Structural Attributes of *Schizachyrium scoparium* in Restored Texas Blackland Prairies

Justin D. Derner,[1,2] H. Wayne Polley,[3] Hyrum B. Johnson,[3] and Charles R. Tischler[3]

Abstract

Structural attributes of the C_4, perennial bunchgrass *Schizachyrium scoparium* in restored prairies may be affected by the time since restoration. One hundred plants each in 8-, 17-, and 23-year-old restored prairies and a native Texas Blackland prairie were assessed for the presence/absence and diameter of a hollow crown (i.e., dead center portion), degree of fragmentation, plant height, and tiller density. Structural attributes of *S. scoparium* plants were generally (1) different between recent (8 years) and older (17 and 23 years) restored prairies (2) similar between the 17- and 23-year-old restored prairies, and (3) more similar between the 8- and 17-year restored prairies and the native, remnant prairie than between the 23-year restored prairie and the native prairie. Plants were shorter in restored prairies, regardless of time since restoration, than in the native prairie. Mean basal area of plants was 80–163% greater in the 17- and 23-year restored prairies compared with the native and 8-year restored prairies. Percentage of hollow crowns and fragmentation was smallest in the 8-year restored prairie, largest in the 17- and 23-year restored prairies, and intermediate in the native prairie. Tiller density exhibited inverse second-order polynomial decreases with increasing plant basal area for all prairies. In contrast to tiller density, diameter of hollow crowns increased logarithmically with increasing plant basal area. Structural attributes of *S. scoparium* in restored prairies changed predictably with age, despite growing in different communities.

Key words: **bunchgrass, fragmentation, hollow crown, tussock.**

Introduction

The Texas Blackland prairie, the southernmost extension of the true prairie, originally encompassed approximately 4.2 million ha. However, less than 1% of the original area remains and this exists as highly fragmented, small (<10 ha) remnants (Riskind & Collins 1975). Restoration efforts, prompted by greater conservation and preservation awareness, have increased in this highly human-modified ecosystem. Because *Schizachyrium scoparium* (little bluestem) is the dominant, perennial species of this ecosystem, restoration efforts often target successful establishment of this species. Yet, information pertaining to structural attributes (e.g., plant basal area, height and fragmentation) of this C_4, bunchgrass (tussock and caespitose) species in chronosequences of restored prairies is limited.

Because plantings in prairie restorations result in an initial cohort of similar-aged plants, a chronosequence of restored prairies provides an opportunity to evaluate structural attributes of plants with known maximum age and compare with the expected architectural development of bunchgrasses (Gatsuk et al. 1980). Understanding the influence of time since restoration on the structural attributes of *S. scoparium* may provide insight into evaluating the success of restoration efforts on ecosystem structure and function of restored prairies. Structural attributes of *S. scoparium* plants have been previously evaluated in response to inter- and intraspecific competition (Briske & Butler 1989), plant size and distribution (Briske & Anderson 1990), above- and belowground resources (Derner & Briske 1999), and grazing (Anderson & Briske 1995; Pfeiffer & Hartnett 1995).

Schizachyrium scoparium plants are characterized by the compact spatial arrangement of tillers within individual plants and the absence of rhizomes or stolons for rapid lateral spread. Developmental morphology and resulting structural changes are driven by the growth and recruitment of juvenile tillers within tiller hierarchies, which are comprised of three connected generations in *S. scoparium* (Welker et al. 1991; Williams & Briske 1991; Derner & Briske 1998). These tiller hierarchies become separated with increasing plant size and age because initial tiller generations die and decompose (Gatsuk et al. 1980; Olson & Richards 1988). As a result of this process, hollow crowns are formed in the center region of individual plants. Once this hollow crown is extended to the plant periphery, rapid fragmentation of plants occurs (Gatsuk et al. 1980). Fragmentation contributes to population maintenance of bunchgrasses (Lord 1993; Danin & Orshan 1995), although other studies suggest that populations of bunchgrasses are maintained by reproduction from seed (Vorontzova & Zaugolnova

---

[1] USDA-ARS, High Plains Grasslands Research Station, Cheyenne, WY 82009, U.S.A.
[2] Address correspondence to J. D. Derner, email jderner@npa.ars.usda.gov
[3] USDA-ARS, Grassland, Soil and Water Research Laboratory, Temple, TX 76502, U.S.A.

1985; Zhukova & Ermakova 1985). Determining the level of fragmentation of *S. scoparium* plants along a chronosequence of restored prairies would provide information relevant to the potential self-sustainability of these populations.

The objective of this study was to determine whether structural attributes of *S. scoparium* plants differed between recent (8 years) and older (17 and 23 years) restorations and a native, remnant Texas Blackland prairie. We hypothesized that (1) plant height, size and occurrence of hollow crowns, and degree of plant fragmentation would be greater in older than recently restored prairies and (2) tiller density (number of tillers per unit basal area) would be lower in older than recently restored prairies. This chronosequence of restored prairies with plants of known maximum age provides an opportunity to estimate age structure of the population of *S. scoparium* plants in the native prairie using the assumption that plant basal area is a surrogate for plant age. The utility of this study from a reclamation perspective is the potential for determining when a restored Texas Blackland prairie may have similar demographic and structural composition of the dominant, perennial grass *S. scoparium* as found in a native prairie.

Study Area

This study was conducted on native and restored mesic tallgrass prairies in the Blackland tallgrass prairie region near Riesel, TX (31° 28′ N; 96°52′ W). Long-term (62-year), mean annual precipitation is 89.6 (±22.0, 1 SD) cm, with peaks in May and October. Precipitation was above average in 2 of the 3 years (1997 and 1998) before this investigation, but precipitation in 1999 was only 56% of average. Precipitation in 2000 to time of sampling was 106% of normal.

Prairies studied include: (1) a native, remnant tallgrass prairie that is hayed annually in late June, as is typical in this region and (2) 8-, 17-, and 23-year-old restored tallgrass prairies that are also hayed in late June. These prairies are small (<2 ha), have the same soil series (Heiden; fine, smectic thermic Udic Haplusterts) with 1–5% slope, have *Schizachyrium scoparium* as the dominant plant species, are within 2 km of each other, and are surrounded by croplands or permanent pastures.

The native prairie is dominated by climax vegetation for Blackland tallgrass prairie: *S. scoparium* (little bluestem), *Sorghastrum nutans* (yellow Indiangrass), *Sporobolus compositus* (meadow dropseed), *Nassella leucotricha* (Texas wintergrass), and *Bouteloua curtipendula* (sideoats grama). Seed hay harvested in late October from the native prairie was spread as mulch on the soil surface to restore each of the other prairies on formerly cultivated (row crops) lands. The same process was used for each restored prairie (P. Mezynski, personal communication). The same seed hay was not used for each restoration effort, but seeds were harvested from the same plant material sources, and years in which seed hay was harvested for each restoration exhibited average or above average precipitation.

Preliminary data from three of the prairies (excluding the 23-year-old prairie) indicate that peak standing crop in the 8- and 17-year-old restored prairies was 50–57% of that in the native prairie (6500 kg/ha) (Polley et al., unpublished data). Species composition of *S. scoparium* was greater in the restored (44–68%) than native prairies (34%), while forb composition exhibited the opposite trend with 13–18% forbs in the restored prairies and 35% forb composition in the native prairie. In addition, species richness was 1.6–2.7-fold greater in the native prairie (15.6 species per 0.5 m^2).

Methods

Five 20-m transects were randomly located in each prairie on 19–22 June 2000. The nearest *Schizachyrium scoparium* plant every meter along each transect (20 plants per transect, 100 plants total for each prairie) was qualitatively assessed for the presence/absence of a hollow crown (i.e. dead center portion) and degree of fragmentation and quantitatively assessed for plant height, tiller number, basal circumference, and diameter of the hollow crown. Degree of fragmentation was assigned “none” if the plant was intact and if there was no evidence of physical separation between neighboring tiller hierarchies, “present” if there was evidence of physical separation, and “complete” if the majority of neighboring hierarchies were physically separated.

Neither the restored nor native prairies were replicated, but this is a unique situation with a chronosequence of restored prairies within close proximity and from the same seed source. Inferences from our findings, however, are specific to our experimental location and treatments. Further experimentation is required to determine the applicability of results to a wider geographic area. Structural attributes of individual *S. scoparium* plants in the native and restored prairies were analyzed using a one-way general linear model (GLM) in SAS (SAS Institute 1994) at the 0.05 probability level. Comparisons between structural attributes for pairs of prairies were conducted using contrasts in GLM when there was a significant overall treatment effect for the structural attribute. Relationships between tiller density and plant basal area and between the diameter of hollow crown and plant basal area for each prairie were fit with linear, polynomial, hyperbolic, power, and logarithmic functions. The model with the greatest r^2 value was used as the best fit.

Results

Plants were shorter in restored prairies, regardless of time since restoration, than in the native prairie (Table 1). Plant height was 41–49% greater in 17- and 23-year restored prairies than in the 8-year restored prairie. Mean basal

Table 1. Structural attributes of the perennial, C_4 bunchgrass little bluestem in a native (NP) and three restored (RP) tallgrass prairies.

	Prairie			
	NP	*8-year RP*	*17-year RP*	*23-year RP*
Height (cm)	71 (1)^c	39 (1)^a	58 (1)^b	55 (1)^b
Basal area (cm^2)	84 (6)^a	85 (4)^a	151 (8)^b	221 (12)^c
Hollow crowns (%)	76 (4)^b	65 (5)^a	88 (3)^c	98 (1)^c
Fragmentation	1.6 (0.05)^b	1.1 (0.03)^a	1.9 (0.04)^c	2.0 (0.04)^c

Values are means ($n = 100$) with SE in parentheses. Values with the same superscript letter are not significantly ($p < 0.05$) different between prairies. Fragmentation was qualitatively assessed as 1, none; 2, present; and 3, complete.

area of plants did not differ between the native and 8-year restored prairies. However, it was 80% greater in the 17-year restored prairie and 163% greater in the 23-year restored prairie. Percentage of hollow crowns and fragmentation was smallest in the 8-year restored prairie, largest in the 17- and 23-year restored prairies, and intermediate in the native prairie.

Tiller density exhibited decreases with increasing plant basal area for all restored prairies and the native prairie (Fig. 1). These decreases were best fit with inverse second-order polynomial regression equations. r^2 values were similar between native and 8- and 17-year restored prairies. In contrast to tiller density, diameter of hollow crowns increased with increasing plant basal area in all restored prairies (Fig. 2). These relationships were best fit with logarithmic regression equations. r^2 values were larger compared with those for tiller density. r^2 values were similar for the native prairie and the 8-year restored prairie, with these values greater than those for the 17- and 23-year restored prairies.

Discussion

Structural attributes of *Schizachyrium scoparium* plants in restored Texas Blackland prairies were generally (1) different between recent (8 years) and older (17 and 23 years) restored prairies (2) similar between the 17- and 23-year restored prairies, and (3) more similar between the 8- and 17-year restored prairies and the native, remnant prairie than between the 23-year restored prairie and the native prairie. Plant height, size and occurrence of hollow crowns, and degree of plant fragmentation were greater in older than recently restored prairies (hypothesis 1). In addition, tiller density was lower in older than recently restored prairies (hypothesis 2). Collectively, our findings indicate that this chronosequence of restored prairies with plants of known maximum age did provide an opportunity to estimate age structure of the population of *S. scoparium* plants in the native prairie using the assumption that plant basal area is a surrogate for plant age. These data suggest that the demographic and structural composition of the dominant, perennial grass *S. scoparium* in 8- and 17-year-old restored prairies are similar to native prairies.

High percentages of hollow crowns, large diameters of hollow crowns, and high levels of fragmentation of *S. scoparium* plants in the older restored prairies follow the pattern of architectural development of bunchgrasses. Tiller hierarchies become separated as plants age, and older generations die and decompose within the interior region of the plant (Gatsuk et al. 1980; Olson & Richards 1988). This region (hollow crown) remains decadent because of an accumulation of old culms and limited recruitment of juvenile tillers (Olson & Richards 1988; Briske & Butler 1989) and resource depletion within this interior region (Wan & Sosebee 2000). The pattern of architectural developmental of bunchgrasses could be used to estimate ages of prairie restoration efforts where such information is lacking.

Differences between recent (8 years) and older (17 and 23 years) restored prairies in structural attributes of height, basal area, hollow crown occurrence, and fragmentation of *S. scoparium* plants and the absence of differences in structural attributes between the two older restored prairies suggest that changes in structure slow down and reach a threshold after about 2 decades in the prairies studied. That this threshold is a product of the pattern of architectural development in bunchgrasses is evidenced by structural differences observed between the early reproductive (<10 years) and late reproductive stages (>15 years) of bunchgrasses (Gatsuk et al. 1980). The age of the oldest restored prairie in this investigation (23 years) coincides with the lower limits of maximum plant longevities for bunchgrasses (25–80 years) (Vorontzova & Zaugolnova 1985; Zhukova & Ermakova 1985; Briske & Richards 1995), implying that the oldest plants in this prairie may soon be completely fragmented. Although these data indicate a clear trend in demographic and structural composition of *S. scoparium* plants, it is unknown whether this is manifest in a change in ecosystem processes and function that may have important ramifications to long-term sustainability of prairie restorations. Yet, greater plant heights from the native prairie than in any of the restored prairies does suggest that soil nutrient levels and/or soil moisture relations in the restored prairies are still below pre-cultivated conditions.

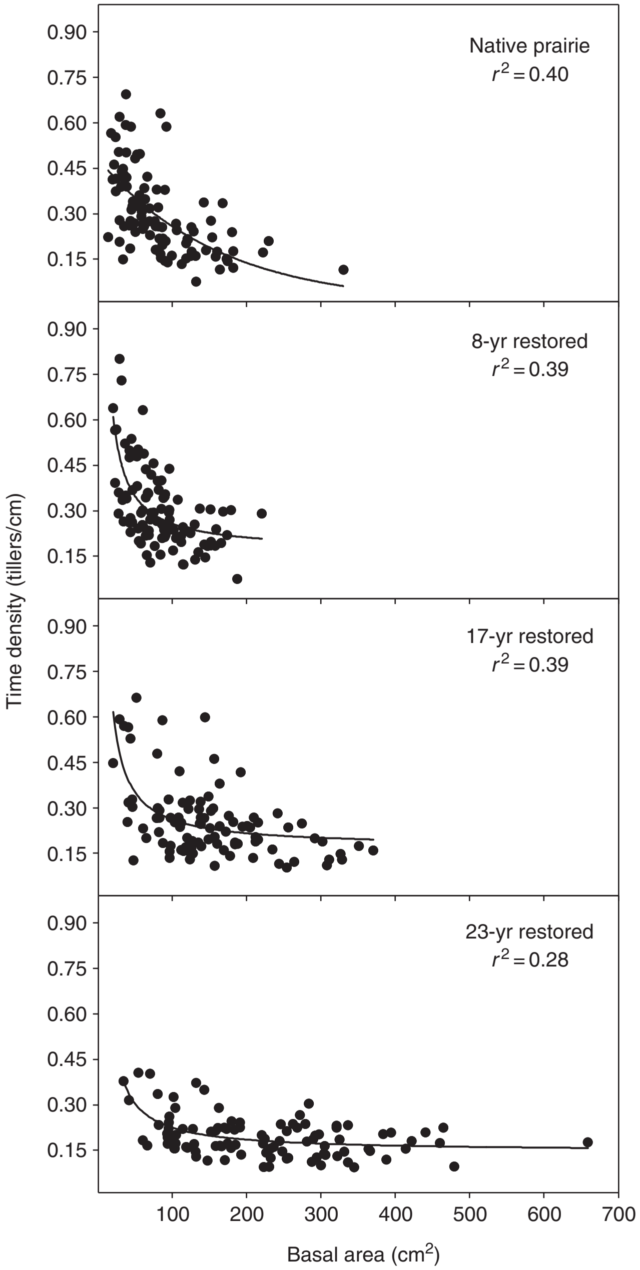

Figure 1. Relationships between tiller density and individual plant basal area of the C_4, perennial, bunchgrass little bluestem in a native tallgrass prairie and three restored prairies differing in time since restoration (8, 17, and 23 years).

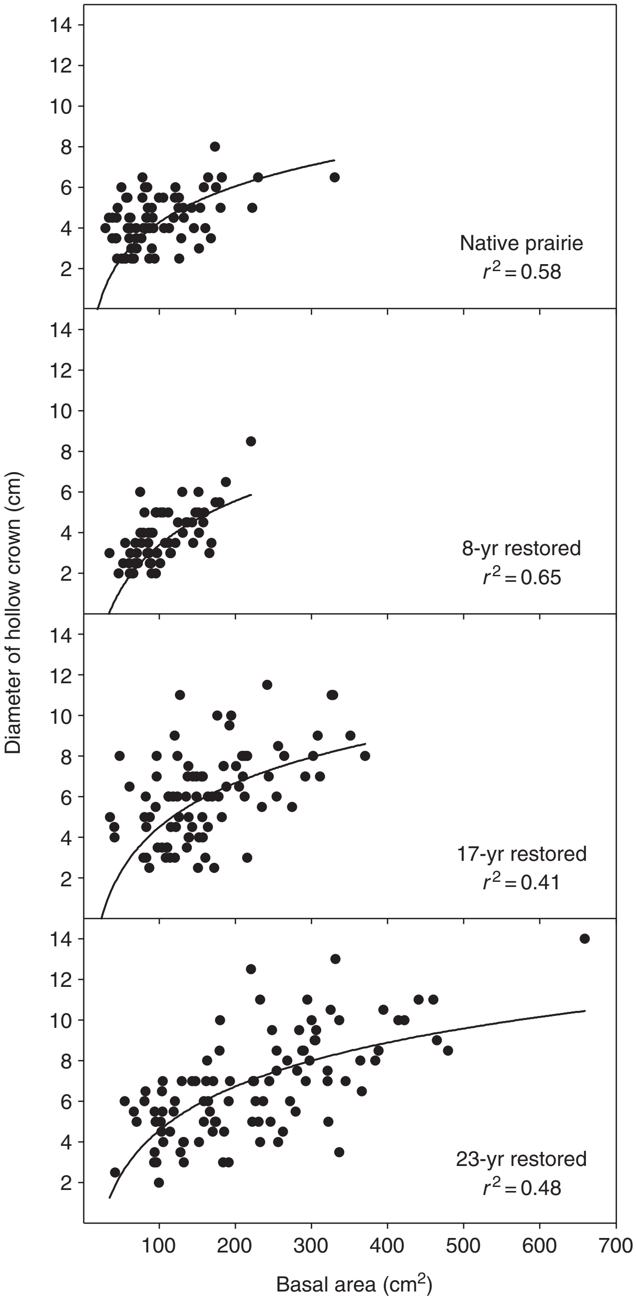

Figure 2. Relationships between diameter of hollow crown and individual plant basal area of the C_4, perennial, bunchgrass little bluestem in a native tallgrass prairie and three restored prairies differing in time since restoration (8, 17, and 23 years).

Existing plants in the native, remnant prairie are probably remaining fragments of formerly large plants because plant fragmentation is a common characteristic in bunchgrasses (Wilhalm 1995). These fragments contribute to genet existence and population maintenance (Lord 1993; Danin & Orshan 1995). However, populations of bunchgrasses may also be maintained by reproduction from seed (Vorontzova & Zaugolnova 1985; Zhukova & Ermakova 1985). Yet, seedling establishment of bunchgrasses is dependent on gap disturbances which reduce the interference of established plants through belowground competition (Aguilera & Lauenroth 1993, 1995) and seed availability and soil moisture (O'Connor 1996). This investigation did not address the contribution of periodic recruitment from seeds in each of these prairies nor the role of recruitment on the demographic and structural composition of *S. scoparium* in these prairies.

Conclusion

Demography and structural composition of *Schizachyrium scoparium* plants were influenced by time since restoration, and these attributes changed predictably with age, despite growing in diverse communities. Structural attributes of *S. scoparium* plants were similar between 8- and 17-year-old restored prairies and the native prairie, but whether plants in the 8- and 17-year-old restored prairies function similarly as those in the native prairie remains unclear. Thus, restoration efforts in Texas Blackland prairie may sufficiently re-establish structural attributes of the dominant species in about a decade, but it is likely that a longer time scale is needed to reach a comparable ecosystem function.

Acknowledgments

We thank K. Tiner, H. Harland, A. Lopez, and J. Corriston for data collection and entry. Mr and Mrs P. Mezynski and A. Abel graciously permitted access to their native and restored prairies.

LITERATURE CITED

Aguilera, M. O., and W. L. Lauenroth. 1993. Seedling establishment in adult neighbourhoods – intraspecific constraints in the regeneration of the bunchgrass *Bouteloua gracilis*. Journal of Ecology **81:**253–261.

Aguilera, M. O., and W. L. Lauenroth. 1995. Influence of gap disturbances and type of microsites on seedling establishment in *Bouteloua gracilis*. Journal of Ecology **83:**87–97.

Anderson, V. J., and D. D. Briske. 1995. Herbivore-induced species replacement in grasslands: is it driven by herbivory tolerance or avoidance? Ecological Applications **5:**1014–1024.

Briske, D. D., and V. J. Anderson. 1990. Tiller dispersion in populations of the bunchgrass *Schizachyrium scoparium*: implications for herbivory tolerance. Oikos **59:**50–56.

Briske, D. D., and J. L. Butler. 1989. Density-dependent regulation of ramet populations within the bunchgrass *Schizachyrium scoparium*: Interclonal vs. intraclonal interference. Journal of Ecology **77:** 963–974.

Briske, D. D., and J. H. Richards. 1995. Plant responses to defoliation: A physiological, morphological, and demographic evaluation. Pages 635–710 in D. J. Budunah and R. E. Sosebee, editors. Wildland plants: physiological ecology and developmental morphology. Society for Range Management, Denver, Colorado.

Danin, A., and G. Orshan. 1995. Circular arrangement of *Stipagrostis ciliata* clumps in the Negev, Israel and near Gokaeb, Namibia. Journal of Arid Environments **30:**307–313.

Derner, J. D., and D. D. Briske. 1998. An isotopic (^{15}N) assessment of intraclonal regulation in C_4, perennial grasses: ramet interdependence, independence or both? Journal of Ecology **86:**305–314.

Derner, J. D., and D. D. Briske. 1999. Intraclonal regulation in a perennial caespitose grass: a field evaluation of above- and below-ground resource availability. Journal of Ecology **87:**737–747.

Gatsuk, L. E., O. V. Smirnova, L. I. Vorontzova, L. B. Zaugolnova, and L. A. Zhukova. 1980. Age states of plants of various growth forms: a review. Journal of Ecology **68:**675–696.

Lord, J. M. 1993. Does clonal fragmentation contribute to recruitment in *Festuca novae-zelandiae*? New Zealand Journal of Botany **31:** 133–138.

O'Connor, T. G. 1996. Hierarchical control over seedling recruitment of the bunch-grass *Themeda triandra* in a semi-arid savanna. Journal of Applied Ecology **33:**1094–1106.

Olson, B. E., and J. H. Richards. 1988. Spatial arrangement of tiller replacement in *Agropyron desertorum* following grazing. Oecologia **76:**7–10.

Pfeiffer, K. E., and D. C. Hartnett. 1995. Bison selectivity and grazing response of little bluestem in tallgrass prairie. Journal of Range Management **48:**26–31.

Riskind, D. H., and O. B. Collins. 1975. The Blackland prairie of Texas: conservation of representative climax remnants. Pages 361–367 in M. K. Wali, editor. Prairie: a multiple view. University of North Dakota Press, Grand Forks.

SAS Institute Inc. 1994. SAS/STAT User's guide. Release 6.03. 4th edition. SAS Institute, Inc, Cary, NC.

Vorontzova, L. I., and L. B. Zaugolnova. 1985. Population biology of steppe plants. Pages 143–178 in J. White, editor. The population structure of vegetation. Dr. W. Junk Publishers, Dordrecht, The Netherlands.

Wan, C. G., and R. E. Sosebee. 2000. Central dieback of the dryland bunchgrass *Eragrostis curvula* (weeping lovegrass) re-examined: The experimental clearance of tussock centers. Journal of Arid Environments **46:**69–78.

Welker, J. M., D. D. Briske, and R. W. Weaver. 1991. Intraclonal nitrogen allocation in the bunchgrass *Schizachyrium scoparium*: an assessment of the physiological individual. Functional Ecology **5:**433–440.

Wilhalm, T. 1995. A comparative study of clonal fragmentation in tussock-forming grasses. Page 19 in B. Oborny and J. Podani, editor. Clonality in plant communities. Proceedings of the 4th International Workshop on Clonal Plants, Visegrad, Hungary, 18–22 April, 1995.

Williams, D. G., and D. D. Briske. 1991. Size and ecological significance of the physiological individual in the bunchgrass *Schizachyrium scoparium*. Oikos **62:**41–47.

Zhukova, L. A., and I. M. Ermakova. 1985. Structure and dynamics of coenopopulations of some temperate grasses. Pages 179–205 in J. White, editor. The population structure of vegetation. Dr. W. Junk Publishers, Dordrecht, The Netherlands.