Research Note

Growth of Chickasaw Plum in Oklahoma

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Abstract

Management of rangelands for wildlife and livestock entails understanding growth of clonal shrubs such as Chickasaw plum (*Prunus angustifolia* Marsh.). We studied growth of this species in one county in north-central (Payne) and two counties in northwestern Oklahoma (Ellis, Harper) during 2006 and 2007. We estimated age of stems and roots by growth rings and area of stands with the use of a handheld GPS unit. Based on zero-intercept regression models, stands grew at similar rates (overlapping 95% confidence intervals [CIs]) among counties with a pooled estimate of 31.0 $m^2 \cdot yr^{-1}$ (95% CI = 26.5–35.6 $m^2 \cdot yr^{-1}$; $n = 95$). This rate showed considerable variability within and among study sites ($r = 0.52$). Stem diameter increased (zero-intercept models) more rapidly in north-central Oklahoma (5.27 $mm \cdot yr^{-1}$; 95% CI = 5.01–5.53 $mm \cdot yr^{-1}$; $r = 0.90$; $n = 53$) than in northwestern Oklahoma (3.68 $mm \cdot yr^{-1}$; 95% CI = 3.55–3.81 $mm \cdot yr^{-1}$; $r = 0.91$; $n = 102$); data were pooled because of similar rates in Ellis and Harper counties. Stem height was a power function of stem age ($y = 0.97x^{0.28}$; $r = 0.56$), indicating rate of growth in height ($m \cdot yr^{-1}$) declined with age according to $dy/dx = 0.27x^{-0.72}$. Knowledge of the area expansion rate of Chickasaw plum clones aids in management planning to increase or decrease canopy coverage by this shrub.

Resumen

El manejo de pastizales para la fauna silvestre y el ganado requiere conocimiento sobre el crecimiento de arbustos que crecen en forma agregada tales como el ciruelo Chickasaw (*Prunus angustifolia* Marsh.). Durante 2006–2007 estudiamos el crecimiento de esta especie en un condado en el norte (Payne) y dos condados en el noroeste de Oklahoma (Ellis, Harper). Estimamos la edad de ramas y raíces utilizando los anillos de crecimiento y medimos el área de matorral utilizando un equipo de GPS de mano. Basado sobre los modelos de regresión de cero intercepto, los matorrales crecieron a tasas similares entre condados con una tasa conjunta de 31.0 $m^2 \cdot año^{-1}$ (95% IC = 26.5–35.6 $m^2 \cdot año^{-1}$; $n = 95$). Esta tasa mostró gran variabilidad dentro y entre los sitios de estudio ($r = 0.52$). El diámetro de las ramas incrementó mas rápido en el norte de Oklahoma (5.27 $mm \cdot año^{-1}$; 95% CI = 5.01–5.53 $mm \cdot año^{-1}$; $r = 0.90$; $n = 53$) que en la parte noroeste del estado (3.68 $mm \cdot año^{-1}$; 95% CI = 3.55–3.81 $mm \cdot año^{-1}$; $r = 0.91$; $n = 102$; datos conjuntos debido a tasas similares en los condados de Ellis y Harper). La altura de las ramas estaba en función de su edad ($y = 0.97x^{0.28}$; $r = 0.56$), indicando que la tasa de crecimiento en altura ($m \cdot año^{-1}$) disminuía con la edad de acuerdo a $dy/dx = 0.27x^{-0.72}$. El conocimiento de la tasa de expansión de los clones de ciruelo ayuda en la planificación del manejo para incrementar o disminuir la cobertura de este arbusto.

Key Words: clonal shrubs, growth models, *Prunus angustifolia* Marsh., shrub expansion, wildlife habitat

INTRODUCTION

The rate of clonal expansion of shrub thickets in rangelands is an important consideration regarding management of wildlife habitat and livestock forage as well as efforts to restore or preserve desired ecosystems. An increase in the area of shrub thicket may be beneficial to wildlife populations, but will decrease forage for livestock because the shade cast by the shrubs reduces herbaceous growth, and thickets restrict access by livestock. Although previous studies documented lineal expansion rates of individual clones (Duncan 1935; Barnes 1966; Gilbert 1966; Petranka and McPherson 1979; Mayes et al. 1998), attempts to quantify area expansion rates are lacking. Also, scant information is available regarding basic biology of clonal shrubs including Chickasaw plum (*Prunus angustifolia* Marsh.; hereafter, plum) which occurs from Florida north to Tennessee and west to western Texas, Oklahoma, and Kansas (Little 1977).

In rangelands of Oklahoma, Texas, and Kansas, plum provides important wildlife habitat (Guthery et al. 2005). For example, we have observed 43 species of birds associated with plum, with 23 of these species using the shrub for nesting, foraging, or cover. We have observed two passerines of numerical concern, painted buntings (*Passerina ciris* L.) and Bell's vireos (*Vireo bellii* Audubon), nesting in plum. Also, the threatened lesser prairie-chicken (*Tympanuchus pallidicinctus* Ridgway) uses plum for resting, roosting, and escape cover (Donaldson 1969).

Knowledge of expansion rate of clones and growth rate of stems and roots within clones would assist in management planning. Managers could use the knowledge to anticipate

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future landscapes and plan for an increase or decrease of plum, depending on objectives. Here, we developed models using ages of roots and stems to predict area of stands, diameter of roots and stems, and height of stems. In addition, we modeled the relationship between stem diameter and stem height. Finally, we compared root and stem ages to provide information on frequency of top-killed stems.

METHODS

Study Areas

We sampled during winter 2006/2007 on private properties in three Oklahoma counties: Payne (lat 36°13′N, long 97°6′W; 84 ha), Harper (36°47′N, 99°27′W; 5 667 ha), and Ellis (lat 36°21′N, long 99°42′W; 4 856 ha). Primary land uses on all sites were hunting and cattle grazing. From west (Ellis) to east (Payne) annual precipitation ranged from 52 cm to 97 cm, mean minimum January temperatures from -5°C to -6°C, and mean maximum July temperatures from 33°C to 34°C (Woods et al. 2005). Soils were moderately deep, well drained, and moderately to very slowly permeable loams in Payne County (Henley et al. 1987); well drained, moderately permeable, shallow to moderately deep sandy loam in Harper County (Nance et al. 1960); and very deep, well-drained, rapidly permeable, fine sandy loam in Ellis County (Cole et al. 1966). Vegetation in Payne County was dominated by little bluestem (*Schizachyrium scoparium* Michx.) (nomenclature follows Gould 1975) with islands of plum, roughleaf dogwood (*Cornus drummondi* G. Meyer), smooth sumac (*Rhus glabra* L.), and flameleaf sumac (*Rhus copallina* L.). Mixed-grass prairie of little bluestem, sideoats grama (*Bouteloua curtipendula* [Michx.] Torr.), blue grama (*Bouteloua gracilis* [Willd. ex H.B.K.] Lag.), and sand sagebrush (*Artemisia filifolia* Torr.) with patches of plum in uplands characterized the Harper County site. The upland vegetation in Ellis County was dominated by lower successional grasses, e.g., three-awn (*Aristida* sp. L.), sand dropseed (*Sporobolus cryptandrus* [Torr.] A. Gray), and tumble windmill grass (*Chloris verticillata* Nutt.) in a matrix of little bluestem, sand sagebrush, and plum.

Sampling and Measurement

We sampled 33 (Payne), 30 (Harper), and 32 (Ellis) stands ranging in size from 29 m^2 to 1 774 m^2 to model stand area as a function of stand age. We chose a range in stand sizes to capture variation in stand ages (initial assumption that stand area increases with stand age). To estimate stand age, we selected the presumptive oldest stem in a stand, i.e., that with the greatest diameter and height (Gilbert 1966; Reinartz and Popp 1987), as the basis for age-based modeling of area. The oldest stem and attached root were removed with a sharpshooter spade and lopping shears.

Because our sampling protocol (oldest stem) resulted in underrepresentation of younger stems, we arbitrarily selected four additional plum stands on each site. From each of these stands, we collected five stems and attached roots for the following ground-line diameter (cm) size classes: <1, 1–<2,…,4–<5. Thus, we had an additional 20 samples per site for modeling diameter and height as a function of age but these additional samples were not used in modeling stand area as a function of age.

All stem and root samples were cross-sectioned, air dried, and sequentially sanded with abrasive grits ranging from 201 μm to 15 μm (Asherin and Mata 2001). We counted annual growth rings with the use of a dissection microscope and verified through cross-dating (Douglass 1941; Stokes and Smiley 1996). We used a staida rod to measure heights of stems and dial calipers to measure diameters (stems, roots) in the field. We measured diameter of stems at ground level and diameter of roots at their junction with a stem (Phipps 1985; Bar et al. 2006). We assumed past disturbance explained root age exceeding stem age for a particular ramet.

To estimate area, we defined a plum stand as an aggregate of stems originating from a parent plant. If ≥ 2 stands were in close proximity, a single stand was defined as a continuous aggregation of stems with a distance <1 m between stems. We estimated area of a stand with the use of a Garmin Etrex Legend® (Garmin International, Olathe, Kansas, USA) handheld Global Positioning System (GPS) unit. The manufacturer reports accuracy with wide-area augmentation enabled to be ≤ 3 m. The perimeter of each stand was delineated three times and each time an area was estimated. We used the average of the three estimates for modeling. The interval used to record locations was 1 s. As an accuracy check, we used Geographic Information System (GIS) analysis to estimate area of stands $>100\ m^2$ ($n = 49$) from aerial photographs taken in 2006. Areas measured with GPS units and GIS analysis were strongly correlated ($r = 0.98$; S. W. Dunkin, unpublished data, 2007), suggesting the averaged GPS estimates were acceptable.

Statistical Analyses

We planned to evaluate plum growth by testing the data against established growth models. However, simplicity of the data indicated this approach would unnecessarily complicate results. We therefore used the linear, zero-intercept model ($y = bx$) or the curvilinear power model ($y = ax^b$) to model growth, as appropriate. We pooled data if the 95% CIs for the parameter b overlapped between or among sites. The 95% CIs for all reported regression coefficients (b) did not overlap 0.0. Thus, we reported results at the traditional $P < 0.05$.

RESULTS

Estimated ages of stems and attached roots were strongly correlated ($r = 0.95$, $n = 155$; Fig. 1). For a zero-intercept model, stem age increased 0.95 yr (95% CI = 0.93–0.97 yr) for each $1-y$ increase in root age. Estimates were identical for 82 samples, stem age was less than root age for 66 samples, and stem age was greater than root age for 7 samples. Results indicated that 42.6% ± 4.4 SE ($n = 155$) of the pooled sample had experienced past aboveground disturbance that resulted in top kill. Stem age was less than root age for 57% ± 6.9 SE ($n = 53$) of the sample for Payne County, 44% ± 6.9 SE ($n = 52$) for Ellis County, and 26% ± 6.2 SE ($n = 50$) for Harper County.

Use of root age or stem age to predict stand area yielded similar results based on overlapping 95% CIs of growth rates (Table 1). Likewise, 95% CIs overlapped among study sites.

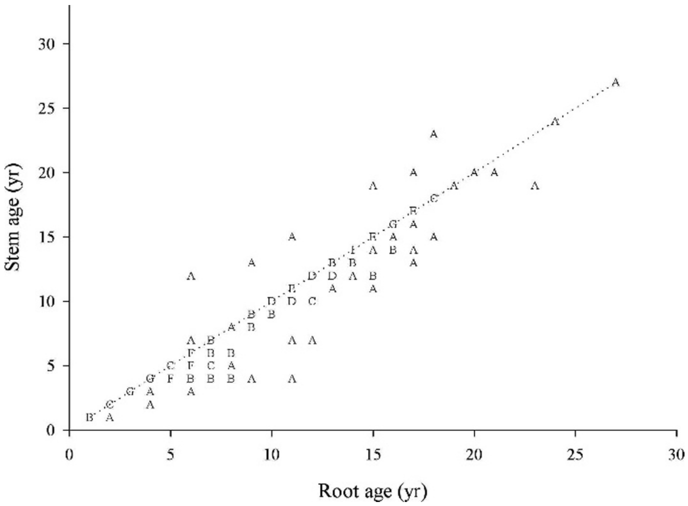

Figure 1. Relationship between root age and stem age for Chickasaw plum on three study sites in Oklahoma, 2006–2007 ($n = 155$). Letters correspond to the numerical frequency of data points where **A** = 1, **B** = 2, **C** = 3,…. The dotted line corresponds to the 1:1 relationship between root age and stem age.

The pooled estimate of annual growth rate (regression coefficient) based on root age was 31.0 $m^2 \cdot yr^{-1}$ (95% CI = 26.5–35.6 $m^2 \cdot yr^{-1}$; Fig. 2A). For stands apparently not experiencing previous top kill (stem age = root age, $n = 47$ for samples with area measurements), growth rate was 33.2 $m^2 \cdot yr^{-1}$ (95% CI = 26.3–40.1 $m^2 \cdot yr^{-1}$, $r = 0.49$). Apparently disturbed stands (stem age < root age, $n = 43$ for samples with area measurements) grew at 24.9 $m^2 \cdot yr^{-1}$ based on root age (95% CI = 20.2–29.6 $m^2 \cdot yr^{-1}$, $r = 0.60$). We observed considerable variability in growth rates within and among study sites.

Root diameter as a function of root age varied among study sites (Fig. 2B). The growth rate was 4.56 $mm \cdot yr^{-1}$ (95% CI = 4.20–4.92 $mm \cdot yr^{-1}$) in Payne County, 3.54 $mm \cdot yr^{-1}$ (95% CI = 3.26–3.82 $mm \cdot yr^{-1}$) in Ellis County, and 2.92 $mm \cdot yr^{-1}$ (95% CI = 2.63–3.21 $mm \cdot yr^{-1}$) in Harper County. Zero-intercept models explained between 52% and 67% of variation in root diameter.

Stem diameter increased more rapidly in Payne County (5.27 $mm \cdot yr^{-1}$; 95% CI = 5.01–5.53 $mm \cdot yr^{-1}$; Fig. 2C) than in Harper and Ellis counties pooled (3.68 $mm \cdot yr^{-1}$; 95% CI = 3.55–3.81 $mm \cdot yr^{-1}$). These relations were relatively strong with $r \geq 0.90$ so stem diameter was a good predictor of age of stands, given that the oldest stem in a stand was identified. For Payne County, age in years (x) was predicted by stem diameter (y; mm) as $x = 0.18y$ ($n = 53$; 95% CI on coefficient = 0.17–0.19; $r = 0.87$). The formula was $x = 0.26y$ for Harper and Ellis counties ($n = 102$; 95% CI on coefficient = 0.25–0.27; $r = 0.90$).

Stem height was a power function of stem age for pooled data (Fig. 2D). The derivative of the function, $dy/dx = 0.27x^{-0.72}$, gives the estimated growth rate at a specified age. For example, growth rate at 10 yr would be estimated at $0.27(10^{-0.72}) = 0.05$ $m \cdot yr^{-1}$. Likewise, stem height was a power function of stem diameter (Fig. 2E).

DISCUSSION

The linear relationship between root age and stand area that fit data from three different sites indicated that clones expanded at a constant rate and simplified predictions of plum growth in central and western Oklahoma. An alternative to constant area growth rate is constant radial expansion and resultant quadratic increases in area. Constant area growth indicates either asymmetric expansion or a biological constraint, such as water or nutrient uptake, which prevents quadratic growth. The number of new smooth sumac ramets produced per year (a surrogate for area) increased from one (initial stem) to a maximum in about 5 yr, after which the number of new ramets fluctuated or decreased (Gilbert 1966).

We observed substantial unexplained variation in the relationship between stand area and root age (Table 1). Potential sources of variation included intensity of interspecific competition (Peltzer 2002), small-scale differences in nutrient and water availability, genetics, and disturbance. We assumed that stands originated from expansion of one clone. If, as in some other species, several clones intermix (Mayes et al. 1998; Torimaru and Tomaru 2005), we overestimated stand area. However, clonal species that exhibit patterns of stand expansion and decreasing ramet height near the periphery, as plum, form pure clones (Gilbert 1966; Reinartz and Popp 1987; Li et al. 1999).

Most occurrences where stem age was less than root age probably indicated disturbance such as fire or herbivory, resulting in top kill and resprouting. Based on the largest measured difference between stem age and root age, plum maintained the ability to resprout at least through age 5–7. Some differences between root and stem age could have resulted from measurement error. Disturbance (as indicated by stem age < root age) decreased the estimated stand expansion rate by 8.3 $m^2 \cdot yr^{-1}$, but segregating data into disturbed and undisturbed stands did not explain further variation in stand expansion based on root age. Fire causes differences between root and stem age (Guerin 1993) and is a common disturbance for plum in our study area. Fire has a null or stimulatory effect on plum stem density (Adams et al. 1982). Besides fire, herbivory is a probable disturbance. However, the foliage is low-preference browse for white-tailed deer (Gee et al. 1994; Miller and Miller 1999).

Table 1. Regression analyses (b = slope of zero-intercept model in $m^2 \cdot yr^{-1}$ with 95% CIs) of the area (m^2) of Chickasaw plum stands as a function of stem and root age (y) on three study sites in Oklahoma, 2006–2007 (LCI = lower confidence interval, UCI = upper confidence interval).

	Payne				Ellis				Harper			
Independent variable	*b*	LCI	UCI	*r*	*b*	LCI	UCI	*r*	*b*	LCI	UCI	*r*
Root age	24.9	18.6	31.2	0.42	31.1	23.4	38.9	0.40	32.4	23.3	41.6	0.24
Stem age	31.4	23.9	38.9	0.49	32.9	25.3	40.6	0.49	31.9	22.8	41.0	0.20

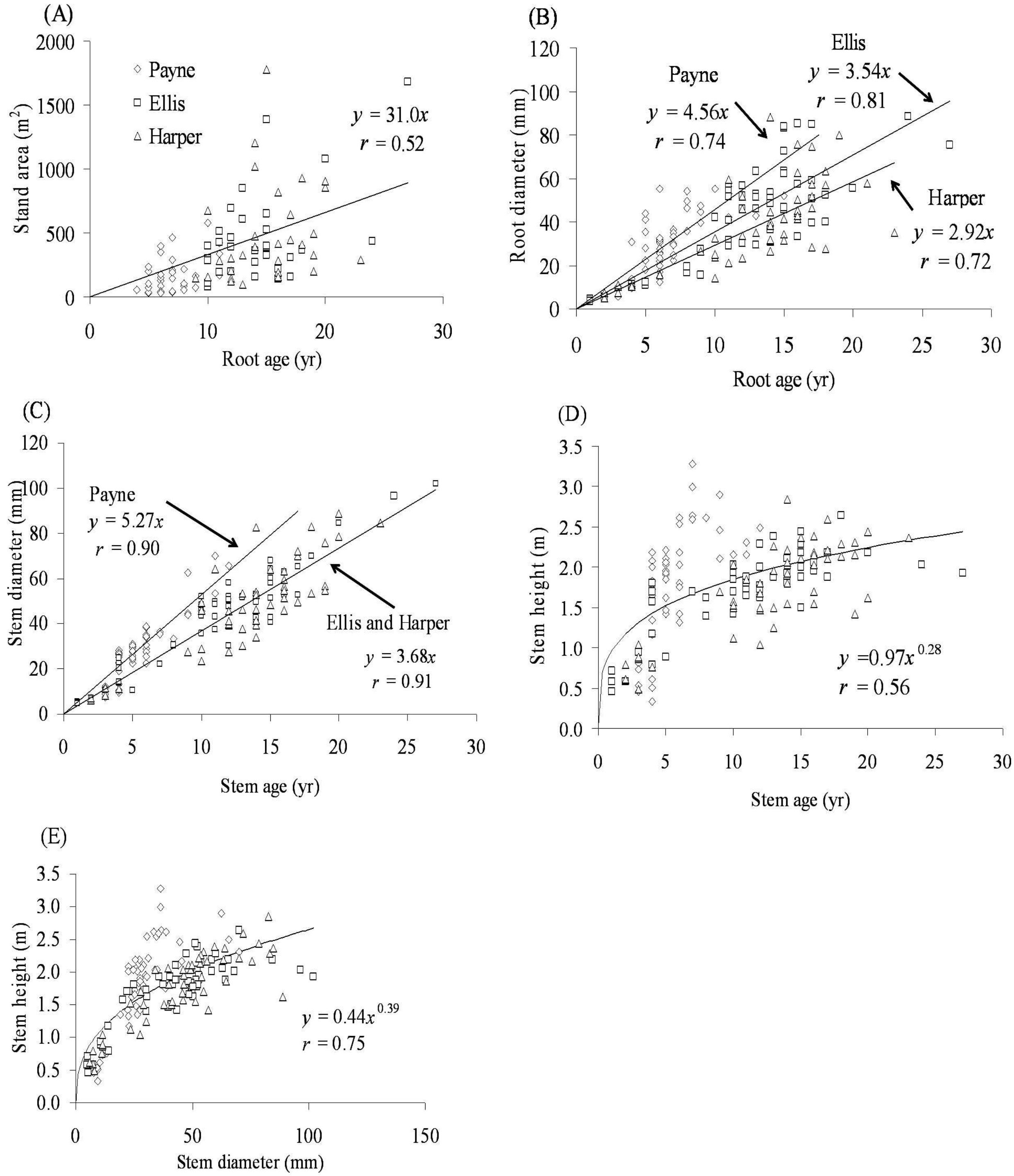

Figure 2. Growth models for Chickasaw plum on three study sites in Oklahoma, 2006–2007. **A**, Stand area as a function of root age ($n = 95$). **B**, Root diameter as a function of root age ($n = 155$). **C**, Stem diameter as a function of stem age ($n = 155$). **D**, Stem height as a function of stem age ($n = 155$). **E**, Stem height as a function of stem diameter ($n = 155$).

Except for Barnes (1966), who reported an expansion rate of 306 $m^2 \cdot yr^{-1}$ for aspen clones (*Populus* sp.) in Michigan, we are not aware of studies that measured clone area. Converting previously reported lineal growth rates to area expansion is not possible because of either irregular shapes of individual clones (Gilbert 1966) or because clone diameters were not reported. For comparative purposes, if one were to assume stands of plum spread in a circular pattern, diameter expansion in our study ranged from 1.34 $m \cdot yr^{-1}$ for a 155-m^2, 5-yr-old stand to 0.62 $m \cdot yr^{-1}$ for a 775-m^2, 25-yr-old stand. In comparison, flameleaf sumac expanded by 0.46 and 2.5 $m \cdot yr^{-1}$ (Duncan 1935; Gilbert 1966; Petranka and McPherson 1979), bigtooth aspen (*P. grandidentata* Michx.) by 1 $m \cdot yr^{-1}$ (Duncan 1935), sassafras (*Sassafras albidum* [Nutt.] Nees) by 0.73 $m \cdot yr^{-1}$ (Duncan 1935), and Havard oak (*Quercus havardii* Rydb.) by rates ≤ 15 $m \cdot yr^{-1}$ (Mayes et al. 1998).

MANAGEMENT IMPLICATIONS

Our results can be used in planning the management of plum on rangelands to meet wildlife and livestock objectives. Estimates of area expansion rates can be used to predict future canopy coverage by plum on a particular site, recognizing that area (m^2) growth is quite variable (Fig. 2A). These predictions have the potential to identify time frames for 1) a maximum expected wildlife response, 2) threshold canopy coverages for species such as grassland birds, and 3) canopy coverage for optimal livestock forage production.

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LITERATURE CITED

Adams, D. E., R. C. Anderson, and S. L. Collins. 1982. Differential response of woody and herbaceous species to summer and winter burning in an Oklahoma grassland. *The Southwestern Naturalist* 27:55–61.

Asherin, L. A., and S. A. Mata. 2001. Basic tree-ring sample preparation techniques for aging Aspen. Washington, DC, USA: US Forest Service Proceedings RMRS-P-18. 7 p.

Bar, A., A. Braun, and J. Loftier. 2006. Dendroecology of dwarf shrubs in the high mountains of Norway—a methodological approach. *Dendrochronologia* 24:17–27.

Barnes, B. V. 1966. The clonal growth habit of American aspens. *Ecology* 47:439–447.

Cole, E. L., A. J. Conradi, and C. E. Rhoads. 1966. Soil survey of Ellis County, Oklahoma. Washington, DC, USA: USDA Soil Conservation Service Series 38. 81 p.

Donaldson, D. D. 1969. Effects on lesser-prairie chickens on brush control in western Oklahoma [dissertation]. Stillwater, OK, USA: Oklahoma State University. 79 p.

Douglass, A. E. 1941. Crossdating in dendrochronology. *Journal of Forestry* 39:825–831.

Duncan, W. H. 1935. Root systems of woody plants of old fields of Indiana. *Ecology* 16:554–567.

Gee, K. L., M. D. Porter, S. Demarais, F. C. Bryant, and G. Van Vreede. 1994. White-tailed deer: their foods and management in the Cross Timbers. 2nd ed. Ardmore, OK, USA: Samuel Roberts Noble Foundation Publications. 370 p.

Gilbert, E. F. 1966. Structure and development of sumac clones. *American Midland Naturalist* 75:432–445.

Gould, F. W. 1975. Texas plants: a checklist and ecological summary. College Station, TX, USA: Texas Agricultural Experiment Station. Miscellaneous Publication 585 rev. 121 p.

Guerin, D. N. 1993. Oak dome clonal structure and fire ecology in a Florida longleaf pine dominated community. *Bulletin of the Torrey Botanical Club* 120:107–114.

Guthery, F. S., A. R. Rybak, S. D. Fuhlendorf, T. L. Hiller, S. G. Smith, W. H. Puckett, Jr., and R. A. Baker. 2005. Aspects of the thermal ecology of bobwhites in north Texas. *Wildlife Monographs* 159:1–36.

Henley, J., R. D. Gelnar, and R. E. Mayhugh. 1987. Soil survey of Payne County, Oklahoma. Washington, DC, USA: USDA Soil Conservation Service. 268 p.

Li, X., J. M. Baskin, and C. C. Baskin. 1999. Contrasting soil seed-bank dynamics in relation to local modes in two clonal shrubs, *Rhus aromatica* Ait. and *R. glabra* L. *American Midland Naturalist* 142:266–280.

Little, E. L., Jr. 1977. Atlas of United States trees, minor Eastern hardwoods. Volume 4. Washington, DC, USA: US Department of Agriculture. Miscellaneous Publication 1342. 247 p.

Mayes, S. G., M. A. McGinley, and C. R. Werth. 1998. Clonal population structure and genetic variation in sand-shinnery oak, *Quercus havardii* (Fagaceae). *American Journal of Botany* 85:1609–1617.

Miller, J. H., and K. V. Miller. 1999. Forest plants of the Southeast and their wildlife uses. Auburn, AL, USA: Southern Weed Science Society. 454 p.

Nance, E. C., J. D. Nichols, H. L. Kollmorgen, R. E. Daniell, H. L. Costilow, and K. T. Lofton. 1960. Soil survey of Harper County, Oklahoma. Washington, DC, USA: USDA Soil Conservation Service Series 8. 59 p.

Peltzer, D. A. 2002. Does clonal integration improve competitive ability? A test using aspen (*Populus tremuloides* [Salicaceae]) invasion into prairie. *American Journal of Botany* 89:494–499.

Petranka, J. W., and J. K. McPherson. 1979. The role of *Rhus copallina* in the dynamics of forest-prairie ecotone in north-central Oklahoma. *Ecology* 60:956–965.

Phipps, R. L. 1985. Collecting, preparing, crossdating, and measuring tree increment cores. Washington, DC, USA: US Geological Survey, Denver, Colorado, USA. Report 85–4148. 48 p.

Reinartz, J. A., and J. W. Popp. 1987. Structure of clones of northern prickly ash (*Xanthoxylum americanum*). *American Journal of Botany* 74:415–428.

Stokes, M. A., and T. L. Smiley. 1996. An introduction to tree ring dating. Chicago, IL, USA: University of Chicago Press. 73 p.

Torimaru, T., and N. Tomaru. 2005. Fine-scale clonal structure and diversity within patches of a clone-forming dioecious shrub, *Ilex leucoclada* (Aquifoliaceae). *Annals of Botany* 95:295–304.

Woods, A. J., J. M. Omernik, D. R. Butler, J. G. Ford, J. E. Heney, B. W. Hoagland, D. S. Arndt, and B. C. Morgan. 2005. Ecoregions of Oklahoma. Reston, VA, USA: US Geological Survey. 2 p.