gram, may then be developed to deal with problems.

Literature Cited

Dollahite, J.W., G.T. Housholder, and B.J. Camp. 1966. Effect of calcium hydroxide on the toxicity of post oak *(Quercus stellata)* in calves. J. Amer. Vet. Medical Association 148:908-912.
Kearny, T.H., and R.H. Peebles. 1960. Arizona flora. Univ. of California Press, Berkeley, CA. p. 216-219.
Kingsbury, J.M. 1964. Poisonous plants of the United States and Canada. Prentice-Hall, Englewood Cliffs, NJ. p. 444-446.
McLeod, M.N. 1974. Plant tannins-their role in forage quality. Nutr. Abst. Rev. 44:803-815.
Panciera, R.J. 1978. Oak poisoning in cattle. *In:* Keeler, R.F., K.R. Van Kampen and L.F. James (eds.). Effects of poisonous plants on livestock. Academic Press, New York. p. 499-506.
Provenza, F.D., and J.C. Malecheck. 1984. Diet selection by domestic goats in relation to blackbrush twig chemistry. J. App. Ecol. 21:831-841.
Sandusky, G.E., C.J. Fosnaugh, J.B. Smith, and R. Mohan. 1977. Oak poisoning of cattle in Ohio. J. Am. Vet. Med. Assoc. 171:627-629.

Succession in Pinyon-Juniper Vegetation in New Mexico

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Pinyon-juniper is a major vegetation complex of the southwestern United States. One-seed juniper and pinyon are the major species of the complex in central New Mexico. Since settlement of the Southwest by Europeans, this vegetation type has increased in distribution and density of individual trees (West et al. 1975). A decline in forb and grass production accompanied these increases (Johnsen 1962). Because of the decline in forage production, land managers have attempted various types of pinyon-juniper control, often without an understanding of the ecology of the complex or an idea of how the vegetation will respond to the treatment. For example, cabling has been used extensively in the Sacramento Mountains of southcentral New Mexico as a form of pinyon-juniper control. Larger trees are pulled out of the ground, but many smaller trees and shrubs survive the cabling. The successional pattern following cabling and other types of disturbance is not understood for many areas in New Mexico.

Research concerned with secondary succession of pinyon-juniper communities where one-seed juniper and pinyon are the dominants has not been extensive. This article presents the result of several studies on pinyon-juniper succession in the Sacramento Mountains in south central New Mexico.

Factors Influencing Succession

Soil depth and the amount of rockiness in the upper soil horizons have a major influence on succession after a community is cabled. Succession after cabling was examined on two different soils: a Lithic Haplustoll rock outcrop complex and a Lithic Haplustoll. Each soil supports a different association, and the successional pattern on each soil is different.

Most studies reported several stages of succession: forb, grass, grass-shrub, shrub and climax. Succession on the Lithic Haplustoll rock outcropping complex does not have the grass or shrub stages. Rocky, broken soils tend to restrict the vegetative spread of blue grama and wavyleaf oak, and other species that spread vegetatively. Thus, the grass and shrub stages are not evident on this type of soil. On deeper soils these stages do develop during succession (Table 1).

Shrubs and trees are restricted to soil patches between the rock outcrops. Because of the patchy soil, little interspecific competition for moisture occurs between the shrubs and trees, except for the patches of soil where wavyleaf oak and junipers occur. Because of the separation, wavyleaf oak is a member of the climax community on these soils.

Pinyon was the only tree that increased in coverage in the 28 years after cabling. Compared to junipers, it is a fast-growing species that produces seeds at younger ages. Both one-seed juniper and alligator juniper grow and mature slowly. Germination trials indicate young one-seed junipers produce seeds of low viability. Apparently, most juniper establishment after cabling is from seeds already on the site at the time of cabling, or seeds brought in by an animal vector. One-seed juniper seeds can remain viable for 20 years. Trees that become established require a minimum of 10-30 years of growth to produce seeds. Except for seeds that did not germinate and those brought in by animals, a seed source is not available until the established trees have matured. Lack of a continuous seed source and the slow growth of junipers accounts for the lack of increase in canopy 28 years after cabling.

Successional Patterns

The Lithic Haplustoll supported a pinyon-juniper/blue grama habitat type. Secondary succession of this habitat type after cabling is similar to the general successional models of Arnold et al. (1964) and Barney and Frischknecht (1974). Initially, the community is dominated by perennial grasses and forbs. An annual community may develop if perennial grasses were not common to the area before cabling. Shrubs such as wavyleaf oak and skunkbush gradually begin to dominate the grass-forb community, after which pinyons and junipers become established under the shrub canopy. Trees finally dominant the area. Rate of succession after cabling is faster than that proposed by the general models, but these were based on succession after catastrophic fire where more plants are destroyed.

Rate of succession after cabling depends on community

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Table 1. General pattern of succession on cabled pinyon-juniper woodlands on two soil types.

Original Conditions	Seral Stages 1	2	3	Climax
General successional model	Annual forb	Grass/forb	Shrub/grass	Pinyon-juniper
Lithic hapustoll	Annuals and perennials from seeds which disperse readily; surviving perennials.	Perennial grasses and forbs with establishment and spread of shrubs (esp. wavy-leaf oak)	Shrubs dominant; shade conducive to tree establishment.	Pinyon and juniper dominating. Pinyon eventually dominant.
Lithic hapustoll-Rock outcrop complex	Annuals and perennials from seed which disperse readily; surviving perennials.	These stages absent or poorly represented. Rock outcrops restrict vegetative reproduction.		Pinyon dominating Climax with juniper.

structure before cabling. If the community had a large canopy coverage of mature junipers and pinyons with few juvenile trees, and little or no wavyleaf oak or other shrub cover before cabling, succession will be slow. Heavy shading by trees and litter accumulation generally suppresses grass cover. Because of the initially sparse grass cover, the grass stage requires longer to develop. Scarcity of oaks before cabling results in the shrub stage taking longer to develop. Finally, the lack of young trees would result in fewer trees surviving the cabling. Trees that survive the cabling will produce seeds earlier than trees established after cabling.

Succession on Lithic Haplustoll soil depends on the species composition before cabling. If there is enough grass present, a grass stage develops quickly. A relatively complete grass cover slows the establishment of shrubs and trees. In contrast, a grass stage that developed slowly on an area with some shrub and tree cover after cabling will be short-lived. If an area does not have many shrubs, the shrub stage develops slowly. Age structure of the pinyons and junipers before cabling also influences succession. If there are many older trees and few young trees, cabling will destroy most of the trees. Except for the seeds already on the area before cabling, there would not be a seed source until trees that became established after the cabling have matured. Seeds from young trees are not highly germinable. Trees established after the cabling are from the seeds already on the area before cabling, or brought in by an animal vector. Thus, the shrub-tree and climax stages will require time to develop. However, if the stand had many young trees before cabling, more trees will survive the cabling and succession will have been much faster.

Interspecific Relations

Interactions among the species change as succession occurs. If a grass-forb stage develops without many shrubs or trees present, the grass interferes with establishment of shrubs and trees, except during favorable moisture years. A good grass cover limits shrub and tree establishment in most years by reducing the available space and moisture. During favorable growing years, shrub and tree seeds germinate and develop a root system that extends deeper than most of the grass root systems, ensuring rapid establishment (Johnsen 1962). If the grass-forb stratum were poorly developed, shrubs and trees are established more readily.

Junipers and pinyons usually become established under the canopy of a shrub or tree. However, one-seed juniper seldom gets established under another one-seed juniper. One-seed juniper litter appears to have an autopathic effect on seed germination. Burkhardt and Tisdale (1976) found that soil surface temperature on open areas can get hot enough during summer to kill the cambium of western juniper seedlings, resulting in mortality of the seedling. In contrast, soil surface temperatures under the canopy of a shrub or tree are not as high. Reduced soil surface temperatures may account for the establishment of pinyons and junipers under the crown of a shrub or tree. Pinyons do not appear to be sensitive to the chemicals in juniper litter because they are often found growing beneath junipers. Pinyons also appear to be more shade tolerant than one-seed junipers because young pinyons are often found in climax communities while young one-seed junipers are uncommon.

Competition for soil moisture between grasses and shrubs is greatest during germination and establishment of shrubs. However, after the shrubs are established, there would probably be some separation in their rooting zones, which reduces the direct competition for soil moisture. Wavyleaf oak, the dominant shrub on this habitat type, spreads vegetatively, forming oak patches. As the patches grow, the less shade-tolerant grasses die. These patches increase in size and height as the oak grows. Also, tree establishment in the wavyleaf oak patches occurs primarily during favorable growing years. Competition for soil water between the oak and the trees is greatest during initial establishment of the trees. After establishment, trees seem to have the competitive advantage over the wavyleaf oak.

Wavyleaf oak and one-seed juniper have higher water potentials on the more recent cablings than on older cablings. As the cabling becomes older, water potential of wavyleaf oak becomes more negative, and as the community nears climax the water potential becomes less negative. These data on plant water status suggest wavyleaf oak is a mid-seral species.

Water potential of one-seed juniper becomes more negative as the community gets older, reaching its most negative water potential in climax communities. These results, when combined with the fact that young one-seed junipers are seldom found in climax communities, indicate one-seed juniper is a late-seral species. On these shallow soils, roots of one-seed juniper and wavyleaf oak occurred at the same depth and probably competed for soil moisture. One-seed juniper appeared to have the competitive advantage for soil moisture over oak.

Trees also have a competitive advantage for light because of their greater size. There appears to be little or no competition for soil moisture on deeper soils between wavyleaf oak and one-seed juniper. There may be a separation of rooting zones on deeper soils, while the rooting zones were similar on shallow soils because of the restrictive layer. Pinyons showed little or no difference in water potential in different seral communities. This lack of change in water potentials indicates pinyon was the climax species of the association. Also, young pinyons are often found in climax communities. There appears to be little competition for soil moisture between pinyon and the other species.

Succession in Tree Pits

Cabling destroys the larger pinyons and one-seed junipers by pulling them out of the ground. Uprooting the trees results in pits where the trees used to stand. Size of the pits is a function of tree size, soil depth, and parent material characteristics. Larger trees have larger root systems, which hold more soil and rock when trees are pulled from the ground. The amount of rock attached to roots determines the amount of soil removed when the tree was pulled out of the ground. Rock kept the soil from falling back into the pit when the tree was removed. The softness and the degree of fracturing of the parent material determines the amount of root penetration into the parent material, which affects how much rock is attached to the roots. Increased soil depth, up to a point, results in deeper pits. If the parent material is relatively deep, roots would not be attached to any rocks, and the soil will not stay attached to the roots, resulting in shallower pits. One-seed junipers have larger lateral root systems than pinyons, and cause largr pits when uprooted.

Plant succession in the pits follows the general successional models. However, in contrast to the rest of cabled area, succession in the pits takes much longer. When trees are pulled out of the ground, seeds under the tree are removed. Also, much of the soil profile is removed with the tree, leaving bare mineral soil of the lower soil horizons. Seeds have to get into the pits before plant establishment can occur. Plants with a good seed dispersal mechanisms probably occupy the pits first; these are probably annual forbs. Perennial forbs and grasses are established next in the pits. Succession here is a slow process. After 28 years, most pits have a perennial grass community and many are occupied by creeping muhly, a seral species. Shrub and tree establishment in pits is rare even after 28 years.

Management Implications

Succession after cabling of pinyon-juniper communities of south-central New Mexico is influenced by several factors: soil depth, degree of rockiness, and community structure before cabling. Rocky soils limit the spread of rhizomatous species and cause great variability in micro-climate over an area. Soil depth influences the species and their occurrence on a given area and the amount of competition between two or more species. Community structure before cabling, to a large degree, determines successional rate and direction. High grass coverage slows establishment of other species, and low grass coverage favors the establishment of other species. Low shrub cover before cabling results in the shrub stage being slow to develop, while high coverages result in a rapid development of the shrub stage. Stands with few young trees before cabling have lower successional rates than stands with large numbers of young trees. Finally, the species of the young trees influences succession. If the young trees are junipers, succession will be slower than if the trees are pinyons.

Successful conversions of pinyon-juniper communities depend on those factors that influence succession. Cabling pinyon-juniper communities that occurred on rocky shallow soil failed to result in a measurable increase in forage. Cabling pinyon-juniper stands that occurred on less rocky soils resulted in more forage being produced. However, over 28 years the increase has disappeared. Cablings on deeper soils generally resulted in more grass. However, if the stand had many shrubs or young trees before cabling, the gain would be shortlived. Therefore, to increase the success of pinyon-juniper conversions, stands should be selected with few young trees and shrubs, and at least 15% grass coverage. Also, cabling should be the first of two treatments. Fire, herbicide or some other method should be used as a secondary treatment about 5 years after cabling. Combination of the two treatments should result in a long-term pinyon-juniper conversion.

Literature Cited

Arnold, J.F., D.A. Jameson, and E.H. Reid. 1964. The pinyon-juniper type of Arizona: Effects of grazing, fire, and tree control. U.S. Dept. of Agriculture, Prod. Res. Rep. 84. 28 p.

Barney, M.A., and N.C. Frischknecht. 1974. Vegetation change: Following fire in the pinyon-juniper type of west-central Utah. J. Range Manage. 27:91-96.

Burkhardt, J.W., and E.W. Tisdale. 1976. Causes of juniper invasion in southwestern Idaho. Ecology 15:472-484.

Johnsen, T.N. 1962. One-seed juniper invasion of northern Arizona grasslands. Ecol. Monog. 32:187-207.

West, N.E., K.H. Rea, and R.J. Tausch. 1975. Basic synecological relationships in pinyon-juniper woodlands. Utah State Univ., utah Agri. Exp. Sta., Logan, Utah. pp. 41-53.