Plant distribution surrounding Rocky Mountain pinyon pine and oneseed juniper in south-central New Mexico

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Abstract

Within the pinyon-juniper type, trees and understory vegetation are interspersed with open areas forming a mosaic of vegetational patterns. The objective of this research was to define and describe vegetational zones surrounding Rocky Mountain pinyon (*Pinus edulis* Engelm.) and oneseed juniper (*Juniperus monosperma* [Engelm.] Sarg.). Transects consisting of contiguous frames were laid out from the base of the tree and continued into the interspace area (outside the canopy) for each cardinal direction. Potential zone boundaries were located by calculating a squared Euclidean distance utilizing basal cover estimates of each frame. Zone boundaries were verified by discriminant analysis. Vegetation associated with both pinyon pine and oneseed juniper exhibited 3 zones. Zone 1 consisted of vegetation associated with the tree bole. Zone 2 was, for the most part, located beneath the tree canopy. Zone 3, consisting primarily of interspace, contained mostly perennial grasses and forbs. Mean basal cover of vegetation surrounding oneseed juniper increased from <1% in zone 1, to approximately 7% in zone 2, to about 12% in zone 3. Mean basal cover estimates of vegetation associated with pinyon pine increased from approximately 4% in zone 1, to 10 and 11% in zones 2 and 3, respectively. Differences in species composition among zones between tree species were apparent.

Key Words: vegetational patterns, understory composition, *Pinus edulis, Juniperus monosperma*

Within the pinyon-juniper woodland, trees and understory vegetation are interspersed with open areas forming a mosaic of vegetational patterns. While these patterns may be obvious to the careful observer, few quantitative evaluations of these gradients have been made. For example, Arnold et al. (1964) found rather drastic reductions in basal cover of grasses and forbs with increasing canopy cover. A similar trend was observed with herbage production.

Everett et al. (1983) studied vegetational patterns in a singleleaf pinyon (*Pinus monophylla*)-Utah juniper (*Juniperus osteosperma*) woodland. Basal cover decreased from north to west to south aspects (6.7, 3.7 and 1.9% respectively). In general, understory cover was displaced from the tree stem with increasing tree size and duff depth. Some species, however, were benefited by tree effects, and older trees with decreasing depth of duff, at times, appeared to allow undergrowth to recover. Peak undergrowth basal cover generally occurred in the vicinity of the duff boundary (increased vigor phase), and declined toward the tree bole (exclusion phase) and interspace (depletion phase). The authors point out, however, these patterns were variable among aspects and cross-slope, upslope, or down-slope transects.

Similarly, Everett and Koniak (1981) found cover highest in the transition microsite between duff under the canopy and bare ground interspace between trees. No significant differences in plant cover were found between the understory microsites and the interspace areas. Some species exhibited an affinity for certain microsites.

Clary and Morrison (1973) found cool-season species production higher (1.6 kg ovendry forage) beneath the canopies of mature and overmature alligator junipers (*Juniperus deppeana* Steud.), compared to only 0.36 kg for a treeless area equivalent in size.

Arnold (1964) delineated 4 distinct vegetation zones surrounding a oneseed juniper near Show Low, Arizona; Zone 1, next to the tree bole possessed no herbaceous vegetation. It received the least light and presumably the most moisture (via stemflow) of the 4 zones. The first zone surrounded the tree bole. Zone 2 produced 132.9 kg air-dry perennial grass and forb herbage per ha. This zone was located beneath the tree canopy, except for the northerly direction, where it extended approximately 2/3 m beyond the canopy edge. Snakeweed (*Gutierrezia sarothrae* [Pursh.] Britt. and Rushby.) had the greatest cover in the second zone, followed by western wheatgrass (*Elytrigia smithii* [Rybd.] D.R. Dewey). In contrast, zone 3 produced 86.1 kg/ha. Zone 3 consisted primarily of interspace, and continued to a distance of approximately 5.5 m. The absorption and depletion of soil moisture by root hairs of the juniper are thought to have prevented the full development of western wheatgrass and snakeweed in zone 3. Blue grama (*Bouteloua gracilis* [H.B.K.] Lag.) dominated this zone. Zone 4 produced

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215.5 kg per ha. This zone is presumably outside the influence of the juniper and consists of interspace. Snakeweed had its highest cover in this zone.

Johnsen (1962) noted, as the size of oneseed junipers increased, vegetation was increasingly excluded from the understory. However, as the tree senesced, its canopy become elevated and grasses and forbs were able to recolonize the understory.

No comparative studies have been conducted on the major dominant tree species of the pinyon-juniper woodlawns of central New Mexico. The objective of this study was to define vegetational zones surrounding Rocky Mountain pinyon and oneseed juniper.

Study Area

The Fort Stanton Experimental Ranch is between the Capitan and Sierra Blanca mountains of south-central New Mexico. Mean annual precipitation is 348 mm, 60% of which occurs during the growing season (Lymbery and Pieper 1983). Precipitation in 1985, until the time of sampling (June), was 74 mm, approximately 95% of the average for this time period. The average annual temperature is 11.1° C, with a mean minimum of -6.6° C occurring in January, and a mean maximum of 28.9° C occurring in July (Pieper et al. 1971). Winds are predominantly from the west and southwest (Lymbery and Pieper 1983).

Average elevation of the study site is 1,870 m. Slope is approximately 5% with a northwest aspect. Soils of the study site have been classified as a fine, loamy, mesic Aridic Haplustoll (Bailey et al. 1982). These areas were not grazed by livestock during this study.

Common grass species of the study area include blue grama (*Bouteloua gracilis* [H.B.K.] Lag.), wolftail (*Lycurus phleoides* H.B.K.), and sideoats grama (*Bouteloua curtipendula* [Michx.] Torr.). Major forbs include groundcherry (*Physalis* sp. L.), scarlet globemallow (*Sphaeralcea coccinea* [Pursh] Rydb.), and chamaesaracha (*Chamaesaracha coronopus* [Dunal] Gray) and the half shrub broom snakeweed (*Gutierrezia sarothrae* [Pursh] Britt & Rusby). The shrub layer is dominated by skunkbush sumac (*Rhus trilobata* Nutt.), algerita (*Berberis haematocarpa* Woot.) and an occasional wolfberry (*Lycium pallidum* Miers). Oneseed juniper (*Juniperus monosperma* Engelm. Sarg.), Rocky Mountain pinyon (*Pinus edulis* Engelm), and an occasional alligator juniper are the sole tree species of the area. Plant nomenclature follows Lebgue and Allred (1985).

Methods

Zonation

Twelve vigorous oneseed junipers relatively uniform in size (4-6m in height) and morphology were selected for study. In each of the 4 cardinal directions, forty 61.00 × 15.24-cm frames were placed from the tree base continuing into the interspace. An ocular estimate of basal cover (to the nearest whole percentage) for each species rooted within the frame was recorded during June 1985. Tree canopy width in each direction was also measured by using an imaginary line perpendicular from the outermost edge of the tree canopy and recording this distance from the tree bole.

Fifteen Rocky Mountain pinyon trees were also selected for study. These trees were in vigorous condition and were 100–150 years of age. For each tree, only as many suitable directions as were available were utilized. A direction was deemed unsuitable if at least 30 frames could not be placed without encountering the influence of another tree. (The edge of a pinyon's influence was assumed to extend 5 m beyond the canopy edge). Basal cover and canopy cover width were measured in an identical fashion to that for the juniper.

Potential vegetational zone boundaries were located by calculating a squared Euclidean distance, as described by Ludwig and Cornelius (1987), utilizing basal cover estimates of each frame. Basal cover estimates of adjacent frames were grouped into window widths along the transect data. A window corresponded to the data from at least 2 frames; windows can be set to any feasible number of frames. The window is then divided into two equal groups of transect data, and a squared Euclidean distance is calculated between these 2 groupings. The squared Euclidean distance formula indicates the difference between the basal cover estimates of each group on an individual species basis. If a species in one group is lacking, its value is set to zero. Differences are squared, repeated for all species within this window. The resulting values are summed, thereby yielding the squared Euclidean distance. The window is then moved one position, or frame, down the transect and another squared Euclidean distance is calculated. This process is continued until the window reaches the last frame along the transect and can be moved no further. A window width of 6 frames was used for this analysis (Fig. 1). This width was used because it

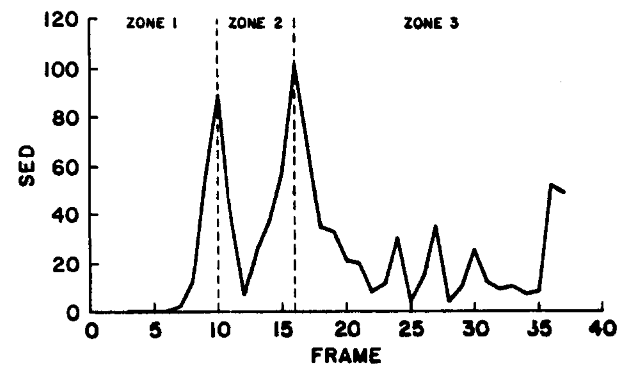


Fig. 1. *Squared Euclidean distance peaks across quadrats placed from tree bole to interspace utilizing a window width of 6 for a sample direction of representative tree.*

tended to lessen, or dampen, the occurrence of peaks resulting from purely random noise compared to procedures utilizing smaller windows.

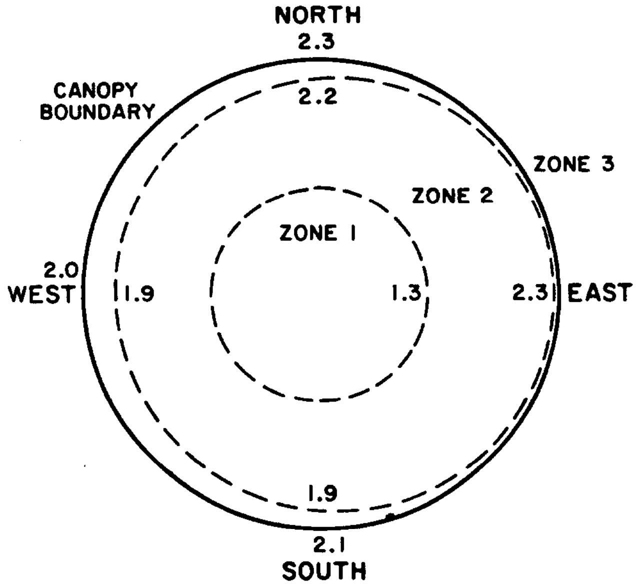
Initially, as many zones as there were major peaks were defined. Once potential zones were delimited, a discriminant analysis using species cover values was employed to test the zone classification. We examined understory species frequency along the transect and selected those species that exhibited a repeatable pattern of occurrence relative to the tree crown. We used discriminant analysis to test the correctness of the number of understory zones based on percentage of frames correctly classified. This process was continued until a high percentage of the frames were correctly classified. Squared Euclidean distance results for both species were similar (Fig. 1).

Basal cover data were subjected to analysis of variance using the Statistical Analysis System with an alpha set equal to 0.05 (SAS Institute 1982). When the analysis of variance indicated a significant difference among zones or directions, individual means were compared by least significant differences. In these analyses, individual trees were considered replications.

Results and Discussion

Three vegetational zones were identified surrounding both oneseed juniper and pinyon pine. Zone 1 around pinyon pine was clearly defined, while zones 2 and 3 were not as distinct, but were still relatively well-defined. Zones surrounding oneseed juniper were somewhat more clear.

Zone 1 of the juniper was located beneath the tree canopy and extended to a distance of approximately 1.0 m from the tree bole. Zone 2 approximated the juniper canopy edge and was roughly 2.1 m from the tree bole. Precise zone location, however, varied somewhat with direction (Fig. 2). Zone 3 consisted of some area beneath the canopy, but was mostly interspace. Results of the discriminant analysis for oneseed juniper are shown in Table 1. For example, 15



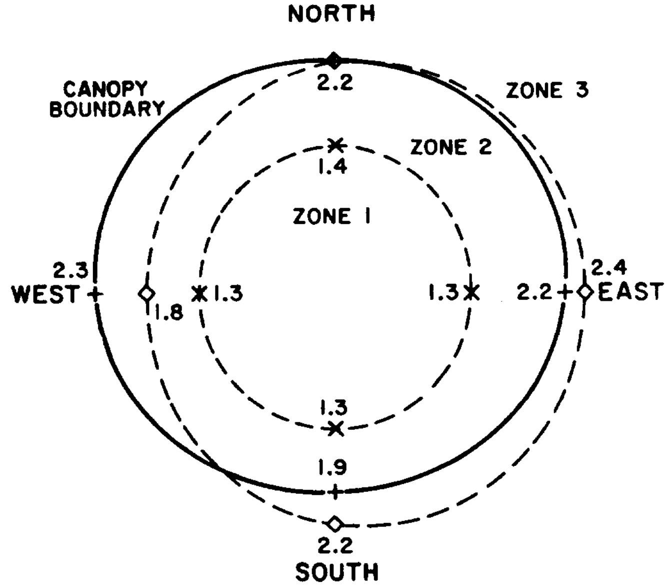


Fig. 2. *Vegetational zones and canopy boundaries for one seed juniper and pinyon pine. All measurements are in meters.*

Table 1. Discriminant analysis classification for oneseed juniper.

Number of observations By sliding window technique	Classified into each zone: By discriminant analysis 1	2	3	Total	% Correct classifications
1	311	15	0	326	95
2	34	241	52	327	74
3	18	155	1094	1267	86
Total	363	411	1146	1920	
Percentage	18.9	21.4	59.7	100	

quadrats classified in zone 1 by the sliding window technique were placed in zone 2 by the discriminate analysis.

This classification correponds rather closely with the findings of Arnold (1964) in terms of zone location and total number of zones. The only major discrepancy is the addition of a fourth zone by Arnold, which was not detected in this study. Differences in plant composition between the study areas may account for this because not all plant species and plant assemblages necessarily respond in the same fashion to varying biotic and abiotic conditions. Furthermore, Arnold based his classification upon a single juniper; perhaps the differences he noted were not as apparent with all junipers. Lastly, if the transect of this study were carried out farther, possibly another zone could have been defined, i.e., zone 3 may still be under the influence of the juniper.

Zone 1 of the pinyon was located entirely beneath the tree canopy. The edge of this zone was about 1.4 m from the tree bole. Zone 2 was, for the most part, beneath the pinyon canopy, although this was dependent upon direction. The edge of the zone 2, for all directions but west, approximated the canopy edge and was roughly 2.2 m from the tree base (Fig. 2). Zone 3 consisted primarily of interspace. Discriminant analysis results for pinyon pine are shown in Table 2. Zone 3 was the most indistinct because 45 quadrats classified in zone 3 by the sliding window technique should be in zone 1 according to the discriminant analysis.

The outward shifting of the northerly and easterly directions, and corresponding contraction of the southerly and westerly portions of the juniper canopy and the zones themselves are shown in Figure 2. Arnold (1964) also noted a similar effect. We speculate that this is probably the result of increased solar radiation in the south and west directions, and subsequent increased shading in the northerly and easterly directions.

Table 2. Discriminant analysis classification for pinyon pine.

Number of observations By sliding window technique	Classified into each zone: By discriminant analysis 1	2	3	Total	% Correct classifications
1	194	22	15	231	84
2	13	103	22	138	75
3	45	139	374	558	67
Total	252	264	41	927	
Percentage	27.2	28.5	44.3	100	

Zone 1 of the pinyon was only slightly bowed outward in the northerly direction. In the westerly direction, however, the zone boundary extended approximately 0.3 m beyond the canopy edge (Fig. 2). This incongruity is in contrast to the findings of both zone 1 and the results of the juniper analysis. Inadequate sample size and sampling methodology (not sampling each of the 4 cardinal directions for each tree) may have contributed to the suspected error.

Mean basal cover among zones was significantly different for both tree species. Mean basal cover increased from 0.7% in zone 1 to 6.9% in zone 2 to 12.4% in zone 3 around juniper trees (Fig. 3). Mean basal cover increased from 3.7% in zone 1 to 9.9% in zone 2 around pinyon trees. The difference in mean basal cover from zone 2 to zone 3 was nonsignificant ($P>0.05$) (Fig. 3).

The relatively low mean herbaceous basal cover in zones 1 and 2 for both tree species as several possible explanations. Allelopathic effects have been demonstrated by Jameson (1961, 1968) for oneseed juniper and by Lavin (1968), and Jameson (1961, 1968) for pinyon pine. Allelopathic effects and litter acting as a physical barrier to plant establishment have been demonstrated by Schott (1985) and Johnsen (1962) for oneseed juniper, and by Johnsen (1962) for both oneseed juniper and pinyon pine. Severe shading, such as that found beneath the canopy of juniper trees, has a deleterious effect on grasses in terms of vigor (Johnsen 1962) and a

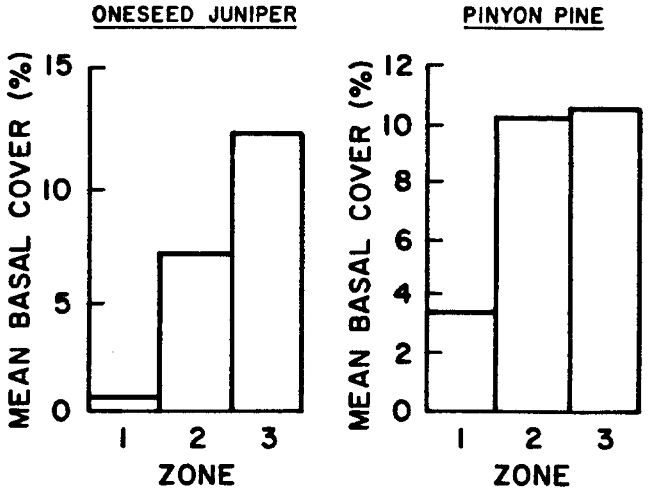


Fig. 3. *Basal cover of herbaceous species in the 3 zones associated with oneseed juniper and pinyon pine.*

basal cover (Schott 1985). Jameson's (1966) finding that pinyon-juniper cover, i.e., shading, did not negatively influence blue grama cover was not confirmed by this study. The juniper canopy also may intercept a significant portion of the total precipitation falling on an area (Gifford 1970, Skau 1964, Johnsen 1962, Young et al. 1984), thereby reducing soil water beneath the tree canopy. Similarly, pinyon pine intercepts light and precipitation, but does not appear to do so to the extent that oneseed juniper does. Presumably, the effects of the tree on understory cover are lessened as the canopy edge was approached and with continuing distance from the tree.

Mean herbaceous basal cover was not significantly different ($P \leq 0.05$) among directions for either the pinyon or the juniper, although mean basal cover was slightly higher in the east and north direction for both species (Table 3). This may result from more mesic conditions in these directions, resulting in less drought stress and higher soil water content.

Table 3. Mean basal cover estimates (%) of each cardinal direction surrounding pinyon pine and oneseed juniper.

Pinyon understory				Juniper understory			
Direction				Direction			
North	South	East	West	North	South	East	West
8.7	8.4	8.0	7.7	6.7	6.6	6.8	6.6

Blue grama and wolftail basal cover varied inversely between the south and north directions for both tree species. Blue grama had its greatest basal cover in the north and its lowest cover in the south. The mean basal cover of wolftail, however, was highest in the south and lowest in the north. Hence, blue grama appears to favor the more mesic directions while wolftail favors the more xeric directions.

Species composition shifts between zones were also apparent for both species (Table 4).

Juniper

Dominant species in zone 1 included blue grama, sand muhly, skunkbush sumac, and algerita. Wolftail, three awns, snakeweed, hairy grama, and sand dropseed were notably absent within this zone. Creeping muhly, scarlet globemallow, galleta, sideoats grama, and blue grama were the predominant species in zone 2. Dominant species in zone 3 included blue grama, galleta, wolftail, mat muhly, scarlet globemallow, three awns, and hairy grama.

Table 4. Mean basal cover estimates (%) of selected species surrounding oneseed juniper and pinyon pine. Means with the same letter are not significantly different ($P \leq 0.05$).

	Pinyon			Juniper		
	1[1]	2[2]	3[3]	1	2	3
Major grasses						
Sideoats grama	0.15a[4]	0.30a	1.0b	0.02a	0.20a	1.1b
Blue grama	2.3a	8.2b	4.6c	0.25a	3.9b	4.4c
Hairy grama	0.00a	0.01a	0.05a	0.00a	0.02a	0.30b
Wolftail	0.11a	0.80b	2.9c	0.0a	0.09a	3.6b
Galleta	0.05a	0.20a	0.60b	0.04a	0.43b	0.50b
Creeping Muhly	0.37a	0.14b	0.01c	0.04a	0.47b	0.01a
Sand dropseed	0.05a	0.08a	0.42b	0.0a	0.18b	0.38c
Major forbs						
Groundcherry sp.	0.09a	0.0b	0.0b	0.03a	0.05b	0.0c
Scarlet globemallow	0.04a	0.06a	0.07a	0.0a	0.21b	0.15c
Half shrub						
Snakeweed	0.03a	0.07a	0.08a	0.0a	0.20b	0.10c
Shrubs						
Algerita	0.02a	0.0a	0.0a	0.05a	0.0b	0.0b
Wolfberry	0.01a	0.0a	0.0a	0.01a	0.0b	0.0b
Skunkbush sumac	0.06a	0.0b	0.0b	0.06a	0.0b	0.0b
Trees						
Oneseed juniper	0.06a	0.0b	0.0b	0.02a	0.0b	0.0b
Pinyon pine	0.02a	0.0b	0.0b	0.02a	0.01b	0.0b

[1]Surrounding the tree bole.
[2]From the tree bole to approximately the canopy edge.
[3]Primarily interspace.
[4]Means with rows with different superscripts are significantly different ($P < .05$) for each tree species.

Pinyon

Dominant species in zone 1 included blue grama and creeping muhly. Species unique to this zone included groundcherry, pinyon pine, oneseed juniper, skunkbush sumac, algerita, and wolfberry. Hairy grama was conspicuously absent within this zone. Predominant species in zone 2 included blue grama, which had its highest basal cover within this zone, sideoats grama, sand muhly, galleta, and wolftail. Dominant species in zone 3 included sideoats, blue grama, galleta, wolftail, sand muhly, and sand dropseed.

These compositional differences may be related to the varying tolerance of different species to the gradients of biotic and abiotic conditions found among zones. Arnold (1964) also noted similar composition changes among zones for oneseed juniper, which were presumably the basis for his zone classification. Everett et al. (1983) also found changes in composition relative to the distance from the tree base and duff boundary in Nevada, although they did not appear to be as distinct as those Arnold (1964) described or the differences found in this study.

Woody species were generally restricted to zone 1 for both tree species. Woody species are probably more prevalent beneath the tree canopy because of concentated avian seed deposition in such locations, although improved microclimatic conditions and reduced competition from grasses may also explain this pattern. Forbs in zone 1 were almost exclusively annuals; they may be related to disturbance, perhaps by small mammal activities beneath the junipers, and either small-mammal or livestock use beneath the canopy of pinyon pine.

These dissimilitudes are probably the result of differences in light and precipitation as related to canopy morphology. Differences in allelopathic toxicity, as well as possible root competition, and differences in animal use patterns may also play a role in these compositional differences.

Knowledge of these vegetational patterns adds to our understanding of the ecology of pinyon-juniper woodlands. In addition, they have implications for the utilization of these areas by livestock and game. Response of herbaceous and shrubby vegetation to manipulation of the tree cover is also influenced by pre-treatment patterns.

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