A COMPARISON OF A WALNUT LIMESTONE GLADE AND PERIPHERAL BARREN HABITATS FOR *DALEA REVERCHONII* (FABACEAE)

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ABSTRACT

Dalea reverchonii is hypothesized to be a Walnut Limestone glade endemic in North Texas. We compare a population discovered in 2010 on a Walnut Limestone glade in Parker County, Texas to populations found in a peripheral prairie barren. For three years, numbers of *D. reverchonii*, diameter of plants, number of flowering spikes, as well as richness and coverage associated with plants significantly differed between glade and barren populations. Associated species also were different in the two habitats. Length of the longest spike was not significantly different when comparing *D. revorchonii* in glade and barren populations. This data provides supports for the hypothesis that *D. reverchonii* is found mostly in and is best adapted to Walnut Limestone glades.

RESUMEN

Se hace la hipótesis de que *Dalea reverchonii* sea un endemismo del Walnut Limestone glade del norte de Texas. Se compara la población descubierta en 2010 en Parker County, Texas con poblaciones encontradas en una pradera periférica árida. Durante cuatro años, los números de *D. reverchonii*, diámetro de las plantas, número de espigas floridas, así como la riqueza y cubierta asociada con las plantas difirió significativamente entre las poblaciones del humedal y del árido. Las especies asociadas fueron también diferentes en los dos hábitats. La longitud de la espiga más larga no fue significativamente diferente cuando se comparó *D. revorchonii* de poblaciones del humedal y del árido. Estos datos dan soporte a la hipótesis de que *D. reverchonii* se encuentra mayormente y está mejor adaptada a los Walnut Limestone glades.

INTRODUCTION

Dalea reverchonii (S. Watson) Shinners is a calciphile that is hypothesized to be restricted to Walnut Limestone glades (O'Kennon 2010; Taylor & O'Kennon 2013) and is considered to be a component of the limestone glade association with *Phemeranthus calycinus* (Engelm.) Kiger and *Minuartia michauxii* (Fenzl) Farw. var. *texana* (B.L. Rob. ex Britton) Mattf. in the North Central Texas Walnut Formation, which is part of an ecoregion called the Fort Worth Prairie. The North Central Texas Walnut Formation consists of shallow, calcareous soils formed from bedrock consisting of alternating layers of limestone and clay marl with glades on ridgetops surrounded by prairie barrens (Swadek & Burgess 2012). Swadek and Burgess (2012) describe glades as having thinner, poorly developed soil over bedrock, patchy vegetation typically with less than 50% vegetative cover and barrens having relatively deeper, more developed soils and typically greater than 50% vegetative cover. Baskin et al. (2007) considered the shallower soils of glades to be less than 5 cm. *Dalea reverchonii* occurs most often in glades and is rare in barrens (Swadek & Burgess 2012; Taylor & O'Kennon 2013). Taylor and O'Kennon (2013) further note that in Tennessee, the closely related limestone cedar glade endemic *D. gattingeri* (A. Heller) Barneby has high light requirements and poor competitive ability, suggesting the species is endemic to limestone cedar glades not because it prefers the habitat but because it is not shaded and outcompeted by other taxa (Breeden 1968) and they hypothesize that *D. reverchonii* occurs in similar habitat for those reasons.

In addition, Taylor and O'Kennon (2013) listed the species associated with *D. reverchonii* during their investigation of 68 sites throughout the known range of *D. reverchonii*. Common associated species in the northern portion of the range included *Croton monanthogynus* Michx., *Erioneuron pilosum* (Buckley) Nash, *Hedeoma drummondii* Benth., *Hedyotis nigricans* (Lam.) Fosberg, *Heliotropium tenellum* Torr., *Minuartia michauxii* var. *texana*, *Opuntia phaeacantha* Engelm. var. *major* Engelm., *Phemeranthus calycinus, Plantago helleri* Small, and *Sporobolus vaginiflorus* (Torr. ex A. Gray) Wood. Less common associates included *Bouteloua pectinata* Feath., *Dalea frutes-*

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cens A. Gray, *Paronychia virginica* Spreng., *Pediomelum reverchonii* (S. Watson) Rydb., and *Yucca pallida* McKelvey. Different associated species were found from Hood County southward and the following species were typically associated with *D. reverchonii* in this region and included *Erigeron modestus* A.Gray, *Linum rupestre* (A. Gray) Engelm. ex A. Gray, *Melampodium leucanthum* Torr. & A. Gray, *Thelesperma simplicifolium* (A. Gray) A. Gray, *Verbena canescens* Kunth var. *roemeriana* L.M. Perry, and *Vernonia lindheimeri* A. Gray & Engelm. Swadek and Burgess (2012) reported *Aristida purpurea* Nutt. var. *nealleyi* (Vasey) Allred, *Minuartia michauxii, Phemeranthus calycinus*, *Plantago helleri*, and *Tetraneuris linearifolia* (Hook.) Greene as common associated species. Poole et al (2007) reported associates that included *Aristida* spp., *Bouteloua rigidiseta* (Steud.) Hitchc., *Dalea aurea* Nutt. ex Pursh, *D. enneandra* Nutt., *D. tenuis* (J.M. Coult.) Shinners, *Evolvulus nuttallianus* Schult., *Hedeoma drummondii, Hedyotis nigricans, Heliotropium tenellum, Indigofera miniata* Ortega var. *leptosepala* (Nutt. ex Torr. & A. Gray) B.L. Turner, *M. michauxii* var. *texana, P. virginica, P. reverchonii, Salvia texana,* and *Thelesperma filifolium.*

Conservation of *D. reverchonii* is a concern in Texas and it has a conservation rank of G2S2 (globally and state imperiled) indicating the species is at high risk of extinction due to a small range, few populations, population declines, or other factors (Poole et al. 2007; Natureserve 2013). Many populations are centered near Weatherford, Texas with urban sprawl, land fragmentation, mining, and herbivory listed as threats to the species (United States Fish &Wildlife Service (USFWS) 2016). In addition, Taylor and O'Kennon (2013) report nonnative plants and their associated competition as a conservation problem for *D. reverchonii.* Though *D. reverchonii* is a rare endemic and at one point was known only from a single population, 68 populations have been discovered in recent years (Taylor & O'Kennon 2013) as botanists have investigated glades and gained access to private property. The goal of this investigation is to compare *D. reverchonii* in glade and barren habitats so that future conservation decisions regarding the species can be more informed.

METHODS

A site from Parker County, Texas (Figs. 1 & 3; Taylor & O'Kennon 2013) that included a glade and peripheral barren was investigated. Based on coverage and the presence of exposed shallow, rocky soil in the glade region, we selected areas that were centered in the glade and adjacent barren. We sampled the two habitats over a three year period (2010–2012) in early May. For each year and site, a large 20×50m quadrat was selected within the two habitats and relocated using coordinates from the four corners of the quadrat. Total numbers of *D. reverchonii* were inventoried in each quadrat by flagging each plant and counting them, and compared for each site.

The large 20×50m quadrat was surveyed by subdividing it into smaller $1m^2$ subquadrats, and 30 subquadrats were selected at random per quadrat to collect data each year, for a total of 90 subquadrats per habitat over the three year investigation. For each subquadrat selected, individual plants of *D. reverchonii* were counted and measured. Each *D. reverchonii* found within or touching the edges of the randomly selected subquadrat was measured in diameter, spikes were counted, and the longest spike was measured in length. Secondly, foliar, vegetative cover per subquadrat was estimated visually and reported as a percentage. To determine richness, each plant species in the quadrat was counted and the dominant plant species, based on the majority of vegetative coverage in the subquadrat, was identified using Diggs et al. (1999; usually one to two or rarely three species if they were equal in foliar coverage). To determine how often these dominants were associated with *D. reverchonii,* percentages of subquadrats where the species co-occurred with *D. reverchonii* were calculated. Voucher specimens were deposited at the herbaria at Tarleton State University (TAC) and Botanical Research Institute of Texas (BRIT).

Statistical analyses were conducted using the data described above between the glade and barren sites using SigmaPlot 11 (Systat Software, Inc.). *P*-values were calculated from Mann Whitney tests for significance using only values less than 0.002.

RESULTS

Dalea reverchonii was most abundant in the glade for all three years of the inventory and mean numbers were over 7× greater in the glade relative to the adjacent barren (Table 1). In the subquadrat, survey data the mean

TABLE 1. Total individuals inventoried of *Dalea reverchonii* in each habitat for each year as well as the mean in each for the three year period.

Year	Walnut Limestone glade	Adjacent barren
2010	754	58
2011	731	108
2012	848	159
Mean	778	108

number of *D. reverchonii* was over 5× greater in the glade than the adjacent barren (Table 2). Mean richness and coverage were significantly greater in the adjacent barren than the glade (Table 2) and within the glade, subquadrats that contained *D. reverchonii*, had greater coverage and richness (Table 3). Counts of spike number and measures of plant diameter for *D. reverchonii* were significantly greater in the barren than the glade while spike length was not significantly different between the habitats (Table 4).

Ten associated species, all native, were recorded in the glade survey with *P. helleri* (35%), *M. michauxii* var. *texana* (19%), *T. linearifolia* (19%), and *T. filifolium* (11%) being most commonly encountered (Table 5). In the adjacent barren, nine associated species, with one introduced, were recorded. The introduced species was *Bromus japonicus* Thunb. ex Murray and was only encountered in 3% of the occurrences. *Tetraneuris linearifolia* (26%) and *Tridens albescens* (Vasey) Wooton & Standl. (23%) were the most commonly encountered associates in the barren. In addition, *T. albescens* was only encountered in the barren as was *B. japonicus* (3%), *Eleocharis acutisquamata* Buckley (=*E. occulta*) (8%), *Gaillardia pulchella* Foug. (8%), *Plantago wrightiana* Decne. (10%), and *Sida abutifolia* Mill. (3%). *Dalea frutescens* A. Gray (1%), *Erioneuron pilosa* (3%), *M. michauxii* var. *texana* (19%), and *Sedum nuttallianum* Raf. (5%) were encountered only in the glade (Table 5).

DISCUSSION

Dalea reverchonii occurred much more often in the Walnut Limestone Glade than the adjacent barren but grew greater in diameter and had more spikes in the barren where coverage was greater. Spike length was not significantly different between the habitats but this may have been due to variation in developmental stages, some still in bud and others at anthesis during the study. Measuring spikes only at anthesis may have yielded more comparable data. Therefore, plant diameter and spike number, which were significantly different between the habitats, are likely better measures of growth and reproduction. Plant diameter and spike number were significantly greater in the barren because of greater numbers of newly germinated plants in the glade, whereas the barren contained only large plants, which were likely older. Taylor and O'Kennon (2013) and Breeden (1968) noted that the closely related limestone cedar glade endemic *D. gattingeri* has high light requirements and poor competitive ability, suggesting the species is endemic to limestone cedar glades not because it prefers the habitat but because it is not shaded and outcompeted by other taxa. Our data support this hypothesis, in terms of plant numbers, since *D. reverchonii* most often occurred in the relatively unshaded glade and occurred in much lower numbers in the barren where coverage and presumably, competition from other species was greater. Larger plants and the associated greater number of flowering spikes in the barren could be due to less young plants, which may not compete well in the densely vegetated barren as seedlings or the larger plants could be remnants from a time when there was less vegetation in the barren.

Taylor and O'Kennon (2013) also noted that at a few sites during their status survey, soil development was more advanced, and the plants were overtopped by annual and perennial grasses. We observed this in our barren habitat, which had much greater vegetative coverage than the glade. Taylor and O'Kennon (2013) predict that these sites have undergone succession from open glades to deeper-soiled barrens as described by for the cedar glades of central Tennessee (Quaterman 1950; Baskin et al. 2007). On surfaces stabilized by a glade of Walnut Limestone, the vegetation tends to be lower, more open, and less grassy than typical mixed grass prairies (Taylor & O'Kennon 2013). Our data supports these observations because in the glade there was less vegetative coverage and only three grasses with low association (2–5%, Table 5) with *D. reverchonii*.

Swadek and Burgess (2012) describe glades as having patchy vegetation typically with less than 50% vegetative cover while barrens typically have greater than 50% vegetative cover. We observed vegetative coverage between the two habitats at 16.9% in the glade and 68.4% in the adjacent barren, which agrees well with the

Table 2. Mean number of plants, richness, and percentage cover per subquadrats between the Walnut Limestone glade and adjacent barren from 2010–2012 using 90 subquadrats from each habitat. *P*-values are from Mann Whitney tests for significance.

Mean/quadrat	Walnut Limestone glade	Adjacent barren	*P*-value
Number of plants	1.1	0.2	<0.001
Richness	5.4	8.4	<0.001
Percent vegetative cover	16.9	68.4	<0.001

Table 3. Mean richness and percentage cover in the Walnut Limestone glade between subquadrats that contained *D. reverchonii* and those that did not from 2010–2012. *P*-values are from Mann Whitney tests for significance.

Mean/quadrat	With *D. reverchonii* *n*=37	Without *D. reverchonii* *n*=53	*P*-value
Richness	6.7	4.5	<0.001
Percent vegetative cover	23.6	13.9	<0.001

Table 4. Mean spike number, spike length, and plant diameter for plants occurring in a Walnut Limestone glade and adjacent barren from 2010–2012. Number of individuals (*n)* is included after the mean. *P*-values are from Mann Whitney tests for significance.

Mean	Walnut Limestone glade	Adjacent barren	*P*-value
Spike number	6.3; *n*=100	14.0; *n*=23	0.002
Spike length (mm)	36.2; *n*=77	43.2; *n*=22	0.318
Plant diameter (mm)	262.1; *n*=100	383.6; *n*=25	0.001

Table 5. Species associated with *Dalea reverchonii* and number of times over three years associated species were found in quadrats that contained *D. reverchonii* in Walnut Limestone glade and adjacent barren.

Associated species	Walnut Limestone glade *n*=81		Adjacent barren *n*=39	
	/81	%	/39	%
Aristida purpurea var. *nealleyi*	4	5	1	3
Bromus japonicus	0	0	1	3
Dalea frutescens	1	1	0	0
Eleocharis acutisquamata	0	0	3	8
Erioneuron pilosa	3	4	0	0
Gaillardia pulchella	0	0	3	8
Minuartia michauxii var. *texana*	15	19	0	0
Plantago helleri	28	35	5	13
Plantago wrightiana	0	0	4	10
Sedum nuttallianum	4	5	0	0
Sida abutifolia	0	0	1	3
Tetraneuris linearifolia	15	19	10	26
Thelesperma filifolium	9	11	2	5
Tridens albescens	2	2	9	23

observations of Swadek and Burgess (2012). However, within the glade where *D. reverchonii* occurred in subquadrats, there was greater vegetative coverage and richness, suggesting that the presence of *D. reverchonii* either promoted the establishment of other plants or that it co-occurred in pockets within the glade with other plants. If the former hypothesis is true, than *D. reverchonii* might promote the growth of other associated plants

by trapping soil with its prostrate form of growth, widening cracks in bedrock (Quarterman 1950), and creating desirable microhabitats within the glade.

Swadek and Burgess (2012) found *D. reverchonii* restricted to glade and barren habitats but most commonly, in glade habitats consisting of shallow soil, which is covered by gravel from Walnut Limestone where it is often associated with *A. purpurea* var. *nealleyi, M. michauxii* var. *texana, P. calycinus*, *P. helleri*, and *T. linearifolia.* This is similar to our glade associates with the exception of *P. calycinus,* which we frequently observed in the glade but never encountered in samples that contained *D. reverchonii.* This could be due to sampling error or *P. calycinus* is an associate that occurs at a greater distance from *D. reverchonii* than our $1m^2$ subquadrats. We also encountered *T. filifolium* in our samples 11% of the time as well as several rare associates of *D. reverchonii* in the glade, which were not noted by Swadek and Burgess (2012). Poole et al (2007) also noted *T. filifolium* as an associate of *D. reverchonii.*

Taylor and O'Kennon (2013) and Poole et al (2007) provide more extensive lists of associates. For the most part, we observed many of the associates within the glade and barren at our site with our glade associates most similar to those reported by Swadek and Burgess (2012). In addition, at our site, two new associates, not recorded by previous investigators, *Sedum nuttallianum,* and *T. albescens* were encountered in our survey. *Sedum nuttallianum* is reported from moist, rocky areas (Diggs et al. 1999) and was sampled from the glade in 5% of our samples associated with *D. reverchonii,* but was less common in 2011 and 2012, when the early May sampling periods were drier. *Tridens albescens* was sampled in only 2% of the quadrats with *D. reverchonii* in the glade but was a dominant associate in the adjacent barren. Its presence in the glade with *D. reverchonii* may represent early succession of the glade as described by Quarterman (1950; Baskin et al. 2007) in Tennessee glades and our region by Taylor and O'Kennon (2013). We did not encounter any of the associated species reported from Hood County southward by Taylor and O'Kennon (2013), supporting differences in associates between northern and southern populations of *D. reverchonii*, which grow on strata that are differ geologically in the south (Swadek & Burgess 2012).

Dalea reverchonii is a rare endemic to North Texas that is considered imperiled locally and globally. Several threats exist to *D. reverchonii* including road widening, land development, spread of non-native plants, and cattle grazing (Taylor & O'Kennon 2013). In addition, USFWS (2016) report that in the Weatherford, Texas area, where our investigation occurred, urban sprawl, land fragmentation, mining, and herbivory are conservation problems. Our site was in a rural area with relatively little development, no cattle grazing or mining, and only one introduced species, *B. japonicus,* which was only encountered in the barren. Non-native, invasive taxa pose a threat to *D. reverchonii* through competition and shading (Taylor & O'Kennon 2013) but this does not appear to be a problem at our site, which was mostly native species. Our data suggests that Walnut Limestone glades are significantly different from adjacent prairie barrens and should be considered in conservation and restoration planning. In addition, if *D. reverchonii* is to be reintroduced, Walnut Limestone glades appear to be their preferred habitat.

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