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1. How do pine bark beetles kill trees?

Pine bark beetles (*Ips* spp. and *Dendroctonus* spp.) feed primarily on the inner bark (phloem tissue). This has the same effect as girdling (peeling off the bark) of the tree. Damage caused by their feeding acts as an internal tourniquet cutting off the flow of nutrients from the leaves to the other parts of the tree. As the damage progresses, sugars and other complex compounds cannot be translocated downward from the leaves to non-photosynthetic areas of the tree. The beetle can also introduce a blue stain fungus which grows into the wood (xylem). This fungus prevents water from being transported upward to the leaves. Both of these factors contribute to the decline and death of colonized trees.

2. What are the early signs bark beetles have colonized a tree?

Fading of the needle color is the primary early sign of colonization by bark beetles. The needles fade from dark green to pale green to straw yellow to a rusty red. The progression from green to red will take several months. Other signs are pitch tubes, boring dust, and galleries (tunnels within the bark). Pitch (resin) is the main natural defense trees use against bark beetles. When beetles colonize relatively healthy trees, pitch tubes will usually be created where the beetle entered the tree. If the tube is connected with a tunnel that continues into the bark, then that beetle successfully entered the tree. Fine boring dust is sometimes visible and caused by bark beetles chewing the bark to enter the tree. During initial colonization, the boring dust is bright red. To inspect for galleries, you can remove a portion of the bark with an axe. This should be done only after the tree appears to be dead. Galleries should be visible within the bark and may contain larvae (grubs), pupae (cocoons), and/or adult beetles on recently killed trees. One or all of these signs or symptoms may be present.

3. What caused the current bark beetle outbreak?

The current level of bark beetle mortality has resulted from a combination of natural factors including, but not limited to: drought, dense forest stands, shallow/rocky soils, and relatively large quantities of bark beetles. Human activities such as fire suppression, past forest management practices, past grazing practices, and ongoing urbanization have also contributed to current conditions. These factors all influence the amount of water, light, and nutrients available to individual trees in the forest. Trees not receiving enough of these resources become stressed. Bark beetles can detect a stressed, susceptible tree and they respond by colonizing it and effectively removing it from the population. This inadvertently makes a larger quantity of resources available for the surviving trees, shrubs, and herbaceous plants.

4. Are the pine bark beetles native to northern Arizona?

Yes. Under endemic (non-outbreak) conditions, pine bark beetles act as a natural disturbance agent in the forest. Occasional outbreaks are also a normal occurrence; however, we should not expect an "un-natural" forest to behave in a "natural" manner. In

other words, some current outbreaks are longer-lived and cover a larger area than historic outbreaks.

5. Are bark beetle outbreaks beneficial?

Even under outbreak conditions, the beetles are decreasing the density of our pine forests. It seems drastic to most residents because the amount of pine mortality may be unprecedented (a similar outbreak was documented during 1956 and more recently in the early 2000s). Remember that our current forest conditions are the result of human impacts and ecosystems are not static. Periodic disturbances help keep our forests healthy.

6. Do bark beetles fly?

Yes. The literature has documented pine bark beetles flying up to 2 miles and there is also evidence that beetles may occasionally disperse long distances via wind currents. In general, they appear to colonize suitable host trees nearby rather than fly long distances.

7. How do bark beetles select a susceptible host tree?

Stressed pine trees emit volatile compounds (terpenes). Bark beetles have evolved to detect these compounds and use them to identify suitable host trees. Many insects communicate with other insects by emitting pheromones (chemical compounds that trigger a specific behavior). Once a bark beetle has located and colonized a susceptible host tree, it emits an aggregation pheromone that attracts other beetles. After enough bark beetles are attracted to that tree, beetles emit an anti-aggregation pheromone signaling them to locate another host tree. In this way, it is thought that bark beetles partition available food among the population.

8. When do the bark beetles start to become active in spring?

Activity varies by species and location and is usually dependent on temperature. In general, once daytime highs begin exceeding temperature of 60°F beetle activity is likely. Bark beetles in Phoenix and Tucson may fly virtually year round, but may be impacted in the summer by extreme heat. In Arizona, at the lower elevations where ponderosa pine grows naturally, beetles have been collected as early as March, while at the higher elevation flights may not begin until late April or May. Timing of beetle flight is important to consider when planning insecticide treatments on un-colonized trees.

9. How many flights (generations) will the beetles have in one year?

The number of flights commonly found in the literature is three. This appears to be variable depending on fall temperatures and localized conditions. During 2002, bark beetles appeared to be actively colonizing trees in late November. They may have had six or seven flights during 2002 in Prescott. This is not proven by actual research, but only by observation and some knowledge of their generation time.

10. Can the wood in beetle-killed trees be used for anything?

Yes. The wood (xylem) is largely undamaged in the first year. Although bark beetles carry blue-stain fungi, these fungi do not breakdown wood, they invade the cells but cause no change in wood structure. Although bark beetles can carry other fungi that do cause decay,

these fungi typically just decay the outer sapwood of the tree. The majority of wood decay organisms come in following tree death no matter how a tree died, and are typically wind dispersed. Significant breakdown in wood structure takes more than a year. Some homeowners utilize the material as firewood. However, if you choose to keep any material on-site, you should strip off the bark or cover the material with plastic as described below.

11. How fast will the beetle-killed trees decay and break apart?

The deterioration rate of bark beetle-killed trees is probably not significantly different than the rate of lightning or fire-killed trees. The available research indicates that no matter how a tree died, it is the species, size, and location that determines the rate of deterioration. For ponderosa pine trees in the 10-12 inch DBH (diameter breast height) range, a few trees start to fall down after the 2nd year, but the majority come down in the 4th and 5th years. For trees greater than 18 inches DBH, the tops usually break off before the entire tree falls. Although bark beetles carry blue-stain fungi, these fungi do not breakdown wood, they invade the cells but cause no change in wood structure. The other fungi they carry do cause decay in the outer sapwood, but the major wood decay organisms come in following tree death no matter how the tree died, and are typically wind dispersed.

12. Why has it taken so long for entomologists and other experts who knew of the potential for a beetle outbreak to develop a means of defense?

The pine bark beetles are native insects that are reacting to favorable conditions for their reproduction. Factors such as fire occurrence and suppression, human activities, and variable weather patterns all interact to create the forest we see at any given time. When stands of timber become too dense, resources (primarily water) become scarce natural processes cause mortality in the stand. Prior to European settlement, northern Arizona's ponderosa pine stands had 20 to 40 trees per acre. Today, many areas of northern Arizona have 800 to 1,200 trees per acre. This is a much greater density than can be supported under our climatic conditions. The bark beetles are simply one of the natural checks and balances that are regulating forest density. The application of science-based forest management can largely control when and where mortality occurs. Some potential forest management tools include natural and prescribed fire, mechanical thinning, controlled grazing, and timber harvest.

13. What are natural enemies of bark beetles?

Just like the pine trees have bark beetles and other organisms to keep their populations in check, bark beetles have an array of natural enemies. Woodpeckers and other birds may eat some bark beetles. Some insects are known to control bark beetle populations under endemic (non-outbreak) population conditions. Predaceous beetles such as the blackbellied clerid (*Enoclerus lecontei*) and a trogositid beetle (*Temnochila chlorodia*), a predaceous fly (*Medetera aldrichii*), and parasitic wasps are natural enemies of beetles but rarely control them. These insects are known to have some effect on bark beetle populations, but most experts feel that parasites and predators of bark beetles are a minor factor in controlling bark beetles. In most cases biotic factors (cold temperature and abundance precipitation) or lack of susceptible food source (size, species, tree vigor, etc.) are the mechanisms that appear to stop an outbreak.

14. What can be done to manage bark beetles on small land ownerships?

Infested trees should be removed and taken off site to a location with no susceptible host trees. The dead and down material (slash) is a refuge for bark beetles, allowing them to breed, and possibly colonize nearby healthy trees. Thinning of stands is a good preventative measure. However, thinning (removal of otherwise, healthy, live trees) is not recommended under outbreak conditions. The disturbance caused by removal may cause stress in remaining trees and predispose them to bark beetle colonization.

15. Can the infested material be chipped and left on site?

Chipping large amounts of pine tree debris will generate large quantities of chips. Freshly processed chips emit the same volatile compounds (terpenes) as susceptible host trees. These chips will attract bark beetles during their active periods. The bark beetles cannot utilize the chips as a food source, but the attracted bark beetles may then colonize suitable host trees adjacent to the chips piles.

16. How can we protect the remaining ponderosa pines on our property?

Un-colonized trees can be protected using tree methods: 1) deep infrequent irrigation; 2) application of preventative insecticides; and 3) thinning of the stand. More details on each of these options follow.

17. How should un-colonized trees be irrigated?

If these trees are irrigated, they should be given enough water to wet the soil to at least a two feet depth. The water should be applied in a donut shaped pattern at the drip-line or outer edge of the trees branches. It generally takes about 2" of rain to soak 2 feet deep. Check the soil 6 to 8 inches deep just outside the drip-line of the trees monthly. If the soil is dry, then water. Generally, the months that most often warrant watering are May, June, and October. However, depending on weather patterns watering may be needed any month of the year. If current dry conditions continue this winter you may need to irrigate in March or April. Keep in mind watering restrictions that may be in effect in your community and follow those guidelines as well.

18. How do I thin my forested property to prevent bark beetle colonization?

Unless you have formal training in forest management, it may be best to consult with a certified forester or arborist. For a listing of certified professionals consult the yellow pages or the International Society of Arboriculture (a listing of local arborists is available at the following web site: www.isa-arbor.com). Stewardship Foresters at the Arizona Department of Forestry & Fire Management are also available to provide guidance on forest thinning. Find out to contact a Stewardship Forester by calling (602) 771-1400.

19. What insecticides can be used to control pine bark beetles?

There are no pesticides labeled or proven effective for the control of *Ips* or *Dendroctonus* bark beetles after a tree is infested. Once the tree is infested it is dead. This includes microinjection insecticides (Mauget or Acecap). Furthermore, beware of companies that claim their organic treatment or fertilizer will prevent attacks by bark beetles. These claims are not backed by peer-reviewed, statistically valid, scientific research.

20. What insecticides can be used to prevent pine bark beetles for colonizing trees?

Three pesticides are labeled and recommended for prevention of colonization by *Ips* and *Dendroctonus* bark beetle species. These pesticides contain the active ingredients carbaryl (trade name Sevin SL) or permethrin (trade names Astro and Dragnet). These active ingredients are present in several other trade name pesticides. However, these other products are not formulated or registered for use on pine bark beetles. These pesticides coat the bark and act as a stomach poison to beetles that chew into the bark where it is coated. Pesticide labels are legally binding documents and all pesticides must be applied in compliance with product label directions.

21. When is the best time to apply preventative pesticide treatments?

The preventative treatments must be applied prior to the bark beetle's first flight in spring or host tree attack. If applying preventative treatments after beetles have become active in spring, the tree must be inspected prior to treatment to ensure that it is not colonized. Highly stressed trees may not produce pitch tubes and outward signs of colonization may not be visible from the ground. In these cases, it may be best to hire a climber to inspect the tree to ensure the tree does not have bark beetles in it. Once the bark beetles have entered the tree, no products are effective at controlling them.

22. How often should preventative pesticide treatments be applied?

According to the Sevin SL label, no more than two applications per year (once every six months) should be applied. According to the Astro label, users should apply no more than 2 lbs of active ingredient/acre/year. You can always contact the manufacturers of these products for more information. Pesticide labels are legally binding documents and all pesticides must be applied in compliance with product label directions.

23. Can homeowners apply these pesticides themselves?

Although the above-mentioned pesticides are not labeled as "restricted use", they do require specialized equipment to correctly apply them. For instance, according to label directions of Sevin SL, the diluted pesticide must be applied to the entire tree trunk from the soil level up until the trunk diameter is less than 5 inches. Few homeowners have the equipment needed to make this application. It is the recommendation of forest health specialists to hire a certified professional pesticide applicator. They are trained in proper handling of pesticides, have the proper equipment, insured and bonded, and aware of the consequences for misuse of pesticides. These applicators should also be able to provide you with a product label and material safety data sheet (MSDS) upon request.

24. How do the recommended pesticides affect non-target organisms such as birds, fish, and other insects?

Carbaryl (the active ingredient in Sevin) is slightly toxic to birds (LD50 > 5,000 mg/kg in mallard ducks and bobwhite quail) and fish (LC50 = 1,950 mg/L in rainbow trout and LC50 = 6,760 mg/L for bluegill sunfish). Sevin is highly toxic to honey bees.

Permethrin (the active ingredient in Astro and Dragnet) is highly toxic to fish (LC50 = 0.5 mg/L to 315 mg/L) and aquatic arthropods (LC50 = 0.2 mg/L to 7.6 mg/L). Permethrin is

slightly toxic to birds and oral LD50 values are greater than 3600 mg/kg. Longer dietary studies showed that concentrations of up to 500 ppm in the diet had no effect on bird reproduction.

25. Are thinned and healthy trees still at risk?

Yes. When populations of bark beetles reach high levels no tree is 100% safe from colonization. Deep infrequent irrigation, stand thinning, removing colonized material, and preventative pesticide applications simply increase the probability that any given tree will survive the current outbreak.

26. Is wood used in homes as structural material at risk of being colonized by bark beetles?

No, wood that has been debarked is not suitable for colonization by bark beetles. Only freshly cut, logs or slabs that have not been debarked are at risk of colonization.

27. If a pine tree has a dead top, but has a lower portion that appears to be healthy, can it be saved by removing the top?

The likelihood of saving a pine tree with a dead top is very low. Anecdotal information indicates that some trees have been saved in this manner. If a tree does survive, the wound created by removing the top will never callous over. This leaves a point where disease organisms (primarily fungi) can enter the tree and weaken it over time. For this reason, the entire tree should be removed.

28. Are junipers, Arizona cypress, Leyland cypress also at risk?

Yes. These trees are colonized by a different species of bark beetle (*Phloeosinus* sp.) that utilizes these tree species. The biology and life cycle of this bark beetle is slightly different than the pine bark beetles. Consult the publication: Cypress Bark Beetles in North Central Arizona, by Jeff Schalau, available on the web at extension.arizona.edu/sites/extension.arizona.edu/files/pubs/az1316.pdf

29. What are some bark beetle-resistant evergreen trees that can be used in northern Arizona landscapes?

Some suitable evergreen trees for the lower elevations (5,500 to 6,500 feet) are Deodar cedar (*Cedrus deodora*), Atlas cedar (*Cedrus atlantica*), and Lebanese cedar (*Cedrus libani*). At the mid elevation ponderosa pine belt (6,500 to 7,500) some good trees are Norway spruce (*Picea abies*), Colorado blue spruce (*Picea pungens*), Engelmann spruce (*Picea engelmannii*), Douglas-fir (*Pseudotsuga menziesii*), Corkbark fir or (*Abies lasiocarpa*), White fir (*Abies concolor*), These have few, if any, pests and are relatively fast-growing. Evergreens have the advantages of providing year-round privacy screening and pine-like foliage. They do require infrequent irrigation to keep them healthy. These species are not as fire retardant as deciduous trees due to their resin content. For this reason, evergreens are not recommended for use next to structures where they may increase risk of property loss in case of forest fire. Elevation strictly speaking is not always an indicator of which tree to plant on each site. Native vegetation is usually a better in indicator. Lower elevation type sites will have piñon pine whereas as the mid elevations will have predominately ponderosa pine. For

more information on trees suitable for the high elevations of the southwest refer to "Beyond the Ponderosa: Successful Landscape Trees for Higher Elevations in the Southwest." 1998. T. DeGomez and J. D. Bailey (Eds.) 1998. Flagstaff Community Tree Board, Flagstaff, Arizona.

30. Is there any type of trap that can be used on personal property to draw the beetles away from healthy trees?

Currently, pheromone baited traps are used to monitor beetle populations. They are not a practical, tested method of population control. Research continues in this area and the use of pheromones may assist in bark beetle population management at some time in the future.

31. Do the ponderosa pine bark beetles colonize pinyon pine trees?

No. Another species of pine bark beetle colonizes pinyon pines: pinyon Ips (*Ips confusus*). This beetle is host specific to pinyon pine, but looks and behaves very similar to the species of Ips that colonize ponderosa pine trees. These beetles can be managed using the same strategies as other pine bark beetles.

32. If the lower part of a pinyon pine has a soapy gray residue at the base of the trunk and in the branch crotches is this a sign of the bark beetle?

No. This material is an egg mass of another insect: pinyon needle scale (*Matsucoccus acalyptus*). These insects weaken pinyon pine trees by decreasing the number of needles (photosynthetic area) leading to a reduction in their ability to produce and store energy. This, and other factors, may predispose them to colonization by pinyon Ips.

33. Will all the bark beetle damaged trees presently in the forest make it vulnerable to fire next year?

There are multiple, interacting factors that determine fire risk. Most research on the interaction between bark beetle killed trees and fire has been conducted using fire models. The models suggest that the potential for active crown fire is high while the red needles are still on the tree. Once the needles have dropped to the forest floor, the danger decreases. Weather, moisture and wind, are obviously factors that strongly influence fire risk and intensity and these interact with the available fuels, both live and dead.

34. Will soil erosion be a problem in the forest after all the damaged trees are removed?

In most areas, the grasses, shrubs, and residual trees should provide enough ground cover to prevent accelerated soil erosion. Where there are large areas of bare ground, seeding with native grasses (blue grama, sideoats grama, sand dropseed) will most effectively prevent excess erosion. These should be seeded in June. Irrigation during the first growing season will increase success of grass seeding.

35. Should ponderosa pines be replanted on sites affected by bark beetles?

In most areas, there are many ponderosa pine seeds in the soil. These will germinate and grow if conditions are favorable. If natural regeneration does not occur, then it is not advisable to replant ponderosa pines.

36. What is the U.S. Forest Service doing about the pine bark beetles on their land?

In any given area, the US Forest Service is actively working to improve forest health and resiliency. In addition, the US Forest Service has an active program to remove currently infested trees and hazard trees from developed recreation areas. Removal of all dead/infested trees at the landscape level is not a realistic or environmentally sound objective. In addition, the US Forest Service must comply with environmental laws that govern activities on public land. To find out more about US Forest Service activities in your area, contact your local District office.

37. What will be the long-term impacts of the current bark beetle outbreak?

The risk of catastrophic wildfire is increased in the short-term where bark beetle-killed trees are not removed (see question 33). Other longer-term impacts are largely unknown. However, potential negative impacts could be: loss of soil due to accelerated erosion; increases of invasive plant species in response to disturbance; decreases in real estate value on properties where tree losses were very high.

The disturbance caused by bark beetle mortality will undoubtedly change vegetative characteristics. Many of these changes could be perceived as beneficial to the impacted ecosystems. A significant reduction in woody species will likely be accompanied by an increase in native herbaceous species such as grasses and forbs. These species have reduced water consumption and are desirable forage for wildlife and domestic livestock. In addition, grasses have fibrous root systems that stabilize soil and aid in soil development. The reduced water consumption could also result in increased water yields from impacted watersheds. This increase in water yield could potentially help recharge local and regional aquifers. Other potential ecosystem benefits will certainly be recognized over time.

38. Is it safe to move bark beetle infested firewood to other areas?

Actually moving bark beetle infested ponderosa or pinyon pine firewood to an area where native pines do not grow is a good way to prevent the spread of the beetles. Likewise one can move infested juniper or cypress firewood to an area where juniper and cypress do not grow.