# Increasing the Abundance of Rare Native Wetland Prairie Species


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**SUMMARY**

Native prairies of the Willamette Valley are considered among the rarest of Oregon's ecosystems and are in critical need of conservation. Management strategies for increasing the abundance of native species are urgently needed, particularly those strategies that promote the regeneration of native species from seed. Fire may be an important factor in promoting regeneration of native species from seed because of its historical role in maintaining the prairie landscape.

The study objectives were (1) to determine the effect of prescribed burning on regeneration of native species from seed, and (2) to establish predictive relationships between easily measured plant traits and seedling establishment rates in the field. The general approach was to sow seeds of target wetland prairie species during the fall into experimental field plots already established at the Danebo Wetland, Eugene, OR. Seedling establishment rates were then compared between burned and unburned plots the following spring. To establish predictive relationships these seedling establishment rates were related to selected seed and seedling traits measured under laboratory conditions.

Overall seedling establishment rates showed no significant differences between burned (7.0%) and unburned plots (8.7%), although for the seven species showing positive responses to prescribed burning, the increase was approximately doubled in the burned plots. Burning significantly increased the seedling establishment rates of three species, *Wyethia angustifolia, Grindelia integrifolia*, and *Danthonia californica*. Seedling establishment significantly decreased with burning for one species, *Sidalcea campestris*. For three of the four endangered, threatened or rare species, *Aster curtus*, *Horkelia congesta*, and *Sidalcea cusickii* var. *purpurea,* seedling establishment rates were smaller in the burned plots compared to the unburned plots, although the differences were not significant. *Lomatium bradshawii* had no seedlings establish in either the burned or the unburned plots.

Plant weight 7 days after germination was the best trait at predicting field seedling establishment rates for both the burned plots and the unburned plots, explaining a significant amount of variation in establishment rates: 70% for the burned plots and 45% for the unburned plots. This model could be used by managers to choose species for

sowing in burned and unburned prairies or to estimate seeding rates at burned and unburned sites.

## INTRODUCTION

The annual fires set by the Kalapuya people to enhance hunting, food gathering, and travel created and maintained a vast landscape of prairies and oak savanna in the Willamette Valley (Habeck 1961, Johannessen et al. 1971, Boyd 1986, Boag 1992). Today less than 1% of the original native prairies remain (Christy and Alverson 1994). They are considered among the rarest of Oregon's ecosystems and are in critical need of conservation (ONHP 1983, Noss et al. 1995).

The Bureau of Land Management is currently taking the lead in managing Willamette Valley wetland prairies in West Eugene. Conservation efforts have emphasized control of woody species and noxious non-native species. Management strategies are also needed to promote the abundance of native herbaceous species and particularly threatened, endangered or rare species. Regeneration from seed is a crucial step for increasing the abundance of these species, but little is known about the conditions that promote seedling establishment. Fire may be an important factor promoting regeneration of native species from seed because of its historical role in maintaining the prairie landscape (Johannessen et al. 1971, Towle 1982, Boyd 1986). Understanding the role of fire in promoting regeneration of native species is particularly important as prescribed burning is a favored choice to control woody encroachment into native prairies (Wilson and Clark 1997, Clark and Wilson 2001).

Field studies to determine fire effects on seedling establishment rates are logistically difficult. An alternative approach is to establish correlations between known seedling establishment rates under specific conditions with more easily measured plant traits such as seed weight or relative growth rates (Smith et al. 1997, Dias et al. 1998). By using such correlations, we can then make predictions about unknown seedling establishment for other species.

The overall goal of this project was to increase the abundance of native wetland prairie species by promoting their regeneration from seed. The project objectives in support of this goal were (1) to determine the effect of prescribed burning on regeneration of native species from seed, and (2) to establish predictive relationships between easily measured plant traits and seedling establishment rates in the field. The general approach to achieve these objectives was to sow seeds of target wetland prairie species during the fall into experimental field plots already established at the Danebo Wetland, Eugene, OR (Clark and Wilson 2001). Seedling establishment rates were then compared between the burned and unburned plots the following spring. To establish predictive relationships these establishment rates were related to selected seed and seedling traits measured under laboratory conditions.

## METHODS

### Study species and seed collection

The study species were chosen from a pool of species that characterize native wetland prairie vegetation, including listed endangered, threatened or rare species, and also had sufficient viable seed required for this study (Table 1). Seeds or fruits of the study species were collected by hand in the summer of 1999 within a 20-mile radius of the Danebo study site. Seed were cleaned by removing chaff and lightweight unfilled seeds and then stored in paper bags at room temperature until counted by hand. Only robust seed were used as determined by visual examination or finger pressure on each individual seed.

### Study site

The study was conducted on a remnant wetland prairie (5 ha), located in west Eugene, Oregon, USA (123° 10’ 28”W and 44° 03’ 05”) at the site of the Bureau of Land Management wetland headquarters. The site, surrounded on three sides by heavily-used city streets, contains both upland prairie vegetation, which has been invaded by the non-native species Scot's broom (*Cytisus scoparius* (L.) Link) and blackberry (*Rubus discolor* Weihe & Nees) and wetland prairie dominated by native tufted hairgrass (*Deschampsia cespitosa*), an indicator species of relatively undisturbed wetland prairie. Several species of *Carex*, *Phalaris aquatica* L., and *Fraxinus latifolia* dominate the wettest areas.

The experimental plots were laid out in a section of wetland prairie dominated by *Deschampsia cespitosa* (Clark and Wilson 2001) but invaded by the woody species *Fraxinus latifolia, Rosa eglanteria* L., *Rosa nutkana* Presl, *Rubus discolor*, and *Crataegus douglasii* Lindl. Before initial management treatments in fall 1994, the cover of woody species ranged between 7 and 21% within treatment areas (Clark and Wilson 2001).

**Field methods**

The field plots, which were part of a larger study (Clark and Wilson 2001), were laid out in a randomized complete block design. Each of the five blocks was approximately 22 m × 17 m and contained four treatments of which only two were used in this study: prescribed burning and no manipulation. Three quadrats (45 cm × 120 cm) were located randomly within each treatment area. Each of these quadrats was subdivided into 24 sowing areas (15 cm × 15 cm) with a 15 cm wide buffer running vertically in the middle to provide access to the interior plots. Each sowing area was sowed, on October 30, 1999, one year after the prescribed burn, with 50 seeds of a single species selected at random. For some species, limited seed was available and fewer seeds were sowed per plot (Table 1). To determine background seedling counts of the study species, a separate sowing plot in which no seeds were sowed was delineated 0.5m away from each of the three quadrats in each of the treatment areas. The number of seedlings was counted on June 1-16, 2000.

Treatments were applied in fall 1994 and repeated in fall of 1996 and 1998. The burn treatment areas were 8-m wide, including a 1-m buffer on each side to reduce edge effects. An additional mowed buffer (2-m wide) was placed around the burn treatment for safety. During the prescribed burn, the perimeter of the treatment area was wet-lined to contain the fire, and then the treatment area was burned by lighting one end, followed by the sides. The no-manipulation treatment was 7-m wide, including a 1.5-m buffer on each side. The length of the treatment areas varied between 8 m and 20 m to fit into the available space at the study site.

**Laboratory methods**

Measurement of seed characteristics

To determine seed germination rates, 25 seeds of each study species were placed into each of five replicate Petri dishes on top of washed sand moistened with Hoagland's basal salt growth solution (Table 2). The Petri dishes were then placed into a growth chamber with 134 $\mu mol/m^2s$ light, at 20°C for 16 hr and at 10°C for 8 hr, and 60% relative humidity. Seeds were kept moist with distilled water and checked daily for germination.

Several species (*Allium amplectens*, *Aster curtus, Camassia quamash*, *Carex densa, Carex unilateralis, Deschampsia cespitosa*, *Eriophyllum lanatum, Sisyrinchium* sp., *Sidalcea campestris, Wyethia angustifolia, Zygadenus venenosus*) were stratified before the germination tests by placing 25 seeds of each study species on moistened filter paper in each of five replicate Petri dishes, which were placed in cold room at 5°C for six weeks. Insufficient seed prevented germination trials and plant trait measurements for the following species: *Lomatium bradshawii*, *Sidalcea cusickii* var. *purpurea*, and *Sidalcea campestris*.

Seed masses were obtained from Guerrant and Raven (1995) with the exception of *Aster curtus*, for which replicate seeds were weighed until the coefficient of variation equaled 15%.

Measurements of plant biomass and leaf area

Laboratory procedures to determine relative growth rates were modeled after those described by Hunt et al. (1993). Germinated seeds were transplanted into 50 ml pots filled with washed sand, which were then placed into a growth chamber with 120 $\mu mol/m^2s$ light, at 22°C for 14 hr and at 15°C for 10 hr, and 50% relative humidity. Pots were bottom watered daily with distilled water. Every other day the pots were also watered with 1.25 ml of Hoagland's basal salt growth solution (Table 2).

At seven days and at 21 days after germination, replicate seedlings were carefully removed from the pots, and soil was gently washed from the roots with distilled water. The shoot portion was separated from the root portion and the leaf area measured using a video image recorder and AG Vision software (Decagon Devices, Pullman, WA). Plant shoots and roots were then dried for 48 hours at 70°C and weighed.

The number of replicates varied between 5 and 28 for each species and for each time period (7 day and 21 day), depending on the rate of germination. Because germination rates were low, three species had insufficient replicates and were not included in the plant trait correlation analysis (*Camassia quamash*, *Sisyrinchium* sp., and *Horkelia congesta*) in addition to the species with insufficient seeds.

A mix-up in the delivery of the growth solution resulted in two concentrations being used during the study: *high* (10 times the concentration described in Table 2 and *low* as described in Table 2). The high concentration was used from February 4, 2000 until February 20, 2000. The low concentration was used from February 23, 2000 until March 25, 2000. So that comparisons in plant traits could be made among replicates receiving different growth solutions, plant trait values were standardized to a specific, intermediate concentration. Using the collected empirical data on plant weights and leaf area of species growing in the different concentrations of plant growth solution, a statistical model was developed that predicted the following plant traits: plant weight, leaf area, leaf area ratio, leaf weight ratio, specific leaf area (Table 3). A detailed description of the model can found in Goodridge (2001**).** Relative growth rates were calculated from the predicted plant weights at seven days and 21 days.

**Data analysis**

The effects of prescribed burning on seedling establishment rates were tested using analysis of variance (ANOVA), transforming the data when necessary to meet the assumptions of normality and constant variance (Statgraphics plus, version 4.0). Multiple regression with forward stepwise regression was used to choose the best parsimonious model of relationships between seedling establishment rates in the field and the 13 plant traits (Table 3) (S-PLUS 2000 Professional Edition for Windows, Release 2). Data were ranked transformed to meet the assumptions for multiple regression.

## RESULTS AND DISCUSSION

**Effects of burning on seedling establishment**

Seedling establishment rates of sowed native wetland prairie species were small, showing no significant differences between the burned (7.0%) and the unburned plots (8.7 %) (Table 4). Two species, *Lomatium bradshawii* and *Sisyrinchium* sp., had no seedlings establish in either the burned or unburned plots (Table 4). Background seedling counts of the study species were negligible with only four seedlings of the study species establishing in the 30 background plots. These establishment rates of native wetland prairie species are very similar to native upland prairie species sowed in burned (10.0%) and unburned plots (8.0%) of native Willamette Valley upland prairies (Clark and Wilson 2000).

Germination rates under laboratory conditions for the study species tested were generally higher than field establishment rates (Table 5), indicating that factors other than seed viability contributed to the low field rates. *Sisyrinchium* sp. germinated neither in the field nor in the laboratory, suggesting that seed may have been non-viable.

Seedling establishment rates were very similar between burned and unburned plots for six of the 17 study species that had seedlings establish: *Allium amplectens*, *Camassia quamash*, *Aster hallii*, *Carex unilateralis*, *Carex densa*, and *Sidalcea cusickii* var. *purpurea* (Table 4). Burning significantly increased the seedling establishment rates of three species (*Wyethia angustifolia*, *Grindelia integrifolia*, and *Danthonia californica*) (Table 4). Seedling establishment rates were greater in the burned plots for four additional species, although the increase was not statistically significant (*Microseris laciniatus*, *Eriophyllum lanatum, Prunella vulgaris* var. *vulgaris*, and *Deschampsia cespitosa*) (Table 4). Burning decreased the seedling establishment rates of four species (*Zygadenus venenosus, Aster curtus, Horkelia congesta, and Sidalcea campestris*), although the decrease was significant for only *Sidalcea campestris* (Table 4).

For three of the four endangered, threatened or rare species (*Aster curtus*, *Horkelia congesta*, and *Sidalcea cusickii var. purpurea*), seedling establishment rates were smaller in the burned plots compared to the unburned plots although differences were not significantly different. *Lomatium bradshawii* had no seedlings establish in either the burned or the unburned plots. In contrast, the seedling establishment rates of *Lomatium bradshawii* were 17-44% in a direct seeding experiment conducted at the same time at other sites in West Eugene in which effects of soil amendments and removal of competing vegetation on seedling establishment were investigated (Kaye et al. 2000). The seedling establishments for *Aster curtus* and *Horkelia congesta* in that study were similar to the present study: *Horkelia congesta* (0.2% to 12%) and *Aster curtus* (1 – 6.7%) (Kaye et al. 2000).

Another study investigating the effects of burning on native species of upland Valley prairies had four species in common with this study (Clark and Wilson 2000). In the experimental upland prairie study, three of the four species showed the same pattern as in this study with seedling establishment of *Zygadenus venenosus* (24.6% unburned, 21.0% burned) and *Sidalcea campestris* (2.1% unburned, 1.7% burned) decreasing with burning, and with *Prunella vulgaris* var. *vulgaris* significantly increasing with burning (14.0% unburned, 26.7% burned) (Clark and Wilson 2000). One species showed an opposite pattern; *Danthonia californica* significantly decreased seedling establishment in the burned plots (4.5%) compared to the unburned plots (9.6%), in contrast to this study where seedling establishment significantly increased in the burned plots.

These data generally do not support the hypothesis that burning promotes seedling establishment of native wetland species as fewer than half of the species showed positive responses to burning (Table 4). However, seeds of these species were sowed in plots that had been not been burned for one year, even though the plots had been repeatedly burned every other year since 1994. For some species, the fire effects that promote seedling establishment may only be present immediately after a fire (e.g., increased soil nutrients, increased cover of bare ground). Additional investigations are needed to determine if responses to fire are different immediately after fire.

From a management perspective, these data suggest that prescribed burning can be considered for promoting seedling establishment in wetland prairies for some species, as seedlings numbers generally doubled for those species showing a positive response to burning. However, prescribed fire must be used cautiously as it may reduce seedling establishment rates for other species. Prescribed fire can also increase the seed regeneration of weedy non-native species in upland prairies (Maret and Wilson 2000).

Sowing seeds of native species into unburned areas is an option for wetland prairie sites where prescribed burns are not feasible or for species whose seedling establishment rates are not affected or negatively affected by burning. Establishment rates of sowed seeds are relatively low in unburned sites, but are still much higher than they would be without adding propagules. The feasibility of increasing sowing rates to achieve desired numbers seedlings depend on availability of seeds.

**Plant traits and seedling establishment rates**

The variability in the species seedling establishment patterns underscores the difficulty of predicting species responses to prescribed burning. One approach to addressing this problem is to classify species into functional groups based on more easily measured plant traits that will predict regeneration responses to management treatments. In selecting plant traits to measure for this study, we chose those traits that have previously been shown to be important in integrating the ability of the plant to obtain water, light, and nutrients under different environmental conditions (Hendry and Grime

1993). For example, seed size may an important attribute determining the ability of plant to successfully establish in conditions where resource supplies are limited by presence of established vegetation (Jurado and Westoby 1992). Specific leaf area (SLA) may be a measure of allocation strategy that reflects the light-capture area deployed per unit of photosynthate invested in the leaves (Wright and Westoby 1999).

In this study, plant weight at 7 days under standard laboratory conditions was the best predictor of field seedling establishment rates for both the burned plots and the unburned plots, with higher establishment rates in species with larger plant weights (Table 5). Plant weight explained a substantial and statistically significant amount of the variation in seedling establishment rate: 70% for the burned plots and 45% for the unburned plots (Table 6). One hypothesis that explains this pattern of increasing seedling establishment rates with increasing plant weight is that a bigger and taller plant in the early stages of development is better able to penetrate a litter layer or surrounding vegetation. Although mature plants and the litter layer are burned immediately after fire, regrowth occurs quickly and litter builds up on the scale of seedling height between biennial prescribed burns (D.L. Clark, personal observations). A related hypothesis is that a bigger plant with a more extensive root system may better survive temporary drying of the soil surface or may be better anchored, resisting frost heaving.

Plant weight at seven days after germination is a relatively easy measure to make for large numbers of species at one time. Thus, the model predicting seedling establishment rates based on plant weight could be useful for managers choosing species for sowing in burned and unburned prairies or for estimating seeding rates at burned and unburned sites. Before its adoption, however, the model should be validated with other data to determine how robust it is for a range of environmental conditions.

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**Table 1.** Native wetland prairie perennials sowed at the Danebo Wetland, showing the number of seeds sowed in each sowing plot. Species marked with an asterisk indicate that they are listed are endangered, threatened or otherwise considered rare.

| | Species | Number of seeds sowed per plot |
|---|---|---|
| | **Monocots** | |
| | *Allium amplectens* | 50 |
| | *Camassia quamash* | 50 |
| | *Carex densa* | 50 |
| | *Carex unilateralis* | 50 |
| | *Danthonia californica* | 50 |
| | *Deschampsia cespitosa* | 50 |
| | *Sisyrinchium* sp. | 50 |
| | *Zygadenus venenosus* | 50 |
| | **Dicots** | |
| * | *Aster curtus* | 50 |
| | *Aster hallii* | 20 |
| | *Eriophyllum lanatum* | 50 |
| | *Grindelia integrifolia* | 20 |
| * | *Horkelia congesta* | 30 |
| * | *Lomatium bradshawii* | 30 |
| | *Microseris laciniata* | 50 |
| | *Prunella vulgaris* var. *vulgaris* | 50 |
| | *Sidalcea campestris* | 25 |
| * | *Sidalcea cusickii* var. *purpurea* | 20 |
| | *Wyethia angustifolia* | 50 |

**Table 2.** Nutrient content of Hoagland's basal salt growth solution for growing seedlings under laboratory conditions. The pH was adjusted to 5.7 (+/-0.1).

| **Nutrients** | **mg/L** |
|---|---|
| Ammonium phosphate monobasic | 115.03 |
| Boric acid | 2.86 |
| Calcium nitrate | 656.40 |
| Cupric sulfate pentahydrate | 0.08 |
| Ferric titrate | 5.32 |
| Magnesium sulfate anhydrous | 240.76 |
| Manganese chloride tetrahydrate | 1.81 |
| Molybdenum trioxide | 0.02 |
| Potassium nitrate | 606.60 |
| Zinc sulfate heptahydrate | 0.22 |

**Table 3**. Seed and seedling traits measured under laboratory conditions and compared with field seedling establishment rates to investigate predictive relationships.

| **Plant traits** | **Equation** | **Interpretation** |
|---|---|---|
| Seed mass | | |
| Seed germination rates | | |
| Plant biomass (7 and 21 days) | | |
| Leaf area (7 and 21 days) | | |
| Relative growth rate (RGR) | (ln plant weight$_{21\ days}$ - ln plant weight$_{7\ days}$)/$\Delta$t | The innate rate of increase in total dry weight per plant over period 7-21 days after germination |
| Leaf area ratio (LAR) (7 and 21 days) | leaf area /total plant weight | The allocation of leaf area to unit amounts of total dry weight |
| Leaf weight ratio (LWR) (7 and 21 days) | leaf weight/total plant weight | The allocation of leaf dry weight to unit amounts of total dry weight |
| Specific leaf area (SLA) (7 and 21 days) | leaf area/leaf weight | The allocation of leaf area to unit amounts of leaf dry weight |

Source: Hendry and Grime (1993).

**Table 4**. Average seedling establishment rates (%) of 19 native wetland prairie species in June 2000 nine months after sowing in October 1999 in burned field plots, which had been burned every other year beginning in 1994, and in unburned field plots in a native wetland prairie (Danebo Wetland). Transformations were applied as necessary before analysis of variance (ANOVA). *P* is the probability that the differences in treatment means occurred just by chance. Significant differences (*P*≤ 0.10) are in bold. All means shown are from untransformed data.

| **Species** | **Treatment** | | |
|---|---|---|---|
| | Unburned | Burned | *P* |
| All species | 7.0 | 8.7 | 0.25 |
| | | | |
| Monocots | | | |
| *Allium amplectens* | 7.1 | 7.1 | 1.00 |
| *Camassia quamash* | 15.3 | 15.1 | 0.95 |
| *Carex densa* | 0.1 | 2.0 | 0.14 |
| *Carex unilateralis* | 1.6 | 1.5 | 0.42 |
| ***Danthonia californica*** | **7.2** | **12.1** | **0.08** |
| *Deschampsia cespitosa* | 0.8 | 4.0 | 0.14 |
| *Sisyrinchium* sp. | 0.0 | 0.0 | |
| *Zygadenus venenosus* | 24.8 | 13.3 | 0.12 |
| | | | |
| Dicots | | | |
| *Aster curtus* | 8.4 | 3.4 | 0.29 |
| *Aster hallii* | 2.0 | 3.2 | 0.71 |
| *Eriophyllum lanatus* | 4.1 | 6.8 | 0.88 |
| ***Grindelia integrifolia*** | **10.3** | **25.3** | **0.05** |
| *Horkelia congesta* | 7.8 | 4.2 | 0.39 |
| *Lomatium bradshawii* | 0.0 | 0.0 | |
| *Microseris laciniata* | 11.7 | 23.8 | 0.16 |
| *Prunella vulgaris* var. *vulgaris* | 16.8 | 24.1 | 0.46 |
| ***Sidalcea campestris*** | **1.9** | **0.3** | **0.09** |
| *Sidalcea cusickii* var. *purpurea* | 4.3 | 3.3 | 0.63 |
| ***Wyethia angustifolia*** | **5.6** | **13.6** | **0.05** |

**Table 5.** Average values for selected plants traits for 11 native wetland species. The values for plants 7 days after germination are indicated by *a*; the values for 21 days after germination are indicated by *b*. Details on the formula and definitions for plant traits are given in Table 3.

| Species | Plant traits | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Seed mass (mg) | Seed germ. (%) | Plant weight a (mg) | Plant weight b (mg) | Leaf area a ($cm^2$) | Leaf area b ($cm^2$) | LAR a ($cm^2$/mg) | LAR b ($cm^2$/mg) | LWR a (mg/mg) | LWR b (mg/mg) | SLA a ($cm^2$/mg) | SLA b ($cm^2$/mg) | RGR /day |
| *Aster curtus* | 0.750 | 65.6 | 0.74 | 2.44 | 0.16 | 1.01 | 0.21 | 0.41 | 0.75 | 0.86 | 0.28 | 0.48 | 0.09 |
| *Aster hallii* | 0.252 | 34.4 | 0.21 | 1.75 | 0.03 | 0.50 | 0.13 | 0.30 | 0.87 | 0.74 | 0.15 | 0.41 | 0.15 |
| *Carex densa* | 0.893 | 91.2 | 0.17 | 0.94 | 0.03 | 0.41 | 0.15 | 0.41 | 0.76 | 0.66 | 0.19 | 0.43 | 0.12 |
| *Carex unilateralis* | 0.459 | 53.6 | 0.12 | 1.51 | 0.04 | 0.51 | 0.28 | 0.34 | 0.72 | 0.81 | 0.35 | 0.42 | 0.18 |
| *Danthonia californica* | 4.956 | 52.8 | 1.50 | 5.00 | 0.30 | 1.33 | 0.19 | 0.26 | 0.79 | 0.83 | 0.23 | 0.28 | 0.09 |
| *Deschampsia cespitosa* | 0.273 | 67.0 | 0.11 | 1.16 | 0.02 | 0.26 | 0.13 | 0.22 | 0.82 | 0.77 | 0.15 | 0.29 | 0.16 |
| *Eriophyllum lanatum* | 0.388 | 20.8 | 0.68 | 3.42 | 0.15 | 1.32 | 0.22 | 0.38 | 0.83 | 0.82 | 0.27 | 0.46 | 0.12 |
| *Grindelia integrifolia* | 3.573 | 48.0 | 1.91 | 11.33 | 0.65 | 3.85 | 0.35 | 0.35 | 0.77 | 0.87 | 0.38 | 0.41 | 0.13 |
| *Microseris laciniatus* | 1.432 | 64.0 | 0.96 | 2.97 | 0.20 | 0.82 | 0.21 | 0.28 | 0.83 | 0.83 | 0.26 | 0.33 | 0.08 |
| *Prunella vulgaris* var. *vulgaris* | 1.133 | 93.6 | 1.10 | 8.55 | 0.32 | 3.72 | 0.27 | 0.45 | 0.81 | 0.78 | 0.33 | 0.58 | 0.15 |
| *Zygadenus venenosus* | 2.827 | 15.2 | 0.81 | 1.22 | 0.08 | 0.18 | 0.09 | 0.15 | 0.72 | 0.77 | 0.12 | 0.19 | 0.03 |

With the exception of *Aster curtus,* seed masses are from Guerrant and Raven (1995)

**Table 6.** Results of multiple regression with forward stepwise regression comparing relationship between 13 plant traits (Table 3) and seedling establishment rates of seeds of 11 native wetland species sowed in burned and unburned plots of a native wetland prairie. The positive coefficients show the positive relationship between plant weight under laboratory conditions and field establishment rates. $R^2$ is the amount of variation in the dependent variable explained by the independent variable (a value of 1.0 explains all the variation). *P* is the probability of getting the coefficient value even if there is no underlying relationship. Data were ranked transformed to meet the assumptions for multiple regression.

| **Seedling establishment rates** | **Intercept** | **Coefficient** | **$R^2$** | ***P*** |
|---|---|---|---|---|
| **Unburned plots** | | | | |
| **plant weight (7 days)** | 3.17 | +3.73 | 0.446 | 0.02 |
| **Burned plots** | | | | |
| **plant weight (7 days)** | 2.45 | +4.68 | 0.700 | 0.00 |