Nutrient Runoff Uptake Potential and Growth for Three U.S. Native Grasses and Tall Fescue[1]

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Abstract

Little research has been conducted into the growth and nutrient uptake potential of native grasses for use in vegetated buffers, grassed waterways, and cover crops for the mitigation of agricultural and horticultural runoff. A greenhouse experiment was conducted with three U.S. native grasses: *Leymus triticoides*, *Melica imperfecta*, *Vulpia microstachys*, and turf-type tall fescue, *Lolium arundinaceum*. Treatments were the rate of nitrogen application, with 0, 460, 920, or 1380 kg·ha^{-1} applied per twelve-week experimental period. Shoot and root material was collected, dried, and analyzed for N and P. Grass quality measurements included visual shoot density and visual root density. Species differences were found for the uptake of water, nitrogen (N), and phosphorus (P), as well as for plant quality measurements such as shoot and root density. Across species, as N application rate increased, apparent N recovery decreased, suggesting that these grasses will exhibit a decreased efficiency in scavenging N when N concentrations in applied runoff are higher. Among native grasses, *L. triticoides* exhibited some advantages over the others which may make it valuable in remediation applications, including high shoot and root density, rapid vertical growth, and high water, N, and P uptake.

Index words: nitrogen, phosphorus, apparent nitrogen recovery, shoot density, root weight.

Species used in this study: beardless wildrye (*Leymus triticoides)*, tall fescue (*Lolium arundinaceum*), small flower melicgrass (*Melica imperfecta*), small fescue (*Vulpia microstachys*).

Significance to the Nursery Industry

With increased scrutiny from regulators and neighbors, good management of runoff and stormwater is an important goal for nursery and greenhouse facilities. The use of grassed areas for vegetated buffers, waterways, and cover crops to absorb and treat runoff is often recommended. Native grasses used for these purposes may offer advantages over non-native species, for example by being adapted to the local climate or being tolerant of adverse conditions such as salinity or drought. Results of this study indicate that the tested native grass species grew well in conditions that included periods of high temperatures and limited water. In particular, *Leymus triticoides* and tall fescue (a non-native grass) quickly established dense ground cover and exhibited a dense root system, suggesting they would be good candidates to slow runoff and prevent soil erosion. Because nutrient uptake by the tested grasses became less efficient when nitrogen concentrations in the water were higher, prudence would suggest implementing nutrient management practices to keep nutrient concentrations in runoff low if mitigation by grassed areas is to be relied upon. Additionally, these results suggest the need to use longer flow paths through grassed areas when nutrient concentrations in runoff are high.

Introduction

Water quality impacts from agricultural production include nitrogen (N) and phosphorus (P) runoff, as well as sediment, pathogens, pesticides, and salts in runoff or leaching (26). For the mitigation of agricultural and horticultural runoff, grass covers have been investigated for use in grassed waterways (10, 11, 22), as vegetated riparian buffers or treatment areas (7, 9, 21, 24), and as cover crops to scavenge excess nutrients during fallow periods (8, 23). Furthermore, there is a interest in using native grass species in vegetated buffer and cover crop applications (12, 15, 25). Purported benefits of native grasses in these applications include native grasses' adaptations for growth during wet periods when runoff and leaching are problematic, providing a habitat for beneficial organisms, and helping to restore native habitat in impacted areas. However, little research has been conducted into the growth and nutrient uptake potential of native grasses to determine the desirability of their use in runoff mitigation. One study found that native grass plots used as riparian buffers were effective at removing diazinon from runoff, but were no more effective than non-native plots (12). Another study found that a native grass cover crop in a vineyard resulted in lower grapevine petiole leaf N, suggesting that native grasses were effective at scavenging N, but competed with grapevines for N (15). Authors in a third study were able to establish native grass buffers, but suggested that non-natives may eventually outcompete native grasses without proper management (25).

Leymus triticoides*,* Melica imperfecta*, and* Vulpia microstachys. Native grasses found in grasslands in the western United States include *Leymus triticoides* (Buckl.) Pilger,

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Melica imperfecta Trin., and *Vulpia microstachys* (Nutt.) Munro, among many others (30). *L. triticoides*, whose common names include 'creeping wildrye' and 'beardless wildrye' is a cool-season perennial grass found in the western United States (2, 5). It is rhizomatous, wear resistant, tolerant of saline soils, and has been used in soil conservation applications (2, 5). Studies have evaluated its use in restoring riparian grass meadows (6) and roadside plantings (4). Populations of *L. triticoides* were found on high-clay soils (30).

A common name for *M. imperfecta* is 'small flower melicgrass', and is a cool-season perennial grass. It is commonly associated with brush lands and oak woodlands, though it is reported to have some tolerance of sun and drought (5). One study found that it didn't establish well on roadside plots, though the authors cautioned that the cause for this might have been excessive depth of seeding in their studies (4).

V. microstachys, commonly called 'small sixweeks grass' or 'small fescue,' is an annual cool-season grass found in the western U.S. and commonly found in California's annual grasslands, particularly on serpentine soils (14, 16, 31).

Nutrient uptake potential for grasses. Apparent N recovery (ANR) is used in agronomic studies as a measure of the efficiency of N uptake by plants. Adjusted for a zero-N treatment, ANR is interpreted as the fraction of applied fertilizer taken up by plants for a given fertilizer treatment. Studies of nutrient uptake of grasses in turf, forage, or remediation stands have often found a decrease in ANR at high N application rates (13, 18, 19, 29). However, this trend was not seen in all studies (33). This decrease in N uptake efficiency suggests that N uptake by a grass stand may reach a maximum at high rates of N found in remediation applications. While a maximum in N uptake has been suggested in one study (19), most studies do not suggest a maximum in N uptake even at high N application rates (13, 17, 29, 33). High values of N uptake for grass stands reported were about 500 $kg{\cdot}ha^{-1}$ N per year at 672 $kg{\cdot}ha^{-1}$ N per year applied (29), 229 $kg{\cdot}ha^{-1}$ N per year at 402 $kg{\cdot}ha^{-1}$ N per year applied (13), and about 200 $kg{\cdot}ha^{-1}$ N per year at 587 $kg{\cdot}ha^{-1}$ N per year applied (19). In studies in which different grass species are assessed, differences in nutrient uptake among species typically have been reported (3, 13, 20, 29, 33). These considerations suggest that there may be differences among native grasses in their nutrient uptake potential, particularly in remediation situations in which high concentrations in runoff could result in high rates of nutrient loadings to the grasses.

The purpose of this study was to evaluate three U.S. native grasses for growth characteristics and nutrient uptake potential, relative to tall fescue, to assess their applicability for runoff mitigation and remediation applications.

Materials and Methods

Experimental design. A greenhouse experiment was set out in a randomized complete block design, with a factorial of four grass species plus unplanted controls, four nutrient solution N concentrations, four blocks, and repeated for two 12-week experimental periods. Three U.S. native grasses, *L. triticoides* 'yolo', *M. imperfecta*, *V. microstachys* 'db', and a turf-type tall fescue blend (S&S Seeds, Carpinteria, CA) were seeded as monocultures on a soilless medium (sunshine mix #4, Sun Gro Horticulture, Vancouver, BC) in plastic pots of 15-cm diameter and 14-cm depth. Seeds were planted at a rate to achieve 1000 seedlings m^{-2} based on stated pure live seed values, covered lightly with coir mulch, and misted daily until establishment. Seeding was done in June 2007 and in February 2008 for the second experimental replication. Grasses were considered established when all pots achieved a density of 1000 plants m^{-2} then grown in a cooled glasshouse under natural light in Riverside, CA. Treatments were begun after establishment and consisted of the N concentration in applied nutrient solutions: 0, 33, 67, or 100 $mg{\cdot}liter^{-1}$, in equal proportions of NO_3–N and NH_4–N. Solutions for all treatments had a concentration of 22 $mg{\cdot}liter^{-1}$ PO_4–P, as well as K, S, Ca, Mg, and other ions. During the treatment period, nutrient solutions were applied at a rate between 5.4 cm (1 liter) and 13.4 cm (2.5 liters) per week, in two split applications, for a total of 140 cm (26 liters) per 12-week period. This resulted in N application rates of 0, 460, 920, or 1380 kg $N{\cdot}ha^{-1}$ per 12-week period and a P application rate of 300 $kg{\cdot}ha^{-1}$ per 12-week period.

Grasses were mowed to a height of 15 cm when the average height for that pot was ≥ 30 cm. Once established, grasses were treated weekly with an insecticidal soap (potassium salts of fatty acids, Safer, Woodstream Corp., Lititz, PA) for the control of aphids (Hemiptera: Aphidoidea), and weekly with a 0.25% hydrogen peroxide solution for the control of powdery mildew (Erysiphales: Erysiphaceae).

Tissue collection and analysis. All grass shoot material from each pot was collected at the end of each 12-week experiment period and composited with any clippings from mowings. At the end of each experiment period, roots were washed to remove potting media. Root and shoot samples were dried at 72C for 48 hr and weighed. A subsample was ground to pass a 0.25 mm (60-mesh) screen, and analyzed for total N and total P by the University of California Agriculture and Natural Resources Analytical Laboratory. Total N was determined by dynamic flash combustion with gas chromatographic separation and thermal conductivity detection (AOAC method 972.43) (1). Total P analysis was conducted with microwave acid digestion (27) and atomic absorption spectroscopy or inductively coupled plasma atomic emission spectroscopy. During nutrient solution application, leachate was collected in polypropylene bottles and composited for the week. Leachate volume was determined gravimetrically.

Grass quality assessments. During the treatment period, visual density of grasses was assessed weekly on a 0 to 6 subjective scale. A rating of 0 represented bare soil; a rating of 2 was a density of 1000 shoots per m^2; a rating of 4 was about 50% ground cover, and 6 was greater than 100% ground cover with shoots exceeding the diameter of the pot. Average shoot height, integrated visually, was measured weekly during the treatment period. Additionally, tissue necrosis was assessed visually weekly. Root density was assessed visually at the end of each period on a 0 to 9 scale.

Statistical analysis. Grass quality measurements were analyzed with analysis of variance (ANOVA) using the MIXED procedure in the SAS (28). Independent variables in these models were experimental block, grass species, nutrient solution N concentration, experiment replication, and first order interactions. Repeated measures analysis was used for grass visual density. Residuals from models were checked to conform to the parametric assumptions of normality and homogeneity of variance. Differences among treatment means were assessed with Tukey-adjusted pairwise comparisons.

Water uptake volume was reported as the amount of water applied minus the amount of water collected as leachate. This value was not adjusted to discount the amount evaporated from unplanted controls or for changes in storage in the growing medium. Nitrogen uptake in shoots was calculated as the product of shoot tissue N concentration and cumulative shoot weight. A similar calculation was performed for roots, and grass N uptake was calculated as the sum of N uptake for shoots and roots. A similar calculation produced P uptake. Apparent N recovery was calculated as N uptake for an experimental unit minus N uptake for the same species and block of the zero-N treatment, then divided by the N applied. Because there was no zero-P treatment, apparent recovery for P was not calculated. Nitrogen and P uptake were analyzed with ANOVAs similar to that used for grass quality measurements.

Results and Discussion

Air and rootzone temperatures. Air temperatures at the center of the greenhouse varied across the course of the experiment, with maximum daily temperatures ranging from 15 to 46C (Fig. 1). Daily minimum air temperatures varied less, ranging from 9 to 24C (Fig. 1). Within the greenhouse, daily maximum air temperatures varied from one side of house to the other by an average of 14C (data not shown). Blocking in the experimental design was arranged to partially account for this variability. Rootzone temperatures at a depth of 7.5 cm were generally similar to air temperatures, and ranged from 8 to 42C during the course of the experiment (data not shown).

Grass germination and quality. In 2007, *L. triticoides* and tall fescue germinated well in the glasshouse, but *M. imperfecta* and *V. microstachys* pots had to be supplemented with seedlings germinated in the laboratory. Considering that the mean daily high temperature during the establishment period in 2007 was 36C, with soil temperatures mirroring air temperatures, temperatures may have been too warm for successful germination of *M. imperfecta* and *V. microstachys*, which typically germinate in the fall (14, 32). In contrast, in 2008 *M. imperfecta*, *V. microstachys*, and tall fescue all established well in the glasshouse, while *L. triticoides* had to be supplemented with laboratory-germinated seedlings. All grasses were considered established, with a density of at least 1000 shoots·m^{-2}, by 47 days after seeding in 2007 and 52 days after seeding in 2008.

All grasses grew well in the glasshouse environment, with N-fertilized pots for all species achieving full ground cover by the end of each experimental period (data not shown). This suggests that covers of any of these grass species would be useful in slowing runoff, although *L. triticoides* and tall fescue were particularly quick in establishing dense ground cover (data not shown). Additionally, because *L. triticoides* and tall fescue had broader and stiffer blades, use of either of these two species may be desirable in applications where water flow may be more intense. This is in contrast particularly to *M. imperfecta* that had very delicate shoots and roots until well-established. Overall, tall fescue had the highest visual density ($P < 0.05$) (Fig. 2A) and the least cumulative vertical growth ($P < 0.05$) (Fig. 2B), suggesting that tall fescue tended to grow low and dense. In contrast to this, *L. triticoides* had the greatest cumulative vertical growth ($P < 0.05$) (Fig. 2B) and among the lowest visual density (Fig. 2A), suggesting that *L. triticoides* is a more tall-growing plant, and might be avoided where tall vertical growth is undesirable, or embraced in cases where establishing a taller stand is desirable.

Cumulative shoot weights were similar among species, although shoot weights for *L. triticoides* and tall fescue were statistically highest ($P < 0.05$) (Fig. 2C). Root weights were similar to shoot weights for *L. triticoides*, *M. imperfecta*, and *V. microstachys* (Figs. 2D and 2C). However, root weights

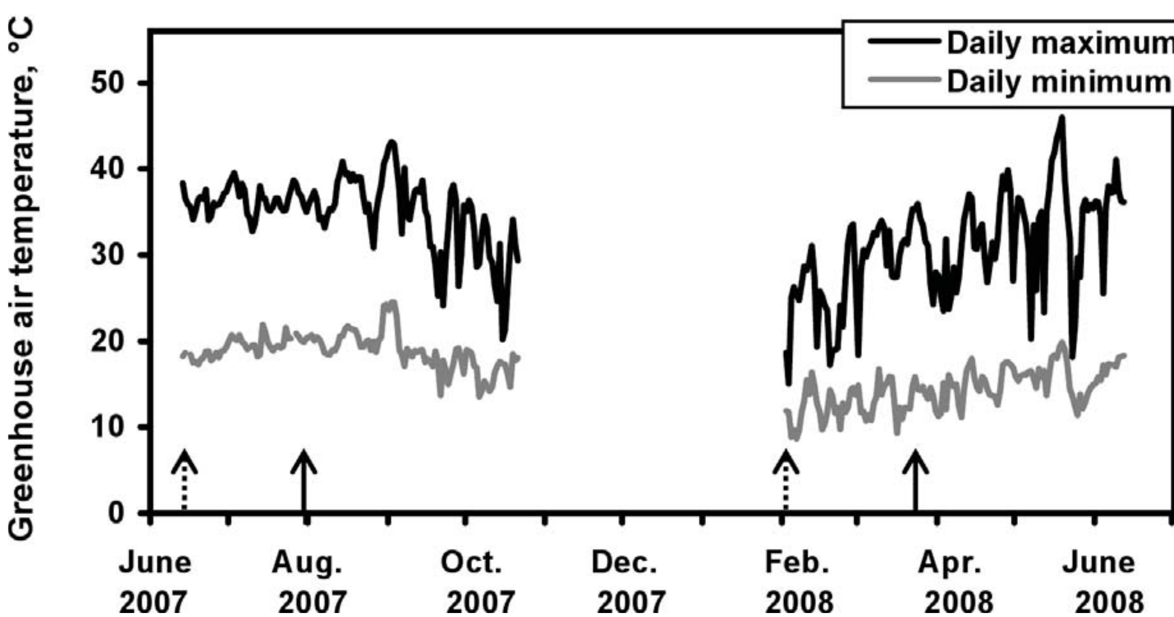

Fig. 1. Daily minimum and maximum air temperatures in a glasshouse in Riverside, CA. Dashed arrows indicate dates of grass seeding. Solid arrows indicate dates of the first application of nutrient solution treatments.

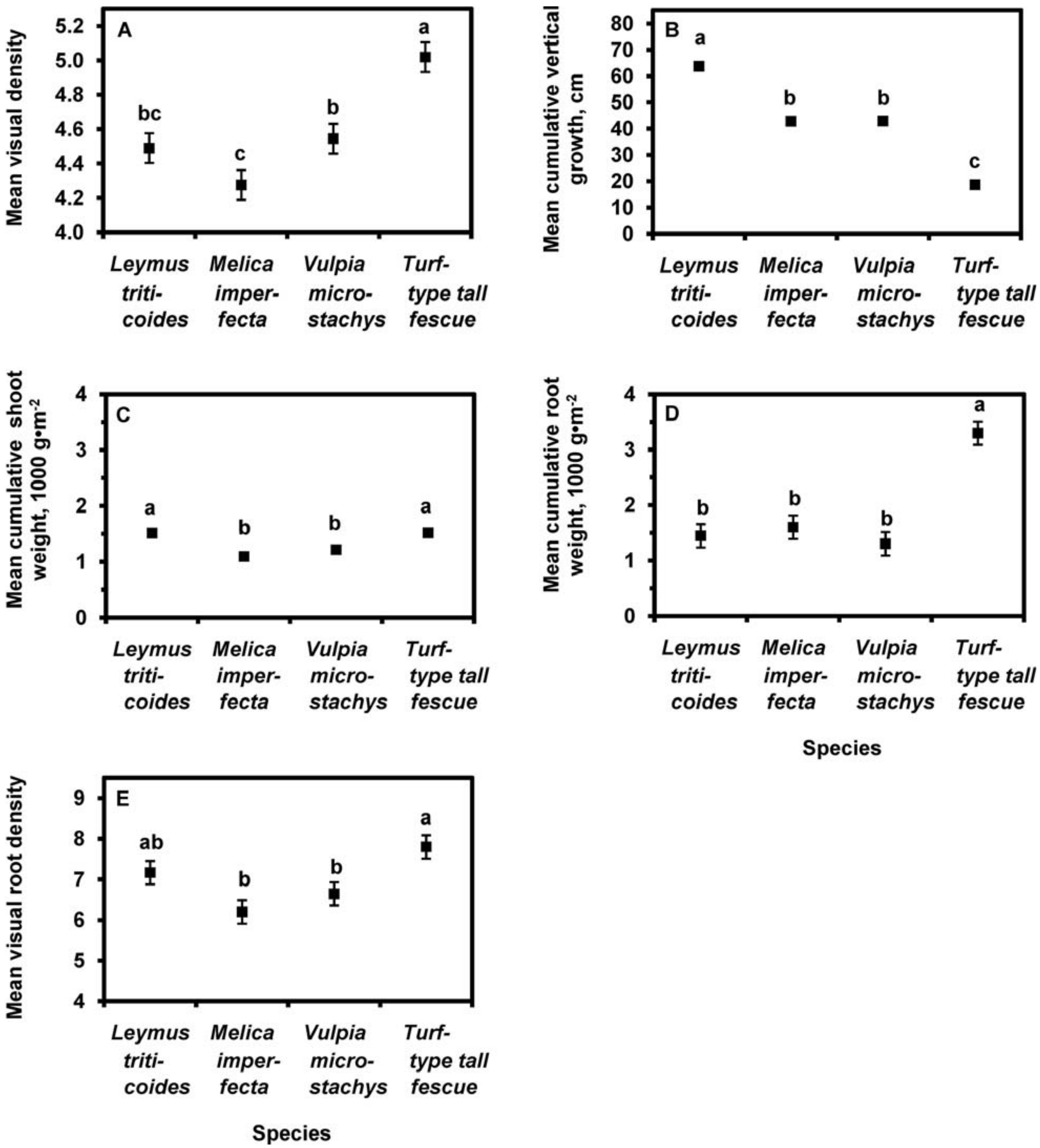

Fig. 2. **Mean values from an analysis of variance for visual density (A), cumulative vertical growth (B), cumulative shoot weight (C), cumulative root weight (D), and visual root density (E) for three U.S. native grasses, *L. triticoides* 'yolo', *M. imperfecta*, *V. microstachys* 'db', and a turf-type tall fescue blend, *Lolium arundinaceum*. Where visible, error bars indicate standard errors of the means from the analysis. Means assigned the same letter in each plot are not significantly different ($P \geq 0.05$) using Tukey-adjusted pairwise comparisons.**

for tall fescue were higher than for other grasses ($P < 0.05$) (Fig. 2D). Additionally, visual root density for tall fescue was among the highest (Fig. 2E). These observations suggest that tall fescue may dedicate more biomass to root growth than do the other investigated species. Visual root density was among the highest for *L. triticoides* and tall fescue (Fig. 2E), suggesting that the use of these two species would be desirable where erosion concerns necessitate grass cover with a dense root system. Because root weights were based on simple root washing and not on ashed weights, reported root weights may be inflated due to any residual adhering growing medium.

Stresses in the glasshouse environment included high temperatures, limited applied water, and also some incidences of aphid infestation and powdery mildew infection. Tall fescue had a greater tendency than the other grasses to wilt between irrigations (data not shown). All grasses experienced some browning out, often apparently in response to high temperatures and limited irrigation, although the cause was not determined definitively. Stands of *V. microstachys* tended to thin out with the setting of inflorescences. Both *L. triticoides* and tall fescue exhibited severe leaf necrosis during the period of high temperatures in May 2008, but recovered nearly fully within three to four weeks (data not shown).

Water and nutrient uptake. Mean water uptake ranged from 6.2 to 7.6 cm·wk^{-1} across species (Fig. 3A), with tall fescue and *L. triticoides* having significantly higher water uptake than the other species ($P < 0.05$). Water uptake in unplanted controls averaged 3.5 cm·wk^{-1} (data not shown).

Mean N uptake by plant tissue ranged from 35 to 60 kg·ha^{-1}·wk^{-1} (Fig. 3B) across species, with tall fescue having the highest N uptake ($P < 0.05$). Among native species, *L. triticoides* had the highest N uptake and *V. microstachys* had the lowest, with N uptake for *M. imperfecta* being not significantly different than that for either other native species ($\alpha = 0.05$). While N uptake generally increased with increasing N application concentration (Fig. 4A), only tall fescue and *L. triticoides* had a significant increase in N uptake between the 33 and 100 mg N·liter^{-1} treatments ($P < 0.001$). This suggests that *M. imperfecta* and *V. microstachys* had essentially reached their maximum N uptake potential within the range of these concentrations. Therefore, *L. triticoides* or tall fescue may be more effective at scavenging N when concentrations in runoff are high.

Apparent N recovery ranged from 0.59 to 0.92 across species (Fig. 3C), and mean separations for species followed the pattern as that for N uptake. These values are high relative to reported ANR rates for remediation, forage, and turf grasses from field and greenhouse studies in which ANR values varied, but were typically below 0.50 (13, 18, 19, 29). ANR values from our study were probably inflated due to the high contribution of N supplied by the rooting medium, which may not have been entirely accounted for by adjusting for the zero-N treatment since zero-N treatment grasses had less developed root systems than other treatments. This idea is supported by the fact that some treatment-species combinations had ANR values greater than 1.0, presumably because there was considerable uptake of N supplied by the root medium. In light of these considerations, ANR values from our study should be considered relative values of the efficiency of uptake of available N and not as absolute fractions of the applied N taken up by plants.

Values for ANR decreased with increasing N concentration in the applied solution (Fig 4B). Lower values for ANR at higher concentrations of N application suggest that these

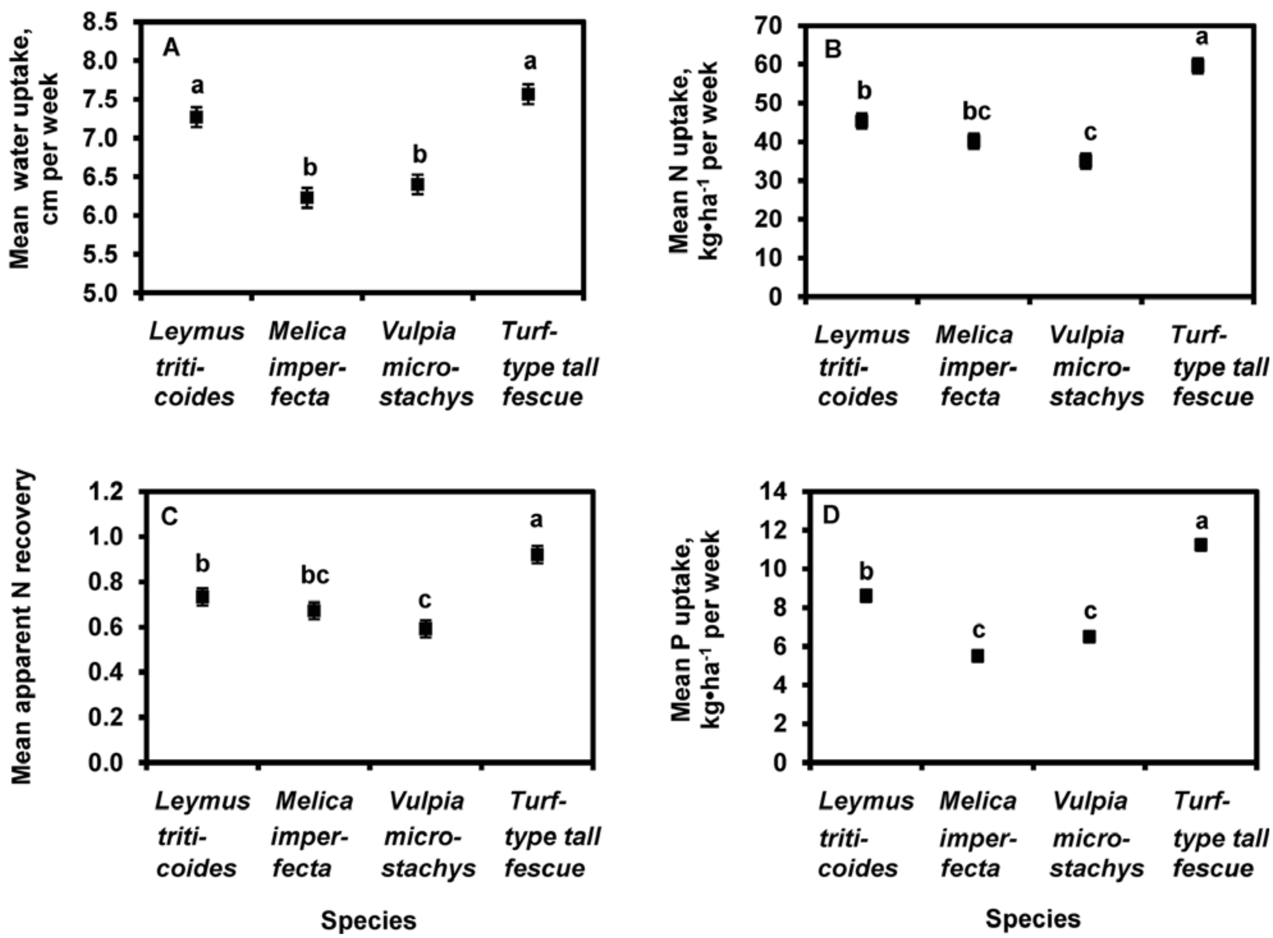

Fig. 3. Mean values from an analysis of variance for water uptake (A), N uptake (B), apparent N recovery (C), and P uptake (D) for three U.S. native grasses, *L. triticoides* 'yolo', *M. imperfecta*, *V. microstachys* 'db', and a turf-type tall fescue blend, *Lolium arundinaceum*. Where visible, error bars indicate standard errors of the means from the analysis. Means assigned the same letter in each plot are not significantly different ($P \geq 0.05$) using Tukey-adjusted pairwise comparisons.

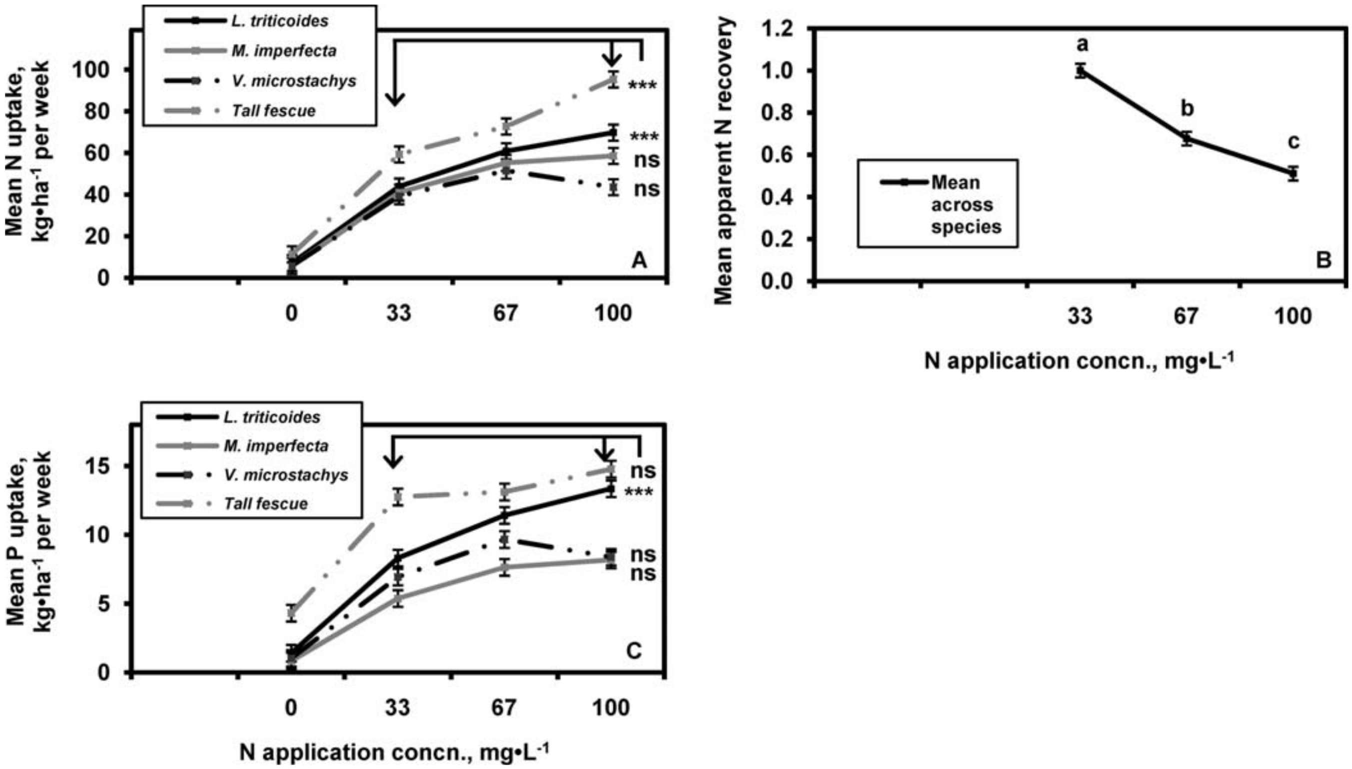

Fig. 4. **Mean values from an analysis of variance for N uptake (A), apparent N recovery (B), and P uptake (C) across N concentration in applied solution for three U.S. native grasses, *Leymus triticoides* 'yolo', *Melica imperfecta*, *Vulpia microstachys* 'db', and a turf-type tall fescue blend, *Lolium arundinaceum*. Error bars indicate standard errors of the means from the analysis. *ns* in plots A and C indicates that mean for the 33 mg·liter^{-1} treatment was not different from 100 mg·liter^{-1} for that species ($P \geq 0.05$). Asterisks indicate that mean for the 33 mg·liter^{-1} treatment was different from 100 mg·liter^{-1} for that species ($P < 0.001$). For plot B, mean values across species are plotted because the species × treatment effect was not significant in the analysis. Means in plot B assigned the same letter in each plot are not significantly different ($P \geq 0.05$) using Tukey-adjusted pairwise comparisons.**

grasses will be less effective, relative to the applied rate, at scavenging N from runoff water. Prudence would suggest the implementation of nutrient management practices that keep N concentrations in runoff relatively low for effective mitigation by grassed remediation areas or using buffers or grassed waterways with longer flow paths when nutrient concentrations in runoff are high.

Mean P uptake in plant tissue ranged from 5.5 to 11.2 kg·ha^{-1}·wk^{-1} across species (Fig. 3D), with tall fescue having the highest uptake, *L. triticoides* the second highest, and *M. imperfecta* and *V. microstachys* the lowest ($\alpha = 0.05$). In general, P uptake increased with increasing N application concentration (Fig. 4C), but only *L. triticoides* had a significant increase in P uptake from the 33 to 100 mg N·liter^{-1} application concentration, suggesting this grass had not reached its maximum P uptake at these levels of nutrient application.

All grass species grew reasonably well in the greenhouse environment that was sometimes hot and sometimes with limited irrigation amounts, with all N-fertilized pots achieving full ground cover during the experimental period. This suggests that covers of any of these grass species would be useful in slowing runoff. Differences among species were found for water, N, and P uptake, though all species were capable of significant uptake. Though N uptake increased as N application rate increased, some species appeared to reach their N uptake potential in the range of applied N concentrations. Similarly, as N application rate increased, ANR decreased, suggesting that these grasses will exhibit a decreased efficiency in scavenging N when N concentrations in applied runoff are higher. Flow paths through grassed buffers or waterways may need to be longer when nutrient concentrations in runoff are high to achieve effective mitigation of nutrients in runoff water. Prudence would suggest the implementation of nutrient management practices that keep N concentrations in runoff relatively low for effective mitigation by grassed remediation areas.

Among native grasses, *L. triticoides* exhibited some advantages over the others, which may make it a good choice for runoff treatment applications, especially in poorly-drained or saline areas where it is reported to grow well. *L. triticoides* exhibited stiff blades and a rhizomatous growth habit, as well high shoot and root density and rapid vertical growth. This suggests this grass may be a good choice where dense roots are desirable to prevent erosion or a tall stand is desirable to slow runoff water. *L. triticoides* furthermore exhibited high water, N, and P uptake, particularly at high concentrations of applied nutrients, suggesting it may be a useful plant for nutrient remediation.

Because this experiment was conducted as a short-term study in a greenhouse environment with plants grown in pots, conditions of this study may not be representative of conditions typical in field applications. In light of this consideration, water, N, and P uptake results of this study should be considered relative values and not absolute values that could expected under field conditions.

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