Factors Affecting the Health of Pinyon Pine Trees (*Pinus edulis*) in the Pinyon-Juniper Woodlands of Western Colorado

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Abstract—Mortality of pinyon pine has recently been on the increase throughout western Colorado. Black stain root disease (*Leptographium wageneri*) is a significant source of mortality for pinyon trees in infested stands. The pinyon ips (*Ips confusus*) is also an important factor in these stands. These mortality agents often act in concert, affecting large areas within the pinyon-juniper stands. Recent increases in human activity, most prominently road building and home construction, have increased the impact of the pathogen-insect complex. Efforts are underway to determine management activities which may reduce undesired mortality of pinyon pine trees.

The pinyon-juniper forest type covers extensive areas of the southwestern United States. In the Four Corners Region over 14.9 million ha (37.2 million acres) are contained in this warm, lowland cover type. There is a total of 1.8 million ha (4.7 million acres) of pinyon-juniper forest lands in Colorado, the majority of which are on the western slope of the Continental Divide, bordering the Red Rock region of the Colorado Plateau.

The pinyon-juniper woodlands of Colorado have long been an important component of the forested landbase. In pre-settlement times, these areas served as the homelands of several indigenous native groups, the trees themselves providing fuel, materials for shelter, habitat for hunting and foraging in addition to supplying an important component of the diet, specifically pinyon nuts (seeds).

Since the time of settlement, this forest type has been utilized in a variety of ways adding forage production and recreation to the list of uses. While the economic value of these lands has been regarded as being rather low in the past, increasing human populations and the development of an infrastructure able to sustain habitation of these harsh lands has increased the rate of development, particularly the construction of homes.

This increase in the human population within the pinyon-juniper forest has been accompanied by an awareness that mortality of the pinyon pines is increasing at an unprecedented rate. Exclusion of disturbance events such as fire has caused a homogenization of stand characteristics, particularly age-class structure, and has resulted in forest stands which tend to be older and more advanced in the successional pathways of this cover type. The combined factors of increased human activity and an older, more successionally advanced condition are believed to be responsible for this increase in pinyon mortality.

A number of different insects and diseases are specifically responsible for the increased mortality, the combined effects of these agents is being called pinyon pine decline. The actions of these various agents are being considered as a whole since the contribution of the various factors can vary greatly between sites. Additionally, these individual disturbance factors have not been studied well enough to separate their effects. There are a number of secondary insects and diseases affecting the health of pinyon pines, but the primary agents responsible for pinyon pine decline in Colorado appear to be black stain root disease (*Leptographium wageneri*) and pinyon ips (*Ips confusus*).

Ips Bark Beetles (*Ips confusus*, Scolytidae:Coleoptera)

Bark beetles are well-known causes of damage and mortality in nearly all species of woody plants. The majority of bark beetles live and mine within the bark and wood of hosts, spending most of their lives within this cryptic environment. The genus *Ips* is a particularly prominent group of bark beetles due to their habit of attacking a number of economically important timber species. Ips beetles are ranked high in terms of destructiveness to various species of pines and spruce. Most species of *Ips* have a restricted host range, for the most part they attack only a few closely related host trees. This is true of the pinyon ips, *Ips confusus*, which attacks both *Pinus edulis* and *P. monophylla* throughout their ranges.

In general, pinyon ips act as a recycling and thinning agent in stands of pinyon pine. They attack and feed upon broken, fallen and dying trees, and are important factors in stand dynamics and nutrient pathways. However, when populations reach high levels in a given area, these beetles can be responsible for widespread mortality of otherwise healthy trees.

Pinyon ips are cylindrical beetles, 3.5 to 4.0 mm in length and are reddish-brown to black in coloration. A distinguishing feature of the *Ips* genus is the pronounced concavity at the rear end (declivity) of the elytra (wing covers) of the adult, which is margined on each side with 3 to six toothlike spines. *Ips confusus* can be recognized by the pattern of 5 spines on each side of the elytra margins.

Pinyon ips become active as temperatures warm up in the spring, beetle flight occurs on warm, sunny afternoons. Adult males leave overwintering sites and fly to potential hosts to initiate attack. The male beetles begin chewing an entrance hole in the host tree and this activity produces the signs of bark beetle attack, boring dust and pitch. The production of pitch is the host tree's way of defending itself.

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If a host tree is to avoid colonization by the beetles, it must have an ample supply of pitch with which to entrap and force the beetles out of their attack sites. In turn, ips beetles must overcome the defenses of potential hosts if they are going to successfully produce brood. The attacking beetles coordinate their attacks on potential hosts by producing pheromones which concentrate large numbers of beetles on a specific host tree. Pheromone production by the initial beetles attracts additional males as well as females which assist in the attacks. This phenomenon of "mass attack" concentrates enough beetles to overcome the tree's defenses.

The attacking beetles are assisted in their efforts to overcome the host's defenses by means of a symbiotic fungus, *Ceratocystis* sp. The adult beetles have small structures on their bodies in which they carry these fungal spores, and as the attack proceeds, these spores are released beneath the bark. The spores germinate, and the fungal mycelium begins to grow into the sapwood of the host tree, cutting off the host tree's vascular system and girdling it. The growth of this fungus is responsible for the characteristic blue staining in the wood of a tree attacked by bark beetles.

As increasing numbers of beetles arrive at the host, the males are able to establish small chambers beneath the host's bark. *Ips confusus* is a polygamous species and three females usually respond to each male. After mating, each female begins to construct an elongate gallery which extends away from the central male chamber. The construction of these galleries produces another characteristic sign of beetle activity, the gallery pattern. In the case of the pinyon ips, the gallery pattern takes the form of an inverted "Y", with the mating chamber at the center of the three "arms" which each female has constructed. Each female then lays between 25 to 40 eggs in small niches along these galleries. The eggs hatch in about a week and the larvae begin tunneling beneath the bark, feeding upon the host phloem. After several molts beneath the bark, the larvae form a pupal chamber and undergo the final metamorphosis to the adult stage. Adults remain beneath the bark for a short time and then emerge to attack new host trees. There can be from 2 to 5 generations per year, depending upon the elevation and climate. As temperatures cool in the autumn, beetles seek out overwintering sites in the duff layer or beneath the bark of host trees.

Black Stain Root Disease (*Leptographium wageneri*)

Black stain is the common name of a fungus which causes a vascular wilt of coniferous trees. While other strains of this fungus which cause black stain in Douglas-fir and ponderosa pine in the far West are relatively well-understood, black stain root disease in pinyon has not been intensively studied. Black stain root disease was first noted in 1942 in Mesa Verde National Park. James Mielke began investigating the cause of pinyon pine mortality which had previously been ascribed to bark beetles. Mielke's work determined that bark beetle activity was secondary to black stain root disease as a cause of mortality. This work also noted the spread of the disease via root to root contacts (Wagener and Mielke 1961).

Symptoms of black stain root disease are usually first manifested in the foliage of the host tree crown. Infected tree needles become shorter and chlorotic and terminal growth is reduced. These general conditions become increasingly acute until the death of the host tree ensues in a relatively short period of time (as little as 2 to 3 years following initial infection). In addition, the disease predisposes the infected tree to attack by other damaging agents. Once a host has died, the fungus does not survive long and pinyon seedlings often reestablish in old black stain centers.

Black stain can be identified by its distinctive coloration as well as the pattern and location of the staining. As the fungus spreads through the vascular system of an infected tree, it leaves a characteristic black to chocolate-brown stain or streaks of stain in the sapwood of the roots and/or root crown. Removal of bark in the area of the root crown and roots should reveal the characteristic coloration in infested trees. A second key characteristic is the pattern of the staining. Black stain appears in arc-like patterns in the sapwood of infested material when viewed in cross-section. This signature is in contrast to the pattern left by the bark beetle fungal symbiont, *Ceratocystis* sp. Blue stain appears as wedge shaped markings, in addition, the silvery-blue coloration appears throughout the length of the bole.

Trees killed by black stain generally occur in groups or "centers". This pattern of mortality is a result of the local spread of the disease by root to root contact. Once established in a new root, the fungus colonizes the distal portions of the root and then grows towards the root crown. After infecting the root crown the fungus spreads throughout the remaining uninfected roots.

Long distance spread of black stain, resulting in the establishment of new centers has also been observed. In the case of Douglas-fir and ponderosa pine black stain, insect vectors, particularly root-feeding weevils, have been shown to vector the disease. However, in the case of pinyon pine, insect vectoring has not yet been proven. Like their "cousins", the bark beetles, wood-feeding weevils are attracted to wounded and damaged host tissues. Their attraction to injured plant tissue makes them a favorable vector for the disease.

Diagnosis of a black stain infestation center can be difficult, the symptoms may be obvious for only a short period of time. After the death of an infected host, the fungus survives only a relatively short period of time. A number of trees may need to be examined before positive identification of the disease can be made, usually those trees which have very recently or soon will be dead provide the best possibility for detection.

Pinyon Decline

Forest management groups from throughout the Four Corners region have noticed an increase in the reporting of pinyon pine mortality over the last several years. While some of this mortality is being reported for the first time due to lack of previous monitoring, it is evident that actual mortality has increased significantly. This mortality is caused by a number of different agents in different locales, but the majority of the cases involve pinyon ips and black stain root disease. These organisms frequently act in concert, causing widespread areas of mortality.

The bark beetles appear more as opportunists, taking advantage and colonizing trees weakened by black stain root disease or other disturbance factors. When a sufficient supply of susceptible host trees are available, numbers of beetles can reach fantastic levels, and the population can swell out to attack many otherwise healthy trees. An outbreak will decline over time, but often not before a large area has been affected and many trees have been killed.

Black stain can be a major source of mortality in pinyon pine, but local spread of the disease occurs at a limited pace. In contrast, long distance spread of the disease can cause widespread mortality over large areas. The spread of the disease appears to be exacerbated by the activities of wood or root feeding insects. These insects are attracted by wounded or damaged host tissues and can compound other forms of stand disturbance.

Both the insect and the fungus are encouraged by stand disturbance. Trees under stress serve as a food source for bark beetles. The spread of black stain may be accelerated by the activities of vectors which thrive on damaged or stressed host trees.

The rapid increase of human activity in the pinyon-juniper woodlands of western Colorado has in some cases created conditions favorable to black stain and pinyon ips. Direct wounding of trees, damage to root systems, and improper treatment of cut trees and slash has created a large source of potential host material. House, road and utility line construction frequently damage pinyon pines and allow the rapid increase of mortality agents. Since many of these trees are valuable as landscape plants, the death of even a few is undesirable. On a landscape scale, dead trees may increase fuel loads and pose a threat due to wildfire. Outbreaks of these mortality agents also interfere with other management objectives. The relatively slow growth of vegetation associated with the pinyon-juniper woodland further increases the impact of widespread mortality.

Conclusions

The best prospects for reducing the impacts of pinyon decline is by maintaining the forest in as vigorous a condition as possible. Variability of stand conditions within a forest reduces the risk of widespread mortality due to one or two factors. Sanitation of stands by prompt removal of damaged host material reduces a potential source of food for damaging agents. Over the long run, reintroduction of prescribed fire will reduce biomass and fuel loads. In other areas, thinning and harvesting can help achieve desired stocking levels and stand conditions.

Two simple tactics that individual land managers can utilize are proper slash management and timing of activities. Removal or treatment (burning, burying, debarking, or tarping can be used under various circumstances) of potential host material (including stumps, logs, and large branches) can reduce the potential for increased mortality due to bark beetles. Scheduling potentially disruptive activities in pinyon-juniper stands during the cooler winter months can also reduce the risk of mortality. Activities should be as non-disruptive as possible, but working in cooler weather (roughly late November to early March in western Colorado) while the insects are inactive will allow time for managers to sanitize the stands following activity. In addition, timing of activities during the winter months allows the trees to "recuperate" a bit before the bark beetles and weevils become active in the spring.

There are many gaps in the information base regarding pinyon pine decline. As the value of these lands continues to escalate these questions will become increasingly important. Information on the stand factors which increase susceptibility to pinyon decline and the longevity of the influence of black stain within infested areas will be necessary for effective long-term management of these stands. The role and identity of vectors of black stain, and the influence of secondary organisms such as other insects, fungi and nematodes also needs investigation.

Public information will be an important part of any effort to reduce pinyon mortality. A better understanding of the natural environment under which these trees evolved is necessary. Many trees are literally "killed with kindness": drowned by water, overfertilized, or paved around. Others are strung with fences and wires, cut and trimmed indiscriminately, or otherwise mistreated. Managers need to consider the trees under their care as part of a larger woodland. They need to work beyond their property lines and consider pinyon-juniper stands as a crucial component of the landscape.

Reference

Wagener, W. W.; and J. L. Mielke. 1961. A staining-fungus root disease of ponderosa, Jefferey and pinyon pines. Plant Disease Reporter. 45 (11) : 831-835.