

DIRECT EFFECTS OF COMPETITION ON INDIVIDUAL JUNIPER PLANTS: A FIELD STUDY

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SUMMARY

(1) Two hundred and forty *Juniperus pinchotii* plants were harvested on each of two sites in western Texas.

(2) The competitive influence of herbs and shrubs associated with each juniper plant was quantified in an attempt to explain variability in survival and regrowth of individual coppiced plants.

(3) Survival and regrowth were greater on the deep-soiled Rolling Plains site than on the shallow-soiled High Plains site.

(4) Pre-harvest age or size largely controlled survival and subsequent regrowth of coppiced *Juniperus pinchotii* plants.

(5) Competition from neighbouring shrubs, though significant, explained little of the observed variation in survival or growth. Competition was most common during periods of active *Juniperus* growth. Competitive influence decreased with increasing distance, but not in a linear manner.

(6) Competition from herbaceous plants was not detected.

INTRODUCTION

Most studies addressing plant competition in semi-arid regions have investigated spatial pattern, with the hypothesis that competition will convert clumped distributions of plants into random, and eventually, regular ones (Fowler 1986b). Few studies have examined direct effects of competition on individual plants, despite the fact that problems associated with inferring competition from spatial arrangements (Ebert & McMaster 1981; Fowler 1984, 1986b; Silander & Pacala 1985) indicate a need for studies which address direct effects of competition on individual plant performance.

The objective of this study was to determine the effect of competing vegetation on survival and growth of a woodland conifer. Competitive status was evaluated for a range of size-classes of several shrub species in a field study. Nearly all field studies of direct interference have been conducted in even-aged woodlands or forests and have ignored the influence of tree size on competitive ability (e.g. Weiner 1984). Cannell, Kothery & Ford (1984) showed that competitive status of individuals was related to tree height in even-aged monocultures of two tree species. Wu *et al.* (1985) extended the concept of size-related regions of influence to natural stands of vegetation. Penridge & Walker (1986) found that a competition model which included plant size predicted growth better than nearest-neighbour distance or Weiner's interference model.

Juniperus pinchotii Sudw., a sprouting evergreen conifer commonly found on limestone and gypsum soils (Correll & Johnston 1970), was selected for this study because of its ability to sprout basally following top removal (Vines 1960). Its resprouting ability is related to the position of the stem bud zone, a region of meristematic tissue near the base of the tree. The bud zone becomes buried with the passage of time as soil and plant

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material accumulate around the plant stem. Burial rate varies between sites and is related to tree age, canopy development, slope, soil depth, and soil surface stability (Steuter & Britton 1983). Additionally, we hypothesize that juniper survival and growth is dependent on the intensity of competition to which individual juniper plants are exposed. Hence, if other factors affecting juniper survival and growth are isolated (via stepwise regression or discriminant analysis), then response of this species serves as a bioassay, presumably reflecting differences in competitive success of neighbouring plants.

MATERIAL AND METHODS

Study areas

Two sites (described by McPherson, Wright & Wester 1988) were selected for this study. The first was situated 11 km north of Snyder, Scurry County, in the Rolling Plains of western Texas, and had light and continuous grazing. *Juniperus pinchotii* stands selected were located on relatively deep clay and clay-loam soils underlain by indurated caliche, shale, and/or fractured sandstone (McPherson, Wright & Wester 1988). Previous history included mechanical control of woody plants (tree-dozing) in the 1960s. Dominant herbaceous species included *Bouteloua curtipendula*, *Stipa leucotricha*, *Trichachne californica*, *Chloris* spp., and *Schedonnardus paniculatus* (nomenclature follows Correll & Johnston 1970). Common woody species included *Prosopis glandulosa*, *Acacia Greggii*, *Opuntia leptocaulis*, *O. phaeacantha*, *O. imbricata*, *Mimosa biuncifera*, *Yucca angustifolia*, and *Ziziphus obtusifolia*. Average annual precipitation is 518 mm (Dixon, Dittmore & Hyde 1973).

The second site was on the Llano Estacado (Texas High Plains) 33 km north-west of Snyder in Borden County. It had a history of heavy and continuous cattle grazing, but had not been grazed during the 2 years preceding the current study. It is characterized by shallow clay-loam soils underlain by indurated caliche (Dixon 1975). Herbaceous dominants included *Aristida* spp., *Buchloe dactyloides*, and several species of perennial forbs. *Prosopis glandulosa* and *Opuntia phaeacantha* were common. Average annual precipitation is 472 mm (Dixon 1975). The site is relatively unproductive compared to the Rolling Plains site (McPherson, Wright & Wester 1988).

Experimental procedures

In general, experimental procedures were performed as follows: (i) *Juniperus pinchotii* trees were selected, described with respect to size and age, and harvested; (ii) competition facing individual trees was characterized for herbs and woody plants; (iii) juniper survival and growth rate were recorded every 2 months. Subsequent analyses attempted to determine the importance of pre-harvest tree characteristics, competition, and environmental factors on juniper survival and growth. Specific procedures are detailed below.

Twenty trees per site were randomly selected every 2 months between September 1984 and August 1986. Height and crown diameter (major and minor axes) were measured to the nearest centimetre. Crown volume, V (cm^3), was calculated as if the tree were an oblate spheroid (Phillips & MacMahon 1981), as $\pi a^2 b/6$, where a = minor axis (cm) (height or average diameter, whichever is smaller), and b = major axis (cm) (height or average diameter, whichever is larger). Two measurements of stem diameter of the main stem were taken at right angles with calipers. Stem diameter was measured within 5 cm of ground level to the nearest 0.1 cm. Trees were removed as near as possible to ground level with a bow or chain saw. Basal diameter (major and minor axes) was recorded, and basal area

calculated as if the stump were an ellipse (Husch, Miller & Beers 1972). A cross-sectional sample was removed and aged by tree-ring analysis (Glock 1937).

Vegetation surrounding each *Juniperus* tree was sampled during the growing season following tree removal. Herbaceous vegetation was sampled by placing thirty inclined 10-point sampling frames (Levy & Madden 1933) at random within 2.5 m of each harvested juniper. Each pin contact was recorded for plant species, bare ground, or litter. An arcsine transformation (Steel & Torrie 1980) was used to transform basal cover of herbaceous vegetation prior to analyses. Distance from the harvested juniper, height, crown dimensions, stem diameter, and number of stems were recorded for each woody plant within 3 m of the harvested juniper. Since large plants usually have a larger zone of influence than small plants, shrubs taller than 2 m were sampled out to 6 m from the harvested juniper.

Several indices were derived to reflect shrub competition around each harvested juniper plant. If present, competitive influence of a plant decreases with increasing distance from competitors; therefore, a measure of distance from the harvested juniper plant served as the denominator for all indices. Since competitive influence may not decrease linearly with distance, squared (cm^2) and cubed (cm^3) distance and the natural log of distance also were used as denominators in indices. Numerators included shrub height (cm), crown volume (cm^3), basal area (cm^2), basal area \times height (cm^3), and number of stems \times height (cm). Competition indices were summed for each species to give a measure of competitive influence associated with each species around each juniper plant. Index values were summed over all species to reflect total woody competition facing each juniper plant. Hence, twenty competition indices were derived for each woody species (and the sum of all woody species) occurring within the measurement area (3–6 m) of each harvested juniper plant.

Juniperus pinchotii plants sprout from a basal caudex following top removal. Regrowth of harvested trees was measured every 2 months from September 1984 to May 1987. The number of resprouting stems was recorded for each tree. Height and crown diameter were measured and crown volume calculated as before. Length was measured on five to fifteen stems per plant, depending on the total number of stems, and average stem length determined.

All above-ground biomass was harvested from each plant in May 1987, at the final period of counting and measuring stems. Plants with no live stems were assumed to be dead. Harvested biomass was dried at 60 °C to constant weight and weighed to the nearest 0.1 g. Stem counts and the physical characteristics of resprouting trees were used to estimate growth rates in above-ground biomass. A regression equation was developed to predict biomass based on measured attributes on the last sample date: $B = 0.00471(V)$, where B = biomass (g), and V = crown volume (cm^3). The relationship between biomass and crown volume was highly significant ($P < 0.01$), accounting for 81.5% of the variation in biomass ($n = 473$ plants). Average stem length, plant height, number of stems, the product of average stem length and number of stems, and the product of stem length, number of stems, and stem diameter were less precise predictors of biomass than crown volume. Since crown volume was the best predictor of biomass, subsequent analyses were restricted to crown volume.

Jack-knifed discriminant analysis (Lachenbruch 1975) was used to determine which competition index best predicted juniper mortality following top removal. Pre-harvest height was the most critical variable influencing post-harvest survival. Therefore, height of the harvested juniper was entered first into a model predicting juniper survival. In a

manner similar to Waller's (1981) approach, indices with significant ($P < 0.05$) critical alpha levels then entered the model in a stepwise manner. If no index for a species affected ($P > 0.05$) mortality, that species was said to exert no influence over post-harvest juniper survival. Chi-squared analysis was used to test for differences in survival between sites.

Growth rate (difference in crown volume from one period to the next, divided by number of days in the period) was regressed against pre-harvest tree characteristics (age, height, stem diameter, basal area, crown volume), weather conditions (precipitation, average daily maximum temperature, average daily minimum temperature) from all previous 2-month periods, and level of competition around the tree (herbaceous basal cover, shrub competition indices). Temperature data from the nearest weather stations and on-site rain gauges were used for growth rate analysis. Stepwise regression analysis was used to select competition indices which were correlated ($P < 0.05$) with growth rate in the presence of variables already in the model (cf. Waller 1981). Stepwise regression minimizes redundant information among variables (Lindeman, Merenda & Gold 1980). Fisher's protected LSD test was used to test for differences ($P < 0.05$) in growth rate between 2-month periods; Student's *t*-test was used to compare growth rate between sites.

RESULTS AND DISCUSSION

Significant ($P < 0.05$) interactions between site and shrub species indicated a need to analyse juniper response (mortality and growth rate) to individual shrub species within each site. Competition indices for the sum of all species were influenced strongly by indices for *J. pinchotii*, the most common woody species on both sites. Furthermore, response of *J. pinchotii* to total shrub competition paralleled response to intraspecific competition. Therefore, response to total shrub competition is not reported. The power of the protected LSD test guards against inflated Type I errors which may otherwise occur when analysing response to several species, time periods, and sites.

Survival

Juniperus pinchotii survival was not affected ($P > 0.05$) by month or year of harvest. Survival was lower ($P < 0.01$) on the High Plains (mean \pm S.E. = $67.1 \pm 4.5\%$) than on the Rolling Plains ($80.8 \pm 2.6\%$) for all periods. Harvested juniper plants varied from 5 to 118 years in age. Survival was greater on the Rolling Plains than on the High Plains for trees 1–20 years old (Fig. 1) ($\chi^2 = 5.2, 8.0$, and 5.6 with 1 d.f. for trees 1–10, 11–15, and 16–20 years old, respectively), probably because burial of the basal caudex occurs sooner on sites with deep soil (i.e. Rolling Plains) than on sites with shallow soil (Steuter & Britton 1983). Survival did not differ ($P > 0.05$) between sites for trees greater than 20 years old ($\chi^2 = 0.3$ and 0.0 with 1 d.f. for trees 21–25 and > 25 years old, respectively). After 20 years, the sprouting region of most trees is buried sufficiently to ensure survival regardless of site.

J. pinchotii survival on the High Plains was reduced ($P < 0.05$) by competition from other *J. pinchotii* plants and *Yucca*. Survival was best predicted by a model which included pre-harvest juniper height, basal area/squared distance of neighbouring *J. pinchotii* plants, and height/distance of neighbouring *Yucca* plants. The model explained 16.7% of the variation in post-harvest juniper mortality. However, the single-variable model (pre-harvest height) accounted for 15.0% of the variability in juniper survival, indicating that survival of large plants (i.e. those with buried basal caudexes or well-developed root systems) was largely independent of competition.

Pre-harvest height and six of the twenty-four species present affected *J. pinchotii*

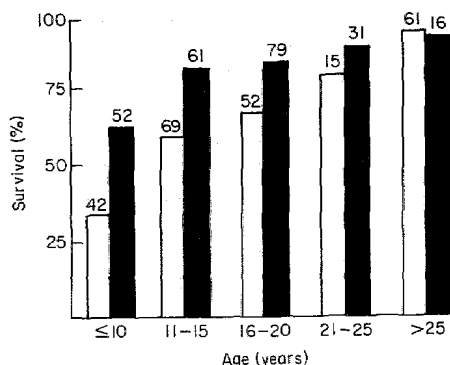


FIG. 1. Relationship between age at harvest and survival of *Juniperus pinchotii* plants on High Plains (□) and Rolling Plains (■) study sites in western Texas. Sample sizes for each age-class are shown on histograms.

survival on the Rolling Plains site. Height/squared distance of *J. pinchotii*, height/cubed distance of *Opuntia leptocaulis*, crown volume/log (distance) of *O. phaeacantha* and *Celtis reticulata*, crown volume/cubed distance of *Acacia Greggii*, and basal area \times height/distance of *Berberis trifoliolata* were included with pre-harvest height in a model which explained 16.5% of the variation in post-harvest survival. As on the High Plains site, the unique contribution of each competitor was relatively small, but significant ($P < 0.05$). Pre-harvest height accounted for 4.8% of the variability in survival. More species competed with coppiced juniper plants on the Rolling Plains than on the High Plains, possibly a result of greater environmental heterogeneity or fewer trees greater than 20 years old (hence, beyond the reach of competitors) on the Rolling Plains site (Fig. 1).

None of the twenty competition indices affected *J. pinchotii* survival ($P > 0.05$) for eighteen of the twenty-four shrub species present in this study. In addition, increased herbaceous cover did not reduce juniper survival ($P > 0.05$). These results indicate that survival of harvested established *J. pinchotii* was primarily dependent on site factors (e.g. soil depth, soil moisture) and pre-harvest size of the plant. Herbaceous plants and most shrubs were apparently unable to exclude harvested *J. pinchotii* plants from resources necessary for their survival. Pre-harvest height accounted for 89.8 and 29.1% of the total explained variation in survival on the High Plains and Rolling Plains, respectively; the few shrubs which reduced juniper survival explained relatively little of the variation in survival: the unique contribution of each species accounted for 3% or less of the variation in juniper survival.

Growth rate

Growth rate of surviving trees primarily depended on mean ambient temperature and total precipitation for the 2-month period. Growth rate was highly variable between periods but was greatest during summer months (Table 1). Growth rates did not differ ($P > 0.05$) between sites for most periods. However, spring (April–May) and late summer (August–September) growth rates were greater ($P < 0.05$) on the Rolling Plains than on the High Plains in 1985 and 1986, reflecting differences in soil moisture between the two sites. Precipitation on the High Plains was slightly below average in spring 1985 and both autumn periods (Fig. 2). Precipitation was far below average for the 4 months preceding the April–May 1986 period.

TABLE 1. Mean daily growth rate (change in crown volume) of *Juniperus pinchotii* trees following top removal in western Texas

Period	Mean* (\pm S.E.) growth rate ($\text{cm}^3 \text{ day}^{-1}$)	
	High Plains	Rolling Plains
Oct–Nov 1984	0.05 \pm 0.02 Aa	0.06 \pm 0.03 Aa
Dec 1984–Jan 1985	0.02 \pm 0.01 Aa	0.16 \pm 0.15 Aa
Feb–Mar 1985	0.31 \pm 0.08 Aa	0.88 \pm 0.28 Aa
Apr–May 1985	14.66 \pm 2.56 Aa	28.10 \pm 4.74 Ba
June–July 1985	196.46 \pm 28.07 Abc	244.18 \pm 33.50 Aabc
Aug–Sep 1985	148.71 \pm 28.65 Aabc	314.60 \pm 47.72 Bbc
Oct–Nov 1985	85.00 \pm 22.24 Aab	94.66 \pm 27.29 Aab
Dec 1985–Jan 1986	-0.46 \pm 10.70 Aa	38.13 \pm 16.61 Aa
Feb–Mar 1986	-2.20 \pm 11.30 Aa	76.54 \pm 22.17 Bab
Apr–May 1986	83.58 \pm 17.89 Aab	258.25 \pm 36.12 Babc
June–July 1986	382.28 \pm 56.77 Ad	468.35 \pm 58.60 Ac
Aug–Sep 1986	271.24 \pm 37.52 Acd	433.20 \pm 59.28 Bc
Oct–Nov 1986	90.38 \pm 19.52 Aab	112.21 \pm 42.86 Aab
Dec 1986–Jan 1987	-1.37 \pm 35.55 Aa	91.26 \pm 37.66 Aab
Feb–Mar 1987	31.66 \pm 32.95 Aa	156.55 \pm 100.65 Aab
Apr–May 1987	283.77 \pm 48.67 Acd	326.28 \pm 74.92 Abc

* Means within a row followed by the same upper case letter or within a column followed by the same lower case letter are not different ($P > 0.05$).

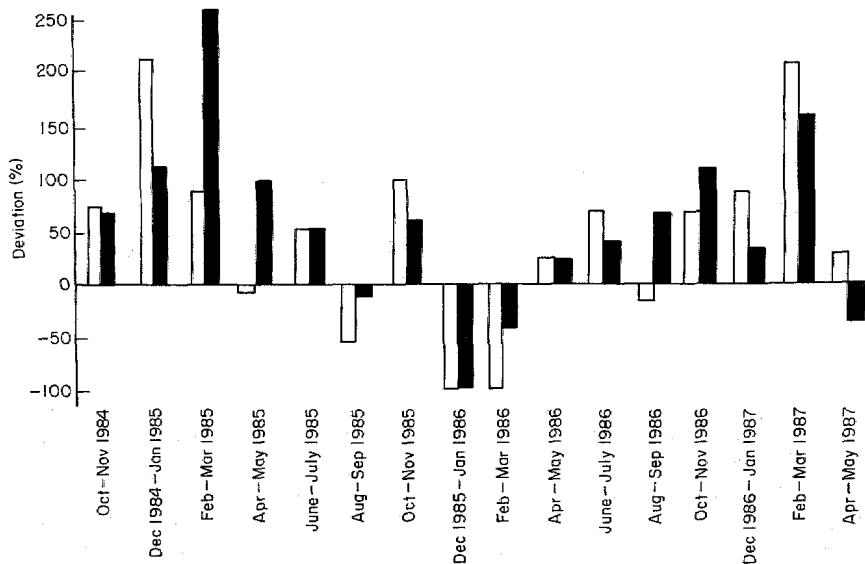


FIG. 2. Deviations from long-term average precipitation at High Plains (□) and Rolling Plains (■) study sites in western Texas from October 1984 to May 1987.

In the presence of all environmental variables (cumulative precipitation, average temperature), increased herbaceous basal cover and shrub competition did not reduce ($P > 0.05$) juniper growth rate in any period on either site. Hence, we conclude that the effect of competing vegetation on growth rate over all periods was masked by (or was less important than) environmental factors. Similarly, Fowler (1986a) reported competitive effects which were relatively weak compared to environmental effects. Therefore, competitive relationships were studied within each 2-month period to minimize environmental effects on growth rate (i.e. precipitation and temperature were 'held constant' by analysing data within 2-month periods).

Analysed within 2-month sampling periods, six shrub species reduced ($P < 0.05$) *J. pinchotii* growth rate in one or more periods (Table 2). The unique contribution (partial correlation) of each shrub was small (Table 3) relative to the contribution of pre-harvest tree height or age. Nonetheless, consistent patterns of interference emerged for a few species. For example, juniper growth rate was reduced by competition from *Ziziphus obtusifolia* (High Plains) and *Yucca* (Rolling Plains) during the October–November period of 1985 and 1986. *Opuntia imbricata* suppressed *J. pinchotii* growth on the High Plains during the only rapid-growth period in which precipitation was substantially below average (August–September 1985). *Opuntia phaeacantha* reduced *J. pinchotii* growth rate on the High Plains during summer 1985 and autumn 1986. Intraspecific competition reduced growth rate during most periods of rapid growth on the Rolling Plains. Intraspecific competition did not reduce ($P > 0.05$) growth rate on the High Plains, and herbaceous cover did not reduce ($P > 0.05$) growth rate on either site.

The manner in which shrubs reduced *Juniperus* growth varied between species. The influence of *Opuntia phaeacantha*, *Prosopis*, *Ziziphus*, and *J. pinchotii* on *J. pinchotii* growth rate decreased cubically with increased distance from the tree (Table 3), indicating that the zone of influence of these species was relatively small. By contrast, the influence of *Yucca* was linearly related to *J. pinchotii* growth rate, and was dependent on the number of stems associated with each *Yucca* plant. These results probably reflect the prolific rhizome production of *Yucca*. That competitive interactions were non-linear for most species is not particularly surprising, though the concept has rarely been tested (but see Silander & Pacala 1985), especially in field studies.

Competition from neighbouring vegetation did not strongly influence *J. pinchotii* growth rate during any period. Shrub competition never accounted for more than 11% of the variation in juniper growth. Furthermore, only six of twenty-four shrub species negatively influenced *Juniperus* growth during any of the periods studied.

This study investigated competitive effects at the level of the individual plant with established plants. Fowler (1986b) noted that competition should be looked for in all stages of the life cycle. Density-dependent mortality and growth of *J. pinchotii* may occur primarily in the seedling stage; hence, this study may well have ignored the period of most intense competition, especially with herbaceous plants. Smith, Wright & Schuster (1975) found strong suppression of seedling *J. pinchotii* plants by *Bouteloua gracilis*. Competition from herbaceous vegetation has also been linked with delayed reproductive maturity of *J. pinchotii* (McPherson & Wright 1987). It is important to note that, in contrast to studies of direct effects of competition, studies of spatial pattern usually fail to identify life-history stages at which competition occurs. Previous work (Smith, Wright & Schuster 1975; McPherson & Wright 1987), along with the current study, indicates the relative importance of competition in various life-history stages of *J. pinchotii*. While further studies are needed to quantify competitive interactions at other life stages, it is clear that

TABLE 2. Variables which affected ($P < 0.05$) growth rate of *Juniperus pinchotii* trees following top removal in western Texas

Period	Site	n	Variables	R ²
Oct–Nov 1984	High Plains	18	Age*	0.27
	Rolling Plains	19	Age	0.89
Dec 1984–Jan 1985	High Plains	38	Age	0.29
	Rolling Plains	38	Age	0.89
Feb–Mar 1985	High Plains	56	Age	0.13
	Rolling Plains	55	Age	0.66
Apr–May 1985	High Plains	74	Height, OPO	0.33
	Rolling Plains	73	Age	0.07
June–July 1985	High Plains	86	Age, OPO	0.50
	Rolling Plains	88	Age, JU	0.26
Aug–Sep 1985	High Plains	102	Age, OPM	0.46
	Rolling Plains	103	Height	0.18
Oct–Nov 1985	High Plains	118	Height, ZI	0.26
	Rolling Plains	123	Age, YU	0.16
Dec 1985–Jan 1986	High Plains	138	—†	0.00
	Rolling Plains	142	—	0.00
Feb–Mar 1986	High Plains	158	—	0.00
	Rolling Plains	162	Age	0.26
Apr–May 1986	High Plains	178	Age	0.19
	Rolling Plains	181	Age, JU	0.20
June–July 1986	High Plains	198	Height	0.44
	Rolling Plains	201	Age, JU	0.27
Aug–Sep 1986	High Plains	215	Age	0.32
	Rolling Plains	221	Age, JU	0.21
Oct–Nov 1986	High Plains	215	Age, ZI, OPO	0.26
	Rolling Plains	221	Height, YU	0.07
Dec 1986–Jan 1987	High Plains	215	PR15	0.06
	Rolling Plains	221	Age	0.08
Feb–Mar 1987	High Plains	215	—	0.00
	Rolling Plains	221	JU	0.19
Apr–May 1987	High Plains	215	Height	0.24
	Rolling Plains	221	Age	0.06

* Age and height refer to pre-harvest condition of trees. All other variables are competition indices for neighbouring shrubs: JU, *Juniperus pinchotii*; OPM, *Opuntia imbricata*; OPO, *O. phaeacantha*; PR, *Prosopis glandulosa*; YU, *Yucca angustifolia*; ZI, *Ziziphus obtusifolia*.

† No independent variables correlated ($P > 0.05$) with *J. pinchotii* growth rate.

competition from neighbours has a greater effect on growth of seedlings than adults. Competition only slightly affected reproductive success (McPherson & Wright 1987), growth rate, and survival following coppicing. Subsequent studies should address the importance of competition in other life-history stages, such as the regeneration niche (Grubb 1977).

Detecting effects of competition at the individual plant level is especially difficult in field studies given the many factors which influence survival and growth. Firbank & Watkinson (1987) found that little variation in individual plant performance could be explained by measures of local competition, even with monocultures or simulated plant

TABLE 3. Shrubs negatively correlated ($P < 0.05$) with regrowth of harvested *Juniperus pinchotii* trees in western Texas

Site	Species*	Index†	n	Period	Partial correlation coefficient
High Plains	OPM	H/D^2	25	Aug-Sep 1985	-0.29
	OPO	N/D^3	61	Apr-May 1985	-0.25
				June-July 1985	-0.16
				Oct-Nov 1986	-0.12
	PR	$(BH)/D^3$	132	Dec 1986-Jan 1987	-0.24
	ZI	H/D^3	17	Oct-Nov 1985	-0.25
				Oct-Nov 1986	-0.25
Rolling Plains	JU	V/D^3	98	June-July 1985	-0.32
				Apr-May 1986	-0.16
				June-July 1986	-0.17
				Aug-Sep 1986	-0.19
				Feb-Mar 1987	-0.14
	YU	$(SH)/D$	87	Oct-Nov 1985	-0.18
				Oct-Nov 1986	-0.21

* JU, *Juniperus pinchotii*; OPM, *Opuntia imbricata*; OPO, *Opuntia phaeacantha*; PR, *Prosopis glandulosa*; YU, *Yucca angustifolia*; ZI, *Ziziphus obtusifolia*.

† B, basal area; V, crown volume; H, height; S, number of stems; D, distance from tree.

populations. In the light of their findings, the relatively low frequency and magnitude of competition exhibited in the current study is not unexpected. Considering the inherent variability associated with natural communities composed of several dozen species, competitive interactions which were detected may be very important in driving system dynamics.

ACKNOWLEDGMENTS

Assistance in the field was provided by B. K. Blair, P. Grissom, S. Merrigan, G. A. Rasmussen, M. Ryan, M. C. Schreiber, and J. Weigel. D. Wester provided inspiration and helpful suggestions. This study is a contribution of the College of Agricultural Sciences, Texas Tech University, Publication Number T-9-500.

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(Received 20 June 1988; revision received 16 January 1989)

APPENDIX

Competition indices

Index	Units
Height/distance	cm/cm
Crown volume/distance	cm ³ /cm
Basal area/distance	cm ² /cm
(Basal area × height)/distance	cm ³ /cm
(Number of stems × height)/distance	cm/cm
Height/distance ²	cm/cm ²
Crown volume/distance ²	cm ³ /cm ²
Basal area/distance ²	cm ² /cm ²
(Basal area × height)/distance ²	cm ³ /cm ²
(Number of stems × height)/distance ²	cm/cm ²
Height/distance ³	cm/cm ³
Crown volume/distance ³	cm ³ /cm ³
Basal area/distance ³	cm ² /cm ³
(Basal area × height)/distance ³	cm ³ /cm ³
(Number of stems × height)/distance ³	cm/cm ³
Height/log _e distance	cm/log _e cm
Crown volume/log _e distance	cm ³ /log _e cm
Basal area/log _e distance	cm ² /log _e cm
(Basal area × height)/log _e distance	cm ³ /log _e cm
(Number of stems × height)/log _e distance	cm/log _e cm

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