



Physiological advantages observed in a C₃ grass invading C₄ grasslands

Cooper-Norris, C.E.¹; Harvey, J.G.²; Norris, A.B.¹

¹ Department of Natural Resources Management, Texas Tech University, Lubbock, Texas, USA;

² Barta Brothers Ranch, Eastern NE Research & Extension Center, University of Nebraska-Lincoln, Bassett, Nebraska, USA

Key words: *Nassella tenuissima*; Mexican feathergrass; shortgrass prairie; invasion mechanisms

Abstract

Mexican feathergrass (*Nassella tenuissima* (Trin.) Barkworth) is a C₃ bunchgrass native to the Trans-Pecos region of West Texas and south-central New Mexico in the United States but has been planted as an ornamental in many other regions. *N. tenuissima* can escape from landscaping areas and become a weedy species on disturbed rangelands. To understand any physiological advantages this species may have over native species, we surveyed three *N. tenuissima* colonies throughout a remnant 54-ha native shortgrass prairie within the limits of Lubbock, Texas, USA in the summer of 2022. We selected *N. tenuissima* from three locations within the colonies: inner, edge, and outer for physiological (i.e., leaf-level gas exchange) and morphological (i.e., basal area) measurements. We also monitored two ‘companion’ native grasses adjacent to *N. tenuissima* in the outer location: blue grama (*Bouteloua gracilis* (Kunth) Lag. ex Griffiths) and purple threeawn (*Aristida purpurea* Nutt.). *N. tenuissima* photosynthesis rates were greater than those of *A. purpurea* and *B. gracilis*, while stomatal conductance and transpiration rates were similar among species. No significant differences were seen in photosynthesis, stomatal conductance, or transpiration rates across the three colony locations for *N. tenuissima*. *N. tenuissima* cover and biomass was greatest in inner locations and decreased with distance away from the center of colonies. In contrast, warm-season grass and forb cover increased with distance away from the center of colonies. *N. tenuissima* appears to exhibit physiological and morphological advantages over native warm-season grasses, which likely contribute to its expansion in the local region, particularly at degraded and overgrazed sites.

Introduction

Mexican feathergrass (*Nassella tenuissima* (Trin.) Barkworth) is a perennial C₃ bunchgrass native to the Trans-Pecos region of West Texas and south-central New Mexico in the United States (Shaw et al. 2011), Mexico, Argentina, and Chile (Jacobs et al. 1998), but has been planted as an ornamental in many regions. *N. tenuissima* is escaping landscaping plantings and becoming a weedy species in shortgrass and midgrass prairies in western Texas and the Texas panhandle (Russell and Rector 2017). In South America where the species is native, overgrazing of desirable forage species and fire suppression are attributed to its spread (Distel and Boo 1996). Additionally, leaf litter of this species has high amounts of lignin, a high C:N ratio,

and is slow to decompose (Moretto et al. 2001), further exacerbating competition with native grass and forb species. *N. tenuissima* has been reported since 1998 to be a potential threat to biodiversity in Australia (Jacobs et al. 1998).

N. tenuissima has long, narrow, tightly-rolled leaves (Jacobs et al. 1998). The foliage is considered to be unpalatable due to low N and P content, high lignin (Moretto and Distel 2002), and high amounts of silica (Russell and Rector 2017). At the field site used in this study, wildlife seem to prefer other grass species to *N. tenuissima*. Horticultural guides advertise the species as “deer resistant” (Chapman and Salwitz 2017). Additionally, a lack of grazing or prescribed burning contributes to large amounts of *N. tenuissima* litter on the soil surface. *N. tenuissima* is drought tolerant and adapted to hot and dry regions (Hillock et al. 2022), with a shallow root system well adapted to capturing soil moisture close to the soil surface following intermittent rainfall events (Humphries and Florentine 2021). The species germinates readily in vegetation gaps (Moretto and Distel 1998) and prefers full sun (Hillock et al. 2022). It also seeds freely, and a single plant can produce up to 100,000 seeds annually (Humphries and Florentine 2021).

Little is known about *Nassella tenuissima*'s physiology. In West Central Texas, the majority of its growth occurs in the late spring through early summer, with seed set continuing into the fall (Russell and Rector 2017). In the Texas High Plains, *N. tenuissima* retains a considerable amount of green tissue into late November. Though it is a C₃ species, its life cycle suggests that it behaves similarly to warm-season C₄ grasses in many ways (Russell and Rector 2017).

Our study was conducted due to a lack of information on *N. tenuissima*'s invasion mechanisms and effects on native warm-season species in the shortgrass prairie of the Texas High Plains. Objectives were to assess: 1) the relationship between *N. tenuissima* cover and biomass and those of native warm-season grasses and forbs, 2) *N. tenuissima* physiognomy relative to location within a colony, 3) leaf-level physiological characteristics of *N. tenuissima* relative to common native warm season-grasses.

Methods

This study took place at a ~53-ha remnant shortgrass prairie located within the city limits of Lubbock (33.60327 N, -101.9003 W) and used for research and teaching by Texas Tech University. Historically, the dominant vegetation was short grass prairie. Today the site has some shortgrass prairie species such as blue grama (*Bouteloua gracilis* (Kunth) Lag. ex Griffiths), and buffalograss (*Bouteloua dactyloides* (Nutt.) Columbus) but with high densities of encroaching honey mesquite (*Prosopis glandulosa* Torr.) and annual Chenopodiaceae forbs (Jackson et al. 2020). The region is semi-arid, with hot summers and mild winters. Local temperatures range from -2.8°C in January to 34.4°C in July, with an average annual precipitation of 466 mm. The site has not been grazed by livestock in ~20 years, though overgrazing occurs via high populations of cottontail rabbits (*Sylvilagus* spp.) and black-tailed jackrabbits (*Lepus californicus*). *N. tenuissima* has been planted in many locations in Lubbock and is thought to have established on the site following escape from planted locations nearby.

We selected three *N. tenuissima* colonies at the site. Colonies ranged in size from ~10 to 20 m in diameter. From the center of each colony, three transects were established in random directions to well beyond the colony margin. Total transect lengths ranged from 20 m at the smallest colony to 40 m at the largest. In November 2024, beginning at the 5 m mark, canopy cover was measured in a 0.1-m² frame every 5 m along each transect. Cover was classified into bare ground, litter, *N. tenuissima*, warm-season grasses, and forbs. On the opposite side of the transect from where we collected cover, we measured the height and diameter of the nearest *N. tenuissima* plant. Heights were measured to the nearest cm and diameters to the nearest 0.5 cm. If no *N. tenuissima* plants were within 2.5 m, no *N. tenuissima* morphology measurements were

taken there. For analysis, data were pooled from the four to eight locations along a transect into three colony zones: 1) *inner colony* consisting of distances nearest the colony center to 1x the distance of the colony radius, 2) *mid colony* which contained locations > 1x the colony radius and < 3x the colony radius, and 3) *outer colony* which contained locations > 3x the colony radius. The number of locations varied in each zone across colonies, but this method provided a standardization for colonies of different sizes.

In summer 2022, we selected three *N. tenuissima* plants from the three colony locations for physiological (i.e., leaf-level gas exchange) measurements. We also monitored three adjacent plants of blue grama and purple threeawn (*Aristida purpurea* Nutt.) in the outer location of each colony. Leaf-level gas exchange [photosynthesis (A ; $\mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$), stomatal conductance (g_s ; $\text{mol H}_2\text{O m}^{-2} \text{ s}^{-1}$), and transpiration (E ; $\text{mol H}_2\text{O m}^{-2} \text{ s}^{-1}$)] was assessed using an open-flow infrared gas analyzer system (LI-6800, Li-Cor, Lincoln, NE, USA). Measurements were taken in May 2022 at midday. Due to the number of colonies, gas exchange measurements were conducted over three consecutive days with similar cloud-free weather. During gas exchange measurements, three fully expanded leaves of each plant were placed parallel in the chamber. Other studies assessing gas exchange of narrow-leaved grass species have used sections from multiple leaves simultaneously as well (Ramirez et al. 2008, Perez-Anta et al. 2024). Following the gas exchange measurement, we measured and recorded the width of each leaf section in the chamber. Widths were multiplied by the length of the chamber cuvette to calculate leaf areas which were then used to normalize gas exchange data. Due to the rolled nature of *N. tenuissima*'s leaves, we were required to use the projected (rolled) leaf area to determine leaf-area corrected gas exchange rates (Haase et al. 1999, Perez-Anta et al. 2024).

Linear mixed models (SAS 9.4) were used to test the effects of colony location on *N. tenuissima* height, basal area, and leaf-level physiological parameters. The interaction of colony location and cover type was tested on canopy cover in colonies. In the outer colony location, the effect of species was tested on leaf-level physiological parameters. Differences were considered significant at $P \leq 0.05$ and tendencies assumed at $0.10 \geq P > 0.05$. Means separation of significant effects and interactions were performed using Tukey's HSD.

Results

N. tenuissima photosynthesis rates, $11.8 \mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$, were greater than those of *A. purpurea*, $4.1 \mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$, and tended to be greater than those of *B. gracilis*, $5.8 \mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$ ($P = 0.06$). Stomatal conductance and transpiration rates were similar among species. No significant differences were seen in photosynthesis, stomatal conductance or transpiration rates across the three colony locations for *N. tenuissima*.

N. tenuissima basal area tended to be related to colony position, with plants in inner colony positions tending to have greater basal areas ($P = 0.052$). *N. tenuissima* height was greatest at inner colony locations. Colony position interacted with cover type to influence ground cover. *N. tenuissima* cover was greater in inner colony locations (40.4%) than mid (10.8%) and outer (3.8%) locations. In contrast, cover by native warm-season grasses and litter was lowest in inner colony locations. Forb cover and amounts of bare ground were not affected by colony position and were low in all colony locations. In every colony location, litter comprised a large portion of the cover, 55.6 – 75.2%. Within inner colony locations, *N. tenuissima* comprised a larger portion of cover (40.4%) than warm-season grasses (1.5%) and forbs (5.2%). In mid colony positions, *N. tenuissima*, warm-season grasses, and forbs had similar cover. In outer colony positions, however, warm-season grasses (17.6%) had greater cover than *N. tenuissima* (3.8%).

Discussion, Conclusions, and Implications

Though *N. tenuissima* is a C₃ species, it maintains actively growing tissue throughout the summer and fall, directly competing with warm-season native shortgrass prairie species during their active-growth period. Gas exchange measurements suggested that, at least early in the summer, *N. tenuissima* had greater intrinsic water use efficiency than warm-season native species at the site. *N. tenuissima*'s drought tolerance and low water consumption has been reported in other studies (Asin et al. 2021), though we did not observe lower transpiration rates or stomatal conductance in *N. tenuissima* than *B. gracilis* or *A. purpurea*. The summer of 2022 was exceptionally dry, which limited our ability to measure gas exchange accurately following May 2022 measurements. Thus, further tests are needed to assess *N. tenuissima*'s gas exchange rates relative to the C₄ grasses under a wider range of soil moisture conditions.

We believe that the combination of the large quantities of durable litter produced by *N. tenuissima* in addition to the live cover from this species results in the suppression of the local warm-season grasses. Following honey mesquite invasion across much of the site, warm-season species have been restricted to areas of low mesquite cover. Those areas are now experiencing encroachment from *N. tenuissima* despite *N. tenuissima* being reported to be a poor competitor against native species in well-managed locations (Amme 2003, Mapaura et al. 2020). Stress from overgrazing by wildlife coupled with the unpalatable nature of *N. tenuissima* and build-up of litter appears to have resulted in warm-season species being displaced in the areas of low mesquite density. Further studies are needed to assess the effects of woody canopy cover on *N. tenuissima* growth and the degree to which it can tolerate high cover of summer-active shortgrass prairie grasses and forbs.

Acknowledgements

We appreciate assistance from Alex Pearson, Will Pfeiffer, Emily Brown, Olivia Strong and Charles Poulard. This study was supported by funding from Texas Tech University.

References

- Amme D (2003) *Nassella* notes. Grasslands 13, 1-5.
- Asin JEF, Martinez CF, Cantón M, Correa EN (2021) Green roofs in dry cities. Selection of plant species according to their biological and thermal behaviour. Available at https://assets-eu.researchsquare.com/files/rs-182694/v1_stamped.pdf [Accessed 02 December 2024].
- Chapman K, Salwitz C (2017) 'Gardening with foliage first: 127 dazzling combinations that pair the beauty of leaves with flowers, bark, berries, and more', (Timber Press: Portland, Oregon, USA)
- Distel RA, Bóo RM (1996) Vegetation states and transitions in temperate semi-arid rangelands of Argentina. In 'Rangelands in a Sustainable Biosphere'. pp. 117-118. (Society for Range Management: Denver, CO, USA)
- Haase P, Pugnaire FI, Clark SC, Incoll LD (1999) Environmental control of canopy dynamics and photosynthetic rate in the evergreen tussock grass *Stipa tenacissima*. Plant Ecology 145, 327-339.
- Hillock D, Schnelle M, Hentges C (2022) Ornamental grasses and grass-like plants for Oklahoma. Oklahoma Cooperative Extension Service, HLA-6470, Stillwater, OK, USA.
- Humphries T, Florentine SK (2021) A comparative review of six invasive *Nassella* species in Australia with implications for their management. Plants 10, 1036.
- Jackson M, Portillo-Quintero C, Cox R, Ritchie G, Johnson M, Humagain K, Subedi MR (2020) Season, classifier, and spatial resolution impact honey mesquite and yellow bluestem detection using an unmanned aerial system. Rangeland Ecology & Management 73, 658-672.
- Jacobs SWL, Everett J, Torres MA (1998) *Nassella tenuissima* (Gramineae) recorded from Australia, a potential new weed related to serrated tussock. Telopea 8, 41-46.
- Mapaura A, Canavan K, Richardson DM, Clark VR, Steenhuisen SL (2020) The invasive grass genus *Nassella* in South Africa: a synthesis. South African Journal of Botany 135, 336-348.

- Moretto AS, Distel RA (1998) Requirement of vegetation gaps for seedling establishment of two unpalatable grasses in a native grassland of central Argentina. *Australian Journal of Ecology* 23, 419-423.
- Moretto AS, Distel RA (2002) Soil nitrogen availability under grasses of different palatability in a temperate semi-arid rangeland of central Argentina. *Austral Ecology* 27, 509-514.
- Moretto AS, Distel RA, Didone NG (2001) Decomposition and nutrient dynamic of leaf litter and roots from palatable and unpalatable grasses in a semi-arid grassland. *Applied Soil Ecology* 18, 31-37.
- Perez-Anta I, Rubio E, Lopez-Serrano FR, Garces D, Andres-Abellan M, Picazo M, Chebbi W, Arquero R, Garcia-Morote FA (2024) Transpiration dynamics of esparto grass (*Macrochloa tenacissima* (L.) Kunth) in a semi-arid Mediterranean climate: unraveling the impacts of pine competition. *Plants* 13, 661.
- Ramirez DA, Valladares F, Blasco A, Bellot J (2008) Effects of tussock size and soil water content on whole plant gas exchange in *Stipa tenacissima* L.: Extrapolating from the leaf versus modelling crown architecture. *Environmental and Experimental Botany* 62, 376 – 388.
- Russell ML, Rector BS (2017) Mexican feathergrass. Texas A&M AgriLife Extension, ERM-039, College Station, TX, USA.
- Shaw RB, Rector BS, Dube AM (2011) 'Distribution of grasses in Texas', (BRIT Press: Fort Worth, Texas, USA)