Recommendations for Control of Tall Oatgrass, Poison Oak, and Rose in Willamette Valley Upland Prairies

Prepared by

Mark V. Wilson
and
Deborah L. Clark

Department of Botany and Plant Pathology
Oregon State University

Submitted to

Oregon Natural Heritage Program
Portland, Oregon
and
U. S. Fish and Wildlife Service
Western Oregon Refuge Complex

December 14, 1998

SUMMARY

Native upland prairies, which once dominated the landscape of the Willamette Valley, are considered among the rarest of Oregon's ecosystems. Even though only remnants remain today, they harbor many rare and endangered species such as the Fender's blue butterfly and its host plant, Kincaid's lupine. Invasion of remnant prairies by woody plants and weedy non-native herbaceous species is of great concern to agencies and managers responsible for conserving these native ecosystems. Available methods for the control of these pests include herbicides, biological control, prescribed burning, and mowing. This report first reviews the literature on the control of tall oatgrass and the shrubs poison oak and rose. Each of these species is an important threat to Willamette Valley upland prairies. We then presents recommendations.

For control of tall oatgrass, we recommend for most situations mowing in late spring or early summer. Mowing height should be just above most of the foliage of native plants to be protected (typically 10 cm - 15 cm). In areas with Kincaid's lupine and Fender's blue butterfly, mowing should be delayed until July, after the flowering and flight seasons.

For control of prairie shrubs, we recommend further studies to evaluate herbicide effectiveness against the target shrubs and safety for non-target native plants and animals. If herbicide use is unavailable, we recommend burning or mowing. All burning or mowing treatments should be repeated, perhaps indefinitely, to maintain pest plant control.

INTRODUCTION

Willamette Valley native prairies

Native prairies, remarkable for their biodiversity, once dominated the landscape of the Willamette Valley. Before the mid-1800's the Kalapuya, indigenous people of the Willamette Valley, maintained the open grassy nature of the valley by setting annual fires to facilitate hunting and gathering of food plants (Boyd 1986, Boag 1992). These fires reduced the abundance of shrubs and trees, favored the abundance of grasses, and promoted a rich variety of native forbs.

With widespread settlement, urbanization and agricultural activities destroyed these native prairies; these threats are also prominent today (Hammond and Wilson 1993). Fire suppression allowed natural succession of woody plants in most of the few unplowed, ungrazed, and undeveloped prairie remnants. Most Willamette Valley prairies are seral communities that have been maintained by fire or other human activities (Franklin and Dyrness 1973). Since the arrival of settlers in the mid-1800's, large-scale fires have been prevented, allowing the encroachment of trees and shrubs onto the prairies (Habeck 1961, Johannessen et al. 1971, Towle 1982). Additionally, invasion of non-native pest species continue to degrade remaining prairies.

As a result of these forces, the once widespread Willamette Valley prairies are now less than 1% of their former extent. In fact, Willamette Valley prairies are among the rarest ecosystems in Oregon (ONHP 1983) and the United States (Noss et al. 1995). Only about 47 native upland prairies remain in the Willamette Valley with only five of these sites containing relatively large areas of high or very high quality prairies (Wilson 1996).

What makes tall oatgrass, poison oak, and rose pest plants?

The original grasslands of the Willamette Valley can be separated into two broad types, wetland prairie and upland prairie. Wetland prairies, often characterized by an abundance of tufted hairgrass (*Deschampsia cespitosa*), occur on bottomlands with poorly drained soils, and generally experience winter flooding or ponding (Finley 1994). Upland prairies, in contrast, have well-drained soils and are characterized by a mix of native bunchgrasses, including Roemer's fescue (*Festuca idahoensis* var. *roemeri*) (Franklin and Dyrness 1973).

Native upland prairies have a low structure, dominated by perennial bunchgrasses interspersed by a wide variety of perennial forbs. These conditions promote high plant species diversity and, as a result, a high animal diversity (Wilson 1998). Part of this diversity are rare organisms like the endangered Fender's blue butterfly (*Icaricia icarioides fenderi*), Willamette daisy (*Erigeron decumbens* var. *decumbens*), Kincaid's lupine (*Lupinus sulphureus* ssp. *kincaidii*), and the northwestern pond turtle (*Clemmys marmorata marmorata*).

Pests plants are an important threat to native upland prairies. Hammond and Wilson (1993) report that woody plant succession is a threat to 12 of 13 Fender's blue butterfly sites and aggressive weeds are a threat to 7 of 13 sites. Tall oatgrass (*Arrhenatherum elatius*), poison oak (*Rhus diversiloba*), and rose (*Rosa* spp.) are widespread and important pest plants of upland prairies, including Fender's blue butterfly habitats. An abundance tall oatgrass, poison oak, or rose is harmful to upland prairies for several reasons. First, these species are taller than the desired natives. Most native plant species cannot tolerate the shade cast by these invading plants. As a result, dense stands of these pest plants effectively eliminate native prairie structure and composition. Competition of non-native plants for water and nutrients also depresses the growth of native plants. Second, shading by these pest plants makes it harder for insects to find food and ovipositioning sites. This is an important threat, for example, to the Fender's blue butterfly (Hammond and Wilson 1993). Third, these pests alter the spatial structure of native prairie. Aggressive plants like tall oatgrass can form dense patches that exclude most native plants. Fourth, the litter of tall oatgrass, poison oak, and rose tends to accumulate on the soil. This thicker litter layer alters nutrient and water availability, disease and herbivory incidence, and patterns of seedling establishment (Facelli and Pickett 1991, Maret and Wilson in review). The combination of pest plant invasion and the accumulation of litter also reduces space for ground nesting animals like the northwestern pond turtle.

Unlike less aggressive plants, tall oatgrass, poison oak, and rose can invade upland prairies. Their tall stature helps them escape from competition from the native herbaceous plants. Tall oatgrass can be particularly competitive under nutrient-rich conditions (Schlaepfer and Ryser 1996, Vazquez de Aldana et al. 1996). Before widespread settlement in the mid-1900s, frequent fires prevented the establishment of woody plants. Fire suppression now allows shrubs like poison oak and rose to survive and expand. Once established, tall oatgrass, poison oak, and rose can spread vegetatively as well as by seed.

CRITERIA FOR CONTROL METHODS

A pest plant control method should have several important attributes in order to be suitable for application in native upland prairies. First, the methods should be effective at controlling abundance of existing populations of the pest plant and/or preventing the spread of the population at the site. Second, control methods should not promote other non-native pest plants and should optimally control their growth and spread. Third, control methods should not cause unacceptable harm to native plants or to other native species such as the Fender's blue butterfly. Finally, the method should be suitable for application at these sites, that is, the method should be inexpensive and safe.

We consider four general methods in this section: herbicide application, biological control, burning, and mowing. After a general discussion, we evaluate these control methods separately for the herbaceous plant tall oatgrass and the shrubs poison oak and rose.

Herbicide application

Herbicide use has the twin advantages of relatively low expense and relatively high effectiveness. Herbicides are often applied once; control methods like fire and mowing often require repeated application to accomplish pest plant control. A disadvantage is that herbicides may have side effects detrimental to non-target plants and animals. A decline in the number of Fender’s blue larvae after application of herbicide to control woody plants was possibly due to direct herbicide toxicity (Wilson and Clark 1997).

Biological control

Biological control is a widely used method for pest control. Successful biological control has the great advantage of requiring little maintenance. It has the disadvantage of high expense and complexity of development.

In the native habitat of tall oatgrass, several fungal pathogens of tall oatgrass, including rusts and bunts, have been identified (Pfitzenmeyer 1962). Biological control using these fungal pathogens might prove to be inappropriate as they (e.g., *Claviceps purpurea*) are also pathogenic on important agricultural grasses of the Willamette Valley (e.g., *Dactylis glomerata* and *Festuca arundinacea*).

Burning

Burning is a favored management tool in many of the native grasslands in the Willamette Valley. A prime reason for the use of prescribed fire is its ability to slow or prevent the invasion of woody plants during natural succession. A second motivation for the use of fire in management is the historical role of fire in the Willamette Valley (Johannessen et al. 1971, Towle 1982, Boyd 1986). Returning the natural disturbance process of fire is thought to aid in habitat restoration.

One hundred years ago, reinstitution of periodic fire may have been sufficient to maintain these grasslands as native-dominated systems. Today, however, widespread invasion of exotic species, which can suppress abundance of native species, has significantly altered the remaining prairies. Moreover, strict smoke management regulations generally require managers to burn in early fall, which may not coincide with historical times of burning.

Although fire might reduce woody plant cover, its effect on native herbaceous plants can sometimes be unclear or even detrimental (Magee 1986, Macdonald 1993, Wilson et al. 1993, Wilson and Maret unpublished data, Clark and Wilson 1997). In other circumstances, prescribed fires can stimulate the growth of some native species (Connelly and Kauffman 1991, Wilson et al. 1993, Clark and Wilson 1997).

Another possible drawback to the use of fire is direct damage to native animals like the Fender’s blue butterfly. At Baskett Slough National Wildlife Refuge almost no larvae of Fender's blue butterfly remained in the years following fall prescribed burning (Wilson and Clark 1997). Leaving a portion of the site unburned should overcome this disadvantage.

Mowing

Mowing, like burning, is widely used for vegetation management in the Willamette Valley. Few studies, however, document the success or failure of mowing in controlling pest plants. Often mowing is done without consideration of timing or height of mowing. Differences in both heights and life-history timing between many pest plants and native herbaceous species provide opportunities for improving the effectiveness of mowing as a control technique while reducing its impact on favored plants and animals.

TALL OATGRASS

Biology of tall oatgrass

Tall oatgrass is a perennial grass native to Eurasia but widely introduced throughout western North America, New Zealand and Australia (Pfitzenmeyer 1962). It is a tall (up to 180 cm), usually erect, tussock-forming perennial grass with very short rhizomes (Pfitzenmeyer 1962). Two types exist in the Willamette Valley, a non-bulbous form and a bulbous form (var. *bulbosum*), which is characterized by corms stacked four or five high (Tanphiphat and Appleby 1990a).

In its native habitat in the British Isles, tall oatgrass is most commonly found on well-aerated, moderately deep, neutral or near neutral soils of high to moderate fertility. Features such as erect tall stature, high growth rates, fast tissue turnover, and rapid allocation of photosynthate after clipping promote the dominance of tall oatgrass on high fertility sites, but these features are believed to adversely affect the competitive ability on nutrient poor grasslands (Berendse et al. 1992, Schlaepfer and Ryser 1996, Vazquez De Aldana et al. 1996, Ryser and Notz 1996).

Caryopses are produced annually from the first year of germination (Pfitzenmeyer 1962). Each mature plant produces 25-30 panicles each with 50-100 spikelets and one caryopsis per spiklet, which readily shed at maturity (Pfitzenmeyer 1962). The seeds have no innate dormancy (Pfitzenmeyer 1962, Tanphiphat and Appleby 1990a, Maret 1996), apparently not forming a persistent seedbank (Wilson and Maret, unpublished data). Germination rates vary with temperature, with germination better at 8C and 15C than at 25C; higher temperatures promote fungal attack (Pfitzenmeyer 1962).

Germination occurs entirely after the fall rains (Maret and Wilson in review); sprouts also appear on mature plants at this time (Tanphiphat and Appleby 1990a). Little growth of seedlings or sprouts occurs during the winter, but rapid growth occurs in the spring with senescence occurring during the summer drought (Tanphiphat and Appleby 1990a).

The way that tall oatgrass invades prairies remains unclear. Vegetative proliferation is reported to be very important for the bulbous variety. In fact, Tanphiphat and Appleby (1990a) found no seedling establishment by the bulbous variety of tall oatgrass. At Carson Prairie, near Corvallis, and at Baskett Slough National Wildlife Refuge, tall oatgrass (the non-bulbous variety) has spread rapidly (personal observation; personal communication by M. Maret, M. B. Naughton, P. C. Hammond). Although this variety of tall oatgrass tillers readily, reproduction is believed to be by seed alone (Pfitzenmeyer 1962). But seedling densities at Carson Prairie and Baskett Slough are relatively low (Maret and Wilson, unpublished data; Wilson and Clark, 1998). Most studies examine either stands already dominated by tall oatgrass or more pristine prairies; more information is needed at the advancing front of tall oatgrass invasion.

Responses to control measures

Little information is available on the effect of fire on tall oatgrass. At Carson Prairie, seedling establishment of tall oatgrass was slightly less in burned seedbeds compared to unburned seedbeds (Maret 1996, Maret and Wilson in review). However, seedlings in the burned seedbeds survived in greater numbers through the winter compared to seedlings in the unburned seedbeds. A relatively thick litter layer strongly promoted tall oatgrass seedling emergence, while litter removal (without burning) was strongly associated low seedling emergence. Because prescribed burning promoted the seedling establishment of other species, especially natives, without increasing tall oatgrass seedlings, burning was recommended as an effective site treatment for improving the establishment of sowed seed into a prairie dominated by the tall oatgrass (Maret 1996). Burning created significantly more favorable microsites for another exotic species, *Hypochaeris radicata*, but establishment response for native species tested was generally much more dramatic than for the exotic species.

Glyphosate is a nonselective herbicide used to control perennial weeds because of its rapid translocation and generally high phytotoxicity. The use of glyphosate for control of the bulbous variety of tall oatgrass has produce inconsistent results (review by Tanphiphat and Appleby 1990b). When glyphosate was applied at the 4 -5 or 6-7 leaf stage under greenhouse conditions, glyphosate significantly reduced corm formation and viability, controlling bulbous oatgrass growth. In addition, a 24-hour period between glyphosate application (at the rate of 2.5 kg per ha) and removal of shoots was sufficient to cause maximum reduction in regrowth (Tanphiphat and Appleby 1990b). Researchers and growers in western Oregon have observed, however, that infestations of the bulbous oatgrass usually reappear the year after glyphosate application (Tanphiphat and Appleby 1990b). Tanphiphat and Appleby (1990b) hypothesized that dormant corms without leaves may not accumulate a lethal dosage of glyphosate, leading to regrowth and persistence of the bulbous variety of tall oatgrass as a pest.

In its native habitat, tall oatgrass tolerates occasional mowing and in European hay meadows is often the dominant species (Pfitzenmeyer 1962). However, tall oatgrass does poorly at sites that are heavily grazed, such as pastures (Pfitzenmeyer 1962). On unshaded limestones scree on which tall oatgrass colonizes and is a dominant species, it will give way under grazing to *Festuca ovina* and *Festuca rubra* (Pfitzenmeyer 1962). Repeated cutting decreases the persistence of most ecotypes (Rebischung et al. 1952 cited by Pfitzenmeyer 1962). Hewett (1985) reports that five years of mowing was necessary for control.

Recovery of tall oatgrass may be slow after grazing or mowing too close to the ground because only a small number of basal axillary buds are available to regenerate new shoots (Pfitzenmeyer 1962). An alternative explanation for limited recovery is that in grasslands an important part of nutrients assimilated by plants is lost with removal of biomass by grazing or mowing (Berendse et al. 1992). Losses are particularly high with species such as tall oatgrass, which are characterized by high growth rates with fast tissue turnover, and rapid response of allocation upon clipping (Berendse et al. 1992, Schlaepfer and Ryser 1996, Vazquez De Aldana et al. 1996, Ryser and Notz 1996).

After four years of applying eight mowing regimes (different heights and times of mowing) to a degraded site dominated by tall oatgrass at Baskett Slough National Wildlife Refuge, most mowing treatments reduced tall oatgrass cover compared to unmanipulated control plots (Wilson and Clark 1998). The best treatment in reducing cover of tall oatgrass, reducing cover of other non-native species, and increasing the cover of native species as compared to unmanipulated controls was mowing at 10 cm - 15 cm in late spring. Also effective was mowing at 10 cm - 15 cm in early summer.

Recommendations for control

Because of the potential lethal effects of herbicides on non-target native plants and on Fender's blue butterfly larvae, and because of the inconsistent results of herbicides in control of tall oatgrass, herbicide application is not a top choice for tall oatgrass control. Limited use, however, on sites with no populations of Fender's blue butterfly and few native plant species could be considered.

Biological control is not an option to land managers because control agents are unavailable at this time.

Prescribed burning has several advantages. It could reduce tall oatgrass abundance by removing biomass and by killing regenerative buds. Studies on the timing of mowing (Wilson and Clark 1998) suggest that best tall oatgrass control would be with burning in late spring or early summer. Burning at this time, rather than the typical September-October window, would also kill flowers and developing seeds before dispersal. It is not known if early-season burning is logistically feasible in tall oatgrass-dominated prairies in the Willamette Valley.

Burning has had mixed effects on survival and growth of native species, although it effectively prepares tall oatgrass-dominated sites for establishing native species from sown seeds, without promoting tall oatgrass establishment (Maret and Wilson in review). Burning might a good choice to control tall oatgrass and establish new populations of native species at sites where few native species are present, but should be used with caution for sites that have a high proportion of native species.

At this time mowing is the optimal choice for both controlling existing stands of tall oatgrass and preventing seed dispersal. Mowing in late spring is best for tall oatgrass control (Wilson and Clark 1998). Mowing height should be set just above the typical heights of any native plants to be protected. For most upland prairies, this will be 10 cm - 15 cm. In areas with Kincaid’s lupine and Fender’s blue butterfly, mowing should be delayed until July, after the flowering and flight seasons (Wilson and Clark 1998). Any mowing program needs to continue for at least three to five years to get strong results (Hewett 1985, Wilson and Clark 1998).

POISON OAK AND ROSE

Responses to control measures

Although several prairie shrubs also grow in woodlands or forests, differences in soil, fuel, animals, and microclimate make extrapolations to prairie conditions difficult. Therefore we limit our discussion to the control of shrubs within Willamette Valley prairies. There is little information on the response of poison oak in prairies to control measures, and most information from the Willamette Valley on the control of rose in prairies is from wetland prairies.

Poison oak and rose have a great capacity to regenerate vegetatively, making control difficult. There was little poison oak mortality in a single prescribed burn in an upland prairie at Carson Prairie (Wilson, unpublished data). Although poison oak did regrow vegetatively, burned poison oak plants remained less than half their pre-treatment size one year after burning. This reduced stature probably decreases the adverse effect of poison oak on the prairie community.

Reports on the response of rose to prescribed burning in wetland prairies is highly mixed. Frenkel (unpublished report), describing the effects of six years of annual burning at Finley National Wildlife Refuge, states that "rose height was lowered, giving the impression of a major die-back, but vegetation reproduction from underground rootstocks maintained rose cover, frequency and density." Rose also diminished in stature with one or two prescribed burns in wetland prairie at Fern Ridge Research Natural Area (Pendergrass 1996 reported in Wilson et al. 1993, Pendergrass et al. unpublished data). But shrub cover and density either stayed the same or increased with burning.

More rigorous studies show more encouraging results. After a single prescribed burn at Finley National Wildlife Refuge, aboveground vegetative biomass of rose was one-fifth that in controls (Clark and Wilson 1997). Reproductive biomass the year after burning was one-ninth that in controls. These results document the decrease in rose stature observed by others. Moreover, frequency of rose within 625 cm^2 quadrats declined 20% with burning (and not at all in controls), suggesting some mortality. Many shrubs (including rose) did die after prescribed burning at the Danebo Wetland (Clark and Wilson 1996). Mortality was 60% in burned plots, compared to 27% in unmanipulated plots. In contrast, three years of mowing with removal of cut material caused almost a doubling of shrub cover, and survival was equal to that in unmanipulated plots.

In one upland prairie, burning twice in three years reduced shrub cover (largely poison oak and rose) to 50% of that in unmanipulated plots (Wilson and Clark 1997). But three years of annual mowing was even better, with shrub cover 40% that in unmanipulated plots and a favorable impact on native plants. Both burning and mowing stimulated flowering of Kincaid's lupine and egg-laying by Fender's blue butterfly.

Recommendations for control

Biological control is not an option to land managers because control agents are unavailable at this time.

Prescribed fire will definitely decrease shrub stature. As a result, repeated burning can probably be effective in stopping shrub expansion where shrub cover is still low. And recent evidence of shrub mortality with burning is encouraging. But when shrub cover is high, a decreased stature will do little to improve the growing conditions of native species.

Mowing performed poorly in one wetland prairie, but was surprisingly effective at shrub control and promoting native species in an upland prairie. More research is needed to better understand the response of poison oak, rose, and other shrubs to mowing.

The mixed results of available studies makes it difficult to make strong recommendations. The effects of shrub invasion are so detrimental to prairies, however, that chemical control is worth considering. We recommend further studies to evaluate herbicide effectiveness against prairie shrubs and safety for non-target native plants and animals. Herbicides might be particularly useful for stopping an advancing front of dense shrub invasion, where native plants and animals have already been largely lost. We advise against spray application of herbicide in native prairies, suggesting instead manual application with wicking wands or brushes.

We also recommend burning or mowing to control poison oak and rose, repeated every 1-3 years. Because of possible adverse effects of burning and mowing, we recommend that prairie responses be monitored so control measures can be adjusted as necessary.

Finally, we recommend the search for new methods of shrub control. For example, all burning and mowing studies have looked at control in early fall. Burning or mowing earlier in the season might improve their effectiveness. Another promising technique is cutting shrubs, allowing their branches to cure, and then burning. Hotter fires with the heavier fuel loads might kill more shrubs. On the other hand, hotter fires might also kill native species.

ACKNOWLEDGMENTS

We gratefully acknowledge the financial support of the Oregon Natural Heritage Program and the U.S. Fish and Wildlife Service. We also thank Maura Naughton for logistical and scientific support for our research at Baskett Slough National Wildlife Refuge. The dedication of each to Oregon ecosystems is inspiring.

LITERATURE CITED

Berendse, F., W. Th. Elberse, and R. H. M. E. Geerts. 1992. Competition and nitrogen loss from plants in grassland ecosystems. Ecology 73:46-53.

Boag, P. G. 1992. Environment and experience: settlement culture in the nineteenth-century Oregon. University of California Press, 209 p.

Boyd, R. 1986. Strategies of Indian burning in the Willamette Valley. Canadian Journal of Anthropology 5:65-86.

Clark, D. L., and M. V. Wilson. 1996. Effects of fire, mowing and hand-removal on woody species in a native wetland prairies. Report to the Bureau of Land Management, Eugene District.

Clark, D. L., and M. V. Wilson. 1997. Fire effects on wetland prairie species. Report to the U.S. Fish and Wildlife Service.

Connelly, K. P., and J. B. Kauffman. 1991. Ecological effects of fire in Willamette Valley wetland prairies with species emphasis on *Lomatium bradshawii* and *Erigeron decumbens* var. *decumbens*, two rare endemic plants. Report to the U.S. Army Corps of Engineers.

Facelli, J. M., and S. T. A. Pickett. 1991. Plant litter: its dynamics and effects on plant community structure. The Botanical Review 57:1-32.

Finley, K. K. 1994. Hydrology and related soil features of three Willamette Valley wetland prairies. M.S. Thesis. Oregon State University, 94 p.

Franklin, J. F. and C. T. Dyrness. 1973. Natural vegetation of Oregon and Washington. USDA Forest Service General Technical Report. PNW-8, Pacific Northwest Forest Range and Experiment Station. Portland, Oregon.

Habeck, R. J. 1961. The original vegetation of the mid-Willamette Valley. Northwest Science 35:65-77.

Hammond, P. C., and M. V. Wilson. 1993. Status of the Fender's blue butterfly. Report to the U.S. Fish and Wildlife Service, 66 p.

Hewett, D.G. 1985. Grazing and mowing as management tools on dunes. Vegetatio 62:441-447.

Johannessen, C.L., W. A. Davenport, A. Millet, and S. McWilliams. 1971. The vegetation of the Willamette Valley. Ann. Ass. AM. Geogr. 61:286-302.

Macdonald, C. 1993. Fire effects on a *Stipa lemmonii-Rhacometrium canescens* grassland community. Final report for Katherine Ordway Stewardship Endowment Grants, The Nature Conservancy.

Magee, T. K. 1986. Vegetation monitoring at Wren Prairie Preserve: I. Initial response of grassland vegetation to controlled burning. Report to the Oregon Field Office of The Nature Conservancy, Portland, Oregon.

Maret, M. P. 1996. Effects of fire on seedling establishment in upland prairies of the Willamette Valley, Oregon. M.S. Thesis, Oregon State University, Corvallis, Oregon.

Maret, M. P., and M. V. Wilson. Fire and seedling population dynamics in western Oregon prairies. Journal of Vegetation Science, in review.

Noss, R. F., E. T. LaRoe III, and J. M. Scott. 1995. Endangered ecosystems of the United States: A preliminary assessment of loss and degradation. National Biological Service, Biological Report 28.

Oregon Natural Heritage Program. 1983. Survey of Willamette Valley 1981-1983 (A report to the Mason Trust). The Natural Conservancy. Portland, Oregon.

Pendergrass, K. L. 1996. Vegetation composition and response to fire of native Willamette Valley wetland prairies. M.S. thesis, Oregon State University.

Pendergrass, K. L., P. M. Miller, and J. B. Kauffman. Prescribed fire and the response of woody species in Willamette Valley wetland prairies. Unpublished manuscript.

Pfitzenmeyer, C. D. C. 1962. Biological flora of the British Isles: *Arrhenatherum elatius* (L.) J & C. Presl. Journal of Ecology 50:235-245.

Rebischung, J., L. Felix, M. Thomas, Y. Demarly, and M. Kerguelen. 1952. Comportement de deux espècies de graminées fourragères explitées suivant des rythmes diffèrents. Ann. Inst. nat. Rech. agron. Paris, Sér. B. Ann. Amélior Pl. 3:473-506.

Ryser, P., and R. Notz. 1996. Competitive ability of three ecologically contrasting grass species at low nutrient supply in relation to their maximal relative growth rate and tissue density. Bulletin of the Geobotanical Institute ETH 62:3-12.

Schlaepfer, B., and Ryser, P. 1996. Leaf and root turnover of three ecologically contrasting grass species in relation to their performance along a productivity gradient. Oikos 75:398-406.

Tanphiphat, K., and A. P. Appleby. 1990a. Growth and development of bulbous oatgrass (*Arrhenatherum elatius* var. *bulbosum*). Weed Technology 4:843-848.

Tanphiphat, K., and A. P. Appleby. 1990b. Absorption, translocation, and phytotoxicity of glyphosate in bulbous oatgrass (*Arrhenatherum elatius* var. *bulbosum*). Weed Science 38:480-483.

Towle, J. C. 1982. Changing geography of Willamette Valley woodlands. Oregon Historical Quarterly 83:66-87.

Vazquez De Aldana, B.R., R.H.M.E. Geerts, and F. Berendse. 1996. Nitrogen losses from perennial grass species. Oecologia 106: 137-143.

Wilson, M. V. 1996. A survey of the native upland prairies of the Willamette Valley. Report to the Bureau of Land Management, Eugene District.

Wilson, M. V. 1998. Upland prairie. Contributed chapter to the USFWS Willamette Basin Recovery Plan.

Wilson, M. V. and D. L. Clark 1997. Effects of fire, mowing, and mowing with herbicide on native prairie of Baskett Butte, Baskett Slough NWR. Final report 1994-1997 to the U.S. Fish and Wildlife Service, Western Oregon Refuges.

Wilson, M. V. and D. L. Clark 1998. Controlling tall oatgrass in Fender's blue butterfly habitats. Final report to the Oregon Natural Heritage Program, Portland, Oregon.

Wilson, M. V., K. P. Connelly, and L. E. Lantz. 1993. Plant species, habitat, and site information for Fern Ridge Reservoir. Report to Waterways Experiment Station, Corps of Engineers.