following native grasses: *Bromus carinatus, Elymus glaucus, Elymus trachycaulus*, all accessions of *Hordeum brachyantherum* ssp. *brachyantherum*, a prostrate accession of *Hordeum brachyantherum* ssp. *californicum, Nassella cernua*, and *Nassella pulchra.*

Precipitation in nearby Davis, Yolo County, during the relevant years was (in cm): 1991: 38.7; 1992: 57.3; 1993: 65.5; 1994: 38.5 (Department of Land, Air, and Water Resources, University of California, Davis). During the critical early establishment phase of 1992, monthly rainfall totals (cm) in Davis were: January: 4.0, February: 21.7, March: 9.2, April: 1.4. We believe that the situation was favorable for native grass establishment, because there were no strong drying conditions during early seedling establishment. Such drying conditions can lead to soil crusting that reduces seedling emergence. Even after emergence, seedlings may die due to lack of water.

Figure 2. Roadside perennial native grasses, native grasses 1 plot, trial I polycultures during spring 1993. Photograph by Robert L. Bugg.

Figure 3. Roadside plots of perennial native grasses, trial II monocultures during spring 1993. Photograph by Cynthia S. Brown.

In blocks I and II of both trials, the dominant resident plants in terms of canopy cover were *Avena fatua* (wild oat), *Malva rotundifolia* (cheeseweed), *Brassica nigra* (black mustard), and *Centaurea solstitialis* (yellow star-thistle). In blocks III and IV, *Polygonum aviculare* (common knotweed), *Bromus diandrus* (ripgut brome), *Bromus hordeaceus* (soft chess), *A. fatua*, and *M. rotundifolia* were common but did not appear to impede establishment of the seeded species. In block V, *A. fatua, Lolium multiflorum* (annual ryegrass), and *Phalaris* sp. (a canarygrass) were the dominant resident plants, based on canopy cover.

Trial I: Polycultures

1992. During 1992, all three seeded polycultures of perennial grasses showed good initial composite establishment in all blocks. There were, however, differences in performance by individual species and in particular topographic zones.

In the non-native grasses, establishment by *Festuca ovina* was spotty (<30% canopy cover) in the unimproved shoulder. By contrast, *T. intermedium* ssp. *trichophorum* and *D. glomerata* both established well and together gave nearly complete canopy cover.

In native grasses 1, *Bromus carinatus, Elymus glaucus, Elymus trachycaulus* var. *majus, Hordeum brachyantherum* ssp. *brachyantherum* (nearly 100% canopy cover in the open-cut ditch zone), and *Poa secunda* ssp. *secunda* established very well in the seeded topographic zones, with lesser performance by *Festuca rubra*. Very few plants of *Leymus triticoides* were observed, and the seeding of this species was considered a failure.

In native grasses 2, the species mentioned for native grasses 1 performed similarly. In addition, *Hordeum brachyantherum* ssp. *californicum* showed excellent establishment, contributing about 30% canopy cover in the unimproved shoulder zone. Spotty establishment (<10% canopy cover for each) was observed for *Festuca idahoensis* in the unimproved shoulder, recovery area, and side slope zones, and by *Elymus multisetus, Nassella pulchra,* and *Nassella cernua* in the recovery area and side slope zones, and virtually no establishment was observed for *N. pulchra* or *Melica californica* in the back berm zone.

Native grasses 1 and native grasses 2 did not differ significantly from each other in height, but both were significantly taller than were non-native grasses based on Fisher's protected least significant difference ($p < 0.05$). There were significant differences in height due to topographic zone ($p = 0.0001$); in this case, mean separation for all pairs of means is inappropriate, given the repeated-measures structure of the ANOVA model. In general, heights appeared greatest in the back berm and least in the recovery zones, with intermediate values obtained in the intervening topographic zones. Percentages of canopy cover did not differ significantly among the levels of plant complex ($p = 0.2001$).

1993. During 1993, height measurements indicated statistically significant differences among levels of plant

Table 1. Mean height and mean percentage canopy cover for various levels of plant complex in trial I polycultures during 1993, estimated across all levels of block and topographic zone.*

	Mean ± SEM		
Plant Complex	*Height (cm)*	*Canopy Cover by Seeded Species (%)*	*Canopy Cover by Resident Species (%)*
Non-Native Perennial Grasses	68.10 ± 6.54 a	49.05 ± 5.92	10.09 ± 4.42 a
Native Grasses 1	85.49 ± 4.48 b	51.03 ± 5.19	6.56 ± 1.79 a
Native Grasses 2	75.11 ± 3.11 ab	46.89 ± 4.80	6.14 ± 2.59 a
Control	101.24 ± 4.97 c	—	69.75 ± 3.31 b
p (based on ANOVA)	0.0031	0.8093	0.0001

*In the event of a significant F-test ($p < 0.05$), post hoc mean separation is by Fisher's protected least significant difference. In a given column, means that are followed by the same letter are deemed not significantly different from one another. Canopy cover was assessed by the Daubenmire (1959) method.

Table 2. Heights (cm) and percentage canopy cover for seeded perennial grasses in trial I polycultures in variuos levels of topographic zone, estimated across all levels of plant complex and block assessed, during 1993.*

	Mean ± SEM		
Topographic Zone	*Height (cm)*	*Canopy Cover by Seeded Grasses (%)*	*Canopy Cover by Resident Species (%)*
Recovery Area	56.94 ± 7.58	31.58 ± 6.19	18.55 ± 5.64
Side Slope	79.06 ± 4.21	55.38 ± 6.03	26.11 ± 7.43
Open-Cut Ditch	82.15 ± 3.68	53.06 ± 6.49	19.59 ± 7.13
Back Slope	88.09 ± 4.99	60.16 ± 5.38	28.64 ± 8.15
Back Berm	96.48 ± 4.93	44.77 ± 7.89	22.79 ± 6.86
p (based on ANOVA)	0.0001	0.0019	0.0017

*Post hoc pairwise mean separation is not appropriate to these data because of the repeated-measures structure of the analysis of variance model. Canopy cover was assessed by the Daubenmire (1959) method.

complex ($p = 0.0031$), with particularly great heights attained in the control (Table 1). There was no significant effect due to block ($p = 0.5801$). Topographic zone had a significant effect on height ($p = 0.0001$) (Table 2). As mentioned earlier, this factor is confounded with the mixtures of grasses sown in the various levels. However, as we desired and planned, height was least on the recovery area, where visibility to motorists is most important. This was substantiated by a highly significant result ($p = 0.0001$) for a planned single-degree-of-freedom linear contrast between height for recovery area and heights obtained in the other levels of topographic zone assessed. As mentioned previously, it would also be desirable to show reduced plant height in the open-cut ditch, by comparison with back slope and back berm. The relevant linear contrast showed a significant effect ($p = 0.0442$), indicating that this aim was attained.

Data for canopy cover by seeded species did not show a statistically significant difference due to plant complex ($p = 0.8093$) (Table 1). There was no significant effect due to block ($p = 0.0782$). However, topographic zone had a highly significant effect on canopy cover by seeded species ($p = 0.0019$) (Table 2).

Data for canopy cover by resident vegetation indicated a highly significant effect due to plant complex ($p = 0.0001$) (Table 1). Fisher's protected least significant difference indicated that all seeded polycultures had significantly less canopy cover by resident vegetation than did the control. There was no significant effect due to block ($p = 0.0909$). A highly significant effect occurred for topographic zone ($p = 0.0017$) (Table 3); post hoc pairwise mean separation techniques are inappropriate for this variable. As mentioned before, topographic zone is confounded with seeded mix, so results should be interpreted with care.

Aboveground biomass of seeded and resident species were evaluated separately and in combination, because these indices may have implications for flooding and fuel load (and, by extension, wildfire). In particular, other things being equal, greater aboveground biomass may imply greater threat of flooding and wildfire. Biomass of seeded species showed a highly significant effect due to plant complex ($p = 0.0034$), and was significantly greater for non-native grasses than for native grasses 1 or native grasses 2 (Table 3). Biomass by resident plant species varied significantly among levels of plant complex ($p = 0.0001$), with lower values obtained in the three seeded plant complexes than in control (Table 3). Total biomass (seeded plus resident plant species) also showed a significant effect due to plant complex ($p = 0.0023$), and was significantly greater for non-native grasses than for native grasses 1, native grasses 2, or control (Table 3). There were no significant effects due to block for any of the types of biomass measure-

Table 3. Mean biomass during 1993 for various levels of plant complex in trial I polycultures, estimated across all levels of block and topographic zone.*

	Dry Biomass (g/0.10–m^2 quadrat), Mean ± SEM		
Plant Complex	*Seeded Species*	*Resident Species*	*Seeded plus Resident Species*
Non-Native Perennial Grasses	165.57 ± 26.96 b	22.33 ± 8.79 a	187.46 ± 22.74 b
Native Grasses 1	96.86 ± 11.63 a	18.73 ± 5.66 a	115.59 ± 9.18 a
Native Grasses 2	71.62 ± 5.46 a	12.29 ± 3.76 a	83.90 ± 5.24 a
Control	—	111.13 ± 11.48 b	111.13 ± 11.48 a
p (based on ANOVA)	0.0034	0.0001	0.0023

*In the same column, means followed by the same letter are deemed not significantly different from each other by Fisher's protected least significant difference.

ment. Biomass of both resident ($p = 0.0010$) and seeded plus resident species ($p = 0.0015$) was significantly affected by topographic zone (Table 4).

Trial II: Monocultures

1992. On February 8, relatively high mean densities of seedlings were observed (mean ranking 3.5 or higher) for *B. carinatus, E. glaucus, E. multisetus, E. trachycaulus, F. ovina, F. rubra*, all accessions of the commercial mix of *H. brachyantherum* ssp. *brachyantherum*, the Hastings accession of *H. brachyantherum* ssp. *californicum, P. secunda* ssp. *secunda*, and *T. intermedium* ssp. *trichophorum*. Intermediate densities (mean ranking 2.5–3.5) were observed for the northern accession of *F. idahoensis*, the Cosumnes and saline accessions of *H. brachyantherum* ssp. *californicum*, the prostrate accession of *H. brachyantherum* ssp. *californicum, M. californica,* and *E. multisetus*. Low densities (mean ranking 1.5–2.5) were observed for *Melica imperfecta, N. cernua*, and the local accession of *F. idahoensis. N. pulchra* showed the lowest initial seedling density (mean ranking 1.3). Initial mean seedling densities appeared greatest in block III, intermediate in blocks II, IV, and V, and particularly low in block I. By May 25, the first measurement of canopy cover indicated patchiness in blocks I and II, consistently excellent canopy cover in blocks III and IV, and poor canopy cover in block V. The patchiness of growth by seeded and resident plant species suggested that there may have been residual herbicides inhibiting establishment of perennial grasses in the open-cut ditch, back slope and back berm zones of blocks I and II. Block V was subject to flooding and intense competition from the non-native annual grasses mentioned earlier.

During 1992, reproduction occurred for *E. trachycaulus, E. glaucus, B. carinatus, E. multisetus*, and all accessions of both subspecies of *H. brachyantherum*. Especially high proportions of canopy cover were attained by *E. trachycaulus, E. glaucus, B. carinatus, T. intermedium* ssp. *trichophorum*, and several accessions of *H. brachyantherum* ssp. *californicum*.

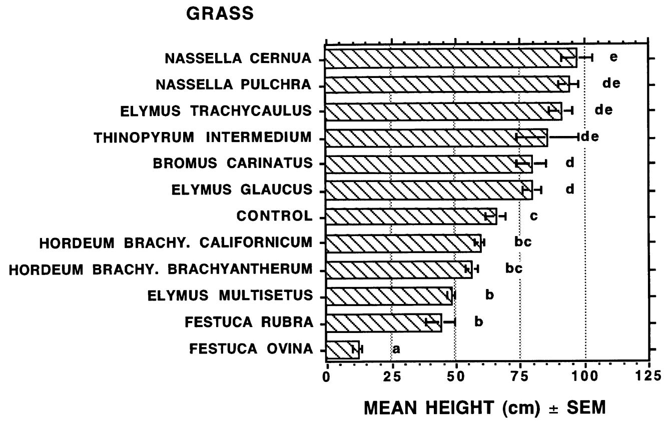

Figure 4. Mean height (±SEM) of seeded perennial grasses or resident vegetation (in control plots) in trial II monocultures, estimated across all levels of block and topographic zone. Based on ANOVA, $p = 0.0001$; means followed by the same letter are not significantly different by Fisher's plsd.

1993. During 1993, height data (Fig. 4) indicated highly significant differences due to grass ($p = 0.0001$), with *F. ovina* showing particularly low stature, and *N. cernua, N. pulchra, E. trachycaulus* var. *majus*, and *T. intermedium* ssp. *trichophorum* showing particularly high stature. Block had a highly significant effect on plant height ($p = 0.0001$), with especially low stature observed in block IV. As indicated in Table 5, topographic zone ($p = 0.0001$) had a highly significant effect on height, with particularly low statures attained in the unimproved shoulder, and especially high statures observed in the open-cut ditch and back slope zones.

The factor grass had a highly significant effect on canopy cover by seeded grasses ($p = 0.0001$). Canopy cover data for various grasses are presented in Figure 5. Relatively low values for percent canopy cover were observed for *F. rubra, F. ovina*, and *E. multisetus*. Particularly great canopy cover was observed for *H. brachyantherum* ssp. *brachyantherum, H. brachyantherum* ssp. *californicum, E. trachycaulus, T. intermedium* ssp. *trichophorum*, and *N. cernua*. Block showed a highly significant effect on can-

Table 4. Biomass for trial I polycultures during 1993 in various levels of topographic zone, estimated across all levels of block and plant complex assessed.*

	Dry Biomass (g/0.10-m² quadrat), Mean ± SEM		
Topographic Zone	*Seeded Species*	*Resident Species*	*Seeded + Resident Species*
Recovery Area	79.93 ± 20.57	53.91 ± 13.65	115.64 ± 13.56
Side Slope	94.58 ± 10.80	35.51 ± 12.25	107.07 ± 9.60
Open-Cut Ditch	97.38 ± 19.93	16.27 ± 5.15	88.88 ± 15.25
Back Slope	130.22 ± 27.97	43.04 ± 16.20	141.23 ± 20.83
Back Berm	135.28 ± 26.96	56.85 ± 12.44	153.20 ± 16.64
p (based on ANOVA)	0.1215	0.0010	0.0015

*Post hoc pairwise mean separation is not appropriate to these data because of the repeated-measures structure of the analysis of variance model.

Table 5. Heights (cm) and percentage canopy cover in various levels of topographic zone in trial II monocultural plots of seeded perennial grasses, estimated across all levels of block and grass assessed during 1993.*

	Mean ± SEM		
Topographic Zone	*Height (cm)*	*Canopy Cover by Seeded Species (%)*	*Canopy Cover by Resident Species (%)*
Unimproved Shoulder	48.13 ± 2.69	42.97 ± 4.38	32.44 ± 3.93
Recovery Area	61.93 ± 3.27	57.14 ± 4.73	18.90 ± 3.10
Side Slope	70.00 ± 3.46	47.16 ± 4.07	36.01 ± 3.92
Open-Cut Ditch	74.00 ± 3.83	—	—
Back Slope	75.00 ± 5.77	—	—
Back Berm	69.78 ± 3.79	—	—
p (based on ANOVA)	0.0001	0.0006	0.0001

*Due to the repeated-measures structure of the experiment, post hoc pairwise mean separation techniques are inappropriate. Canopy cover was assessed by the Daubenmire (1959) method. Measurements of canopy cover were not made for the open-cut ditch, the back slope, or the back berm levels of topographic zone.

opy cover provided by seeded grasses ($p = 0.0001$). Block V showed relatively little canopy cover by seeded species, and blocks III and IV showed especially great amounts of canopy cover. There was a highly significant effect by topographic zone on canopy cover by seeded species ($p = 0.0028$) (Table 5).

The factor grass had a highly significant effect on canopy cover provided by resident plant species ($p = 0.0001$). Figure 6 depicts canopy cover data for resident plant species, with particularly great values obtained in control and *F. ovina* plots, and particularly low values observed in plots seeded to *T. intermedium* ssp. *trichophorum* and both subspecies of *H. brachyantherum*. Block had a nonsignificant effect on canopy cover by resident plant species ($p = 0.1142$). Topographic zone showed a highly significant effect on canopy cover for resident plant species ($p = 0.0001$) (Table 5).

Regression analysis using paired per-plot observations from 1993 of canopy cover of seeded perennial grasses versus canopy cover of resident plant species indicated a highly significant inverse linear relationship ($p < 0.0001$, $r^2 = 0.297$, slope $= -0.336$, intercept $= 39.442$) (Fig. 7).

1994. For the final canopy cover data from the monocultural plots, ANOVA indicated highly significant differences due to the factor grass ($p = 0.0002$). The data suggested virtual failure of the stands for both accessions of *F. idahoensis* as well as for *P. secunda* ssp. *secunda*, *E. multisetus*, *F. rubra*, and *F. ovina*. By contrast, relative success (at least 25% mean canopy cover) was obtained with *T. intermedium* ssp. *trichophorum*, *E. trachycaulus*, *N. pulchra*, all accessions of *H. brachyantherum* ssp. *brachyantherum*, the prostrate accession of *H. brachyantherum* ssp. *californicum*, *B. carinatus*, *N. cernua*, and *E. glaucus*. There was a highly significant effect due to block ($p = 0.0014$), suggesting that the best overall perfor-

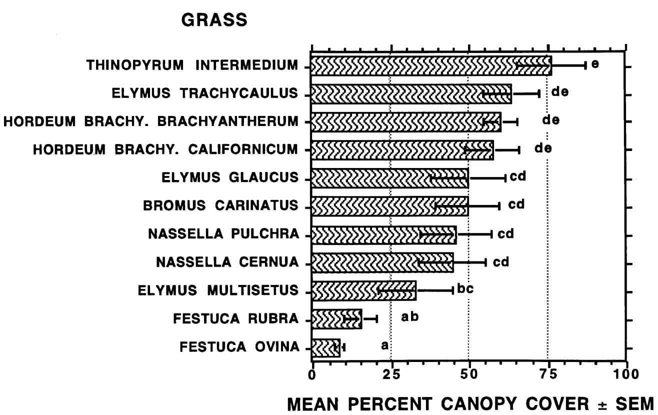

Figure 5. Mean percent canopy cover (±SEM) of seeded perennial grasses in trial II monocultures, estimated across all blocks and topographic zones. Based on ANOVA, $p = 0.0001$; means followed by the same letter are not significantly different by Fisher's plsd.

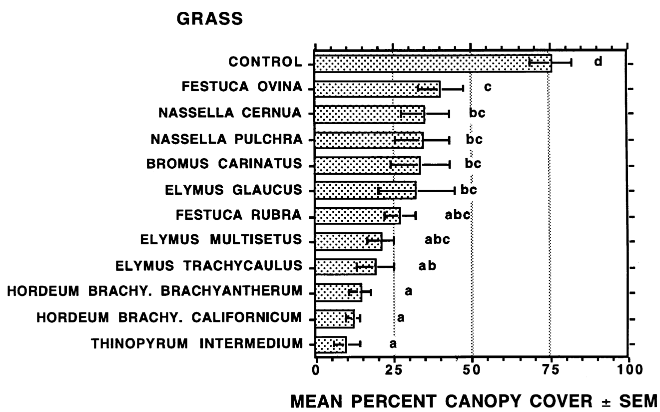

Figure 6. Mean percent canopy cover (±SEM) of resident (weed) plant species in trial II monocultures, estimated across all blocks and topographic zones. Based on ANOVA, $p = 0.0001$; means followed by the same letter are not significantly different by Fisher's plsd.

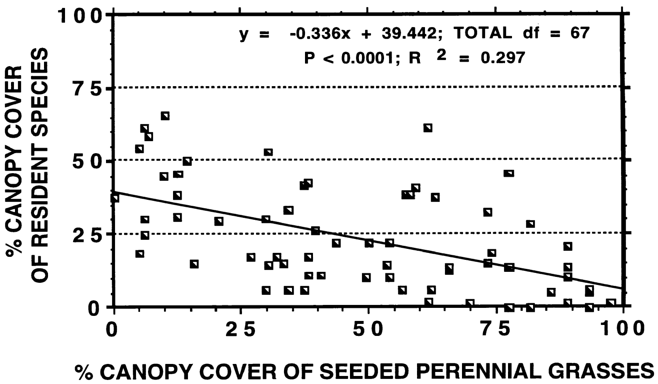

Figure 7. Scattergram and fitted regression line based on percent canopy cover of seeded perennial grasses as a predictor of percent canopy cover of resident (weed) plant species, trial II monocultures. Perennial grasses were seeded on January 14, 1992, and canopy cover was assessed on May 26, 1993 (68 pairs of plot means, estimated across all levels of topographic zone assessed).

mance was obtained in block IV (43.77% ± 8.64), and the worst in block V (9.35% ± 3.66).

In general, the prostrate form of *H. brachyantherum* ssp. *californicum*, *B. carinatus*, *E. trachycaulus*, var. *trachycaulus*, *N. pulchra*, *N. cernua*, *T. intermedium trichophorum*, and *E. glaucus* grew well in all topographic zones. By 1994, *F. ovina*, *P. secunda* ssp. *secunda*, and *E. multisetus* were limited to a few isolated plants in the unimproved shoulder and the recovery area. *F. rubra* was limited to a few areas in the unimproved shoulder and the open-cut ditch.

Discussion

The results suggest good establishment and persistence of several of the seeded perennial grasses, both in polycultures and in monocultures. In trial I, the polycultures performed well in all blocks, which represented a range of soil-moisture conditions. In the first spring (1992), height was greater for both native plant complexes than for the complex of non-native perennial grasses. By the spring of 1993, differences were not so clear cut, with control taller than all other levels of plant complex, native grasses 1 taller than non-native perennial grasses and native grasses 2 statistically indistinguishable from either of the other two seeded complexes.

In 1993, all seeded plant complexes in trial I had significantly less canopy cover by resident vegetation than did the control. Moreover, biomass of resident plant species was significantly greater in control plots than in any of the seeded polycultures. As noted by Fenner (1978), tall turf reduces the establishment of many weedy species. However, in light of the past use of herbicides and other weed-control measures in the seeded plant complexes but not in the control plots, there is no firm basis in the present study for attributing reduced weed cover to the presence of perennial grasses. Trial II data on canopy cover by resident species strongly suggest a pervasive effect of the chemical and mechanical weed-control measures used. In plots where seeded *Festuca ovina* failed to establish, cover by resident vegetation was nevertheless significantly less than in control plots (Fig. 6). Furthermore, the results of the regression analyses for 1993 data from trial II indicate that greater canopy cover by seeded perennial grass species is associated with lesser canopy cover by resident plant species. The Y-intercepts obtained suggest that in the absence of seeded perennial grasses (0% canopy cover by perennial grasses), canopy cover for resident plant species would be about 39%. These values are much less than the values observed for resident plant species in the untreated control (75.59% ± 6.50), but correspond closely to the 40.37% ± 8.71 canopy cover observed for resident plant species in plots seeded to *F. ovina*. The differences between the reported intercepts and the observed values for control suggest the effect of the chemical and mechanical weed-control measures applied to all but control plots. Other experiments are clearly needed to address the use of perennial grass borders to control agricultural weeds.

As suggested earlier, high biomass of seeded, resident, and seeded plus resident plant species may imply greater threat of flooding and fire. All three seeded complexes showed similar biomass for resident species (Table 3), but non-native perennial grasses showed by far the greatest total biomass for seeded plus resident species. This suggests that the two native perennial grass complexes might be preferable to the non-native perennial grasses in terms of flood and fire issues.

In monocultural plots of trial II, low-statured grasses that showed good initial establishment were *F. ovina*, *Poa secunda* ssp. *secunda*, *Elymus multisetus*, and the prostrate form of *Hordeum brachyantherum* ssp. *californicum*. Of these, only the last-mentioned grass persisted well. Intermediately-statured grasses that showed good initial establishment and persistence included all accessions of *Hordeum brachyantherum* ssp. *brachyantherum*. Tall-statured grasses that performed well included *Bromus carinatus*, *Elymus trachycaulus* var. *majus*, *Nassella pulchra*, *Nassella cernua*, *Thinopyrum intermedium* ssp. *trichophorum*, and *Elymus glaucus*.

Several accessions performed poorly in the present experiments. These included both forms of *Festuca idahoensis*, *Melica californica*, *Melica imperfecta*, and *E. multisetus*. For seed produced in very dry years, *F. idahoensis* shows reduced germination rates and seed longevity (Goodwin & Doescher 1995; Scott Stewart, personal communication; Jennifer Anderson, personal communication). These factors may have contributed to the failure

Figure 8. California native perennial grasses and wildflowers are being restored to rural roadsides in parts of the Sacramento Valley of California. On the left (back slope and back berm of the roadside), the bunchgrasses *Elymus glaucus* (blue wildrye) and *Elymus trachycaulus* var. *majus* (slender wheatgrass) are interspersed with native winter-annual forbs, including *Eschscholtzia californica* (California poppy), *Layia platyglossa* (tidy tips) and *Lupinus* spp. (lupins). In the center (open cut ditch), the flood-tolerant bunchgrass *Hordeum brachyantherum* ssp. *brachyantherum* (meadow barley) dominates. On the right (unimproved shoulder and recovery area), the drought-tolerant bunchgrasses *Nassella pulchra* (purple needlegrass) and *Poa secunda* ssp. *secunda* (pine bluegrass) prevail. Photograph by Robert L. Bugg.

of the local forms of *F. idahoensis* in the present trials, inasmuch as 1990–1991 was a dry year in Solano County, where the seed was collected (see Appendix 3 for 1992 germination data). Despite the present findings, several other form of *F. idahoensis* have done well in subsequent vineyard trials (e.g., in San Joaquin County) and in other plantings (Scott Stewart, personal communication). Based on our recent experience, depth of seed incorporation may have been excessive for both *M. californica* and *M. imperfecta*. Moreover, both species are susceptible to weed competition, and embryo dormancy in both species may limit stand development if first-year seed is used (Scott Stewart, personal communication), as was the case in this study. *E. multisetus* showed good establishment, but stands of this species later deteriorated markedly. This species is generally considered more appropriate for poor, rocky sites than for the rich agricultural soils used in this study (Scott Stewart, personal communication).

In trial II, establishment of monocultures on wet, heavy soil (block V) was relatively poor. On such sites in the Sacramento Valley, the weedy grass *Lolium multiflorum* was a particular problem, apparently due to its vigorous growth, late-season maturation, and great tolerance of mowing.

Oryzalin herbicide was applied in the autumn of 1992 at recommended rates, based on promising initial data obtained in an experiment by W. T. Lanini (personal communication 1991), yet it virtually eliminated *P. secunda* ssp. *secunda*. Members of the genus *Poa* are particularly susceptible to the pre-emergence herbicide oryzalin (C. L. Elmore 1993, personal communication). In nearby untreated replicated plots, *P. secunda* ssp. *secunda* continued to survive and to reproduce (data not presented). Oryzalin has approximately six months of activity at the rates used here, and probably reduced seedling recruitment by most perennial grasses as well as by resident vegetation, during 1992–1993. Growth by established plants of some species was probably reduced, as well. Oryzalin is probably inappropriate for use in this context, and other pre-emergence herbicides should only be used with caution (Lanini et al. 1996). Oryzalin is commonly used on agricultural crops, and moves offsite with eroded soil. Thus, the intentional application of this herbicide in these trials may have simulated the conditions encountered in rights-of-way adjoining some conventionally managed agricultural fields. In addition to problems with oryzalin, inadvertent drift from a nearby aerial application of glyphosate (spring of 1992) severely damaged monocultural stands of *E. trachycaulus* var. *majus* in blocks I and II. This species appears particularly sensitive to this commonly used contact herbicide.

Conclusions

Despite difficulties due to herbicides, persistent stands were obtained for several species, including local native forms, as indicated by the 1994 data. We believe that the accessions that retained at least 25% canopy cover in the present monocultures are probably suitable for use in roadsides and other rights-of-way in the Sacramento Valley. This belief is bolstered by our collective experience in large-scale, long-term plantings, and additional ongoing small-plot work by C. S. Brown.

With the increased interest among farmers in reestablishing native plants along field edges, our results raise the possibility of including certain native perennial grasses, and incorporating the theme of restoration ecology into standard production-agriculture and right-of-way management. Based in part on the present studies, native grass plantings are now being established along rights-of-way in Yolo County and elsewhere (Fig. 8).

Future studies on the use of perennial grasses in Sacramento Valley rights-of-way should concern the role of irrigation in enhancing establishment of perennial grasses (O'Keefe 1996), and the effect of sowing rates (Stevenson et al. 1995) and other practices (Wilson and Gerry 1995) on stand establishment and composition. Other issues that should be considered include the effects of perennial grasses on water infiltration and soil erosion; flammability and other fire issues; harborage of pests and desirable wildlife; competitiveness against resident vegetation including important agricultural weeds; and compatibility with various native forbs, shrubs, and trees. Finally, an economic analysis of the costs of various roadside management regimes would be desirable.

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Appendix 1. Assignment of mixtures of perennial grasses to different levels of topographic zone, polycultures (trial I).*

Plant Complex	*Topographic Zones/Accessions Included* — *Unimproved Shoulder*	*Recovery Area*	*Side Slope*	*Open-Cut Ditch*	*Back Slope*	*Back Berm*	*Field Edge*
Non-Native, Perennial Grasses	*Festuca ovina* cv Covar	*Thinopyrum intermedium* and *Dactylis glomerata* cv Berber	*Thinopyrum intermedium* and *Dactylis glomerata* cv Berber	*Thinopyrum intermedium* and *Dactylis glomerata* cv Berber	*Thinopyrum intermedium* and *Dactylis glomerata* cv Berber	*Thinopyrum intermedium* and *Dactylis glomerata* cv Berber	*Thinopyrum intermedium*
Native Perennial Grasses 1	*Poa secunda* ssp. *secunda*	*Poa secunda* ssp. *secunda*, *Festuca rubra*, and *Hordeum brachyantherum* ssp. *brachyantherum*	*Poa secunda* ssp. *secunda*, *Festuca rubra*, and *Hordeum brachyantherum* ssp. *brachyantherum*	*Hordeum brachyantherum* ssp. *brachyantherum*	*Elymus glaucus*, *Elymus trachycaulus* var. *majus*, and *Bromus carinatus*	*Elymus glaucus*, *Elymus trachycaulus* var. *majus*, and *Bromus carinatus*	*Elymus glaucus* and *Leymus triticoides* cv Rio
Native Perennial Grasses 2	*Poa secunda* ssp. *secunda*, *Festuca idahoensis*, and *Hordeum brachyantherum* ssp. *californicum*.	*Poa secunda* ssp. *secunda*, *Festuca idahoensis*, *Nassella pulchra*, *Nassella cernua*, and *Elymus multisetus*	*Poa secunda* ssp. *secunda*, *Festuca idahoensis*, *Nassella pulchra*, *Nassella cernua*, and *Elymus multisetus*	*Elymus glaucus* and *Hordeum brachyantherum* ssp. *brachyantherum*.	*Elymus glaucus* and *Hordeum brachyantherum* ssp. *brachyantherum*.	*Bromus carinatus*, *Elymus glaucus*, *Elymus multisetus*, *Elymus trachycaulus* var. *majus*, *Melica californica*, and *Nassella pulchra*.	*Elymnus glaucus*, *Elymus trachycaulus*, and *Leymus triticoides* cv Rio

*Control was resident vegetation for all levels of topographic zone.

Appendix 2. Seeding rates for trial I polycultures, given in kg/ha.*

Plant Complex	*Topographic Zone*	*Grass*	*Block* I	II	III	IV	V
Non-native Grasses	Unimproved Shoulder	*Festuca ovina*	41.01	41.01	27.34	27.34	27.34
	Recovery Area and Side Slope	*Thinopyrum intermedium*	21.03	21.03	21.03	45.57	15.19
		Dactylis glomerata	21.03	21.03	21.03	45.57	15.19
	Open-Cut Ditch	*Thinopyrum intermedium*	13.02	13.02	19.52	20.51	13.67
		Dactylis glomerata	13.02	13.02	19.52	20.51	13.67
	Back Slope	*Thinopyrum intermedium*	21.03	21.03	31.55	25.63	22.78
		Dactylis glomerata	21.03	21.03	31.55	25.63	22.78
	Back Berm	*Thinopyrum intermedium*	34.17	34.17	68.35	68.35	45.57
Native Grasses 1	Unimproved Shoulder	*Poa secunda* ssp. *secunda*	34.17	34.17	41.01	41.01	41.01
	Shoulder and Side Slope	*Poa secunda* ssp. *secunda*	27.34	27.34	21.03	45.57	15.19
		Festuca rubra	13.65	13.65	10.51	22.79	75.99
		Hordeum brachyantherum ssp. *brachyantherum*	20.26	20.26	15.59	33.77	11.25
	Open-Cut Ditch	*Hordeum brachyantherum* ssp. *brachyantherum*	18.64	18.64	29.30	30.76	20.51
	Back Slope	*Elymus glaucus*	9.76	9.76	15.77	12.81	11.39
		Elymus trachycaulus	9.76	9.76	15.77	12.81	11.39
		Bromus carinatus	9.76	9.76	15.77	12.81	11.39
		Elymus glaucus	13.67	13.67	12.81	12.81	8.54
		Leymus triticoides	27.34	27.34	25.63	25.63	17.09
Native Grasses 2	Unimproved Shoulder	*Poa secunda* ssp. *secunda*	13.67	13.67	6.84	6.84	6.84
		Festuca idahoensis	6.84	6.84	6.84	6.84	6.84
		Hordeum brachyantherum ssp. *californicum*	10.09	10.09	10.09	10.09	10.09
	Recovery Area and Side Slope	*Poa secunda* ssp. *secunda*	21.03	21.03	10.33	22.38	7.46
		Nassella pulchra	5.26	5.26	5.26	11.39	3.80
		Nassella pulchra	5.26	5.26	5.26	11.39	3.80
		Hordeum brachyantherum ssp. *californicum*	10.51	10.51	10.33	22.38	7.46
		Elymus multisetus	5.26	5.26	4.70	10.18	3.40
	Open-Cut Ditch	*Hordeum brachyantherum* ssp. *brachyantherum*	13.02	13.02	19.18	20.14	13.43
		Elymus glaucus	6.51	6.51	9.65	10.13	6.76
	Back Slope	*Elymus glaucus*	5.26	5.26	7.89	6.41	5.69
		Bromus carinatus	5.26	5.26	7.89	6.41	5.69
		Nassella pulchra	5.26	5.26	7.89	6.41	5.69
		Elymus multisetus	5.26	5.26	7.89	6.41	5.69
		Melica californica	5.26	5.26	7.89	6.41	5.69
		Elymus trachycaulus	5.26	5.26	7.89	6.41	5.69
	Back Berm	*Elymus glaucus*	5.49	5.49	10.68	10.68	7.11
		Leymus triticoides	10.68	10.68	21.36	21.36	14.25
		Elymus trachycaulus	5.49	5.49	10.68	10.68	7.11

*For seeds/kg, percentage germination, refer to Table 3, except for *Dactylis glomerata*, which featured 992,000 seeds per kg and 90% germination (low estimation), and *Leymus triticoides* cv Rio (creeping wildrye or beardless wildrye), which featured 279,448 seeds per kg and 88% germination (1991 data).

Appendix 3. Grasses and seeding rates for trial II monocultural plots. Seed count and germination data were provided by Hedgerow Farms and ConservaSeed.

Scientific Name and Authority(ies)	*Common Name*	*Cultivar, Accession(s), or Source*	*Seeding Rate (kg/ha)*	*Seeds/kg*	*Germination* (%)*	*Live Seed/ m²*
Elymus glaucus Buckley	Blue wildrye	Winters, Yolo County	44.83	210,225	89	839
Hordeum brachyantherum ssp. *californicum*	California barley	Hastings, Monterey County	33.62	296,352	81 (1992)	807
Nevski ssp. *californicum* (Covas and Stebbins) V. Bothmer, N. Jacobsen, and O. Seberg;		Prostrate form, Mt. Burdell, Monterey County		349,446	82 (1992)	963
Bromus carinatus Hooker & Arnott	California brome	Berkeley, Alameda County	22.42	163,137	88	322
Melica californica Scribner	California oniongrass	ConservaSeed	22.42	728,362	74	1,208
Festuca idahoensis Elmer	Idaho fescue	cv Joseph	22.42	956,970	85 (1992)	1,823
		Quail Ridge, Solano County			58 (1992)	1,244
Hordeum brachyantherum	Meadow barley	Cosumnes River, Sacramento County	44.83	284,568	30	383
Covas and Stebbins ssp. *brachyantherum*	(ConservaSeed, saline site, and Cosumnes Forms in separate plots)	Suisun Marsh, Contra Costa County		364,899	87	1423
		ConservaSeed		145,971	95	622
Nassella cernua (Stebbins and Love) Barkworth	Nodding needlegrass	Dunnigan, Yolo County	11.21	412,302	79	365
Thinopyrum intermedium (Host) Barkworth & D. R. Dewey	Pubescent wheatgrass	cv Luna	44.83	164,052	85 (low estimate)	625
Poa secunda J. Presl. ssp. *secunda*	Pine bluegrass	Fisk Creek, Yolo County	33.62	2,411,773	88	7,135
Nassella pulchra (A. Hitchc.) Barkworth	Purple needlegrass	Stone Ranch, Yolo County	11.21	1,005,213 (De-awned)	85	958
Festuca ovina cv. L.	Sheep fescue	cv Covar	33.62	1,169,356	85 (low estimate)	3,342
Elymus multisetus (J.G. Smith) Burtt Davy	Squirreltail	ConservaSeed	22.42	220,604	90 (1992)	445
Festuca rubra L.	Red fescue	cv. Molate, Pt. Molate, Contra Costa County	33.62	888,615	94	2,808
Elymus trachycaulus (Link) Shinners ssp. var. *majus*	Slender wheatgrass	Willow Slough, Yolo County	44.83	295,055	91	1204
Melica imperfecta Trinius	An oniongrass	Big Sur, Monterey County	11.21	1,138,647	79	1008

*Percentage germination data were provided by the suppliers of the 1991 seed. Where noted, measurements of germination were made for the subsequent lots of the same accession (e.g., 1992) or are representative figures given the production and cleaning techniques used.