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Short Note

Identification and management of heart-rot fungi

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Heart-rot fungi are key players in trees health, diversity and nutrient dynamic in forest as pathogens and decomposers along with a number of invertebrates are associated with Wood-decay fungi serve as vectors for fungal pathogens, or are fungivorous and influence rates of Wood-decay and nutrient mineralization.

A number of fungi, *viz. Polyporus* spp., *Serpulala crymans*, *Fusarium negundi*, *Coniophora cerebella*, *Lentinus lapidens* and *Penicillium divaricatum* cause destruction of valuable timbers by reducing the mechanical strength of wood. Molds cause rotting of the heartwood in the middle of tree-branches and trunks. Wood-decay fungi can be classified according to the type of decay that they cause. The best-known types are brown rot, soft rot, and white rot. Each type produces different enzymes, can degrade different plant materials, and can colonize different environmental niches (Bednarz *et al*. 2013).

Wood-decay fungi are also divided into those that attack heartwood causing heart-rots and those that attack sapwood causing sap rots and canker rots. Further subdivision (white rots, brown rots, and soft rots) is based on the appearance of the decayed wood or location in the tree; the decay is called a butt rot if it is at the base of the trunk (Vasaitis, 2013). Canker rots usually appear on branches or the trunk. When a fruiting body is visible on a tree, it is usually associated with advanced decay; the extent of decay may be far above or below the location of the fruiting body. Trees with extensive sap rot may show symptoms of decline, including increased deadwood and a thinning canopy with reduced density of foliage.

White rots

White rots break down all the major wood components *i.e.* cellulose, hemicellulose and lignin, and commonly cause rotted wood to feel moist, soft, spongy, or stringy and appear white or yellow. Mycelia of fungi colonize much of the woody tissues. White rots usually form in flowering trees (angiosperms) and less often in conifers (gymnosperms). Fungi that cause white rots also cause the production of zone lines in wood, sometimes called "spalted wood". This partially rotted wood is sometimes desirable for woodworking. The examples of white rot fungi are *Armillariell amellea*, *Pleurotus ostreatus*, *Coriolus versicolor*, *Cyathus stercoreus*, *Ceriporiopsissu bvermispora*, *Trametes versicolor*, *Hetero basidionannosum*, and so on.

Brown rots

Brown rots primarily decay the cellulose and hemicellulose (carbohydrates) in wood, leaving behind the brownish lignin. Wood affected by brown rot usually is dry, fragile, and readily crumbles into cubes because of longitudinal and transverse cracks occurring which follow cellular lines, or across cells, respectively. The decay commonly forms columns of rot in wood. Brown rots generally occur in conifers as heart-rots. Hardwood trees are more resistant to decay by brown rot than by white rot fungi. Only about 6% of wood-decay fungi cause brown rots, and all these fungi are members of the basidiomycota. Examples of brown rot fungi are *Laetiporus portentosus*, *Fomitopsis lilacinogilva*, *Schizophyllum commune*, *Piptoporus betulinus*, etc.

Soft rots

Soft rots are caused by both bacteria and fungi. These organisms break down cellulose and hemicellulose but only in areas directly adjacent to their growth. Soft rot organisms grow slower than brown or white rot organisms, and therefore damage occurs to the host tree more gradually. Given enough time, however, any rot can cause extensive structural damage. Examples of soft rot fungi are the members

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of the genera *Phoma*, *Cephalosporium*, *Phialophora,Pestalozzia, Chaetomium*, etc. Bacterial soft rots are caused by several types of bacteria, but most commonly by species of gram-gramnegative bacteria, e.g., *Erwinia, Pectobacterium, Pseudomonas,* etc.

Causes of heart-rot

Heart disease in trees is caused by fungal invasions. Although there are many species of fungi which cause decay in living trees, most important are those that cause heart decay, often called heart-rot. These pathogens usually enter a tree as a result of injury. Such points of entry may come from broken branches caused by wind, fire, lightening, and even from improper pruning by humans. Fungi kill the tree's hemicellulose, cellulose, and sometimes its lignin, ultimately causing the fall of tree (Leelavathy & Ganesh, 2000).Heart-rot disease cannot be visible because all the rot sareconcerted inside. Fungi cause decay after they enter a tree. Heart-rot can occurs in many hardwoods, and all deciduous species can get heart-rot (Table 1),but it is especially found in Sal (*Shorea robusta*), Simal (*Bombax malabricum*), Asna (*Terminalia termentosa*), Sisso (*Dalbergia sisso*), Salla (*Pinus rosburghi*),Katus (*Castenopsis indica*), Chilaune (*Schima wallichii*), and oak (*Quercus glauca*.) in Nepal (Sinclair & Lyon, 2005; Jha & Tripathi, 2012; Aryal & Budhathoki, 2013; Acharya & Parmar, 2016).

Symptoms of heart-rot

Detecting heart-rot can be difficult as it occurs internally and remains out of sight for many years. Usually, in the latter stages of heart-rot, mushrooms grow on the trunk or branch. This is one of the first visible signs that a fungal pathogen resides within a tree and primary pathogens that directly kill living sapwood cells in advance of infection (Shortle *et al*., 1996). Unfortunately as decay progresses, the heartwood is destroyed and the integrity of the tree's strength becomes a serious issue. These external mushrooms are the fruiting bodies of the fungi generally called "conks" or "bracket fungi". These visible conks produce spores. Spores become wind-borne and microscopic. Wind carries spores to other susceptible trees, thus perpetuating the life cycle of conks. These fungi appear bracket-like, attached to the tree and varying greatly in size, color and texture. Eliminating or minimizing heart-rot can keep tree healthy. Proper mending can take place with pruning branches, making cuts just outside the branch collar. Major branch removal creates small wounds,and thus shapes a tree at an early age. So, the broken branch-stubs should be removed immediately following storm damage, and the suspected trees with heart-rot should be checked by an arborist to determine structural safety of live wood.

Prevention and control of heart-rot

As long as a tree is growing vigorously, rot will be confined to a small central core within the tree. This behavior is called "tree wood compartmentalization". But if the tree is weakened and fresh wood exposed by severe pruning or storm damage, decay fungi can advance into more and more of the tree's heartwood. There is no economically feasible fungicide to use on a tree that hosts the heart-rot fungi. The best way to prevent heart-rot in hardwood tree is to keep it healthy using following proper management techniques:

- Minimize pruning wounds that expose large areas of wood.
- Prune periodically to remove all dead, dying, interfering, and broken branches. Prune broken stems below the damaged portion so that water will drain off and not collect on the wound surface. The severed ends of roots should be made blunt rather than left jagged. Pruning is best done during the dormant season when the weather is dry ; pruning in late spring often leads to separation of wood and bark around pruning wounds.
- Identify the trees suspected of heart-rot and get them checked by an arborist to determine whether sufficient live wood is present for structural safety.
- Whenever feasible, keep woody plants vigorous through- proper applications of fertilizer in mid- to late-autumn or early spring; soaking of the soil to a 12-inch depth every 10 to 14 days during extended hot, dry periods; and wrapping the trunks of newly transplanted, thin-barked trees with Sisalkraft paper, special tree-wrapping paper, or other appropriate material prior to winter.

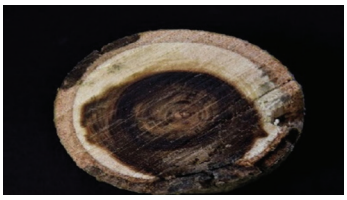
- Check trees every few years, and be certain about new growth maintaining a sound structure; large trunks and main branches with extensive decay may have little sound wood to support the tree.

- Avoid all unnecessary bark wounds. When bark and wood injuries do occur, treat them promptly. Cut away all loose or discolored barks. Remove splintered wood. Clean, shape, and smooth the wound into a streamlined oval or vertical ellipse, and then swab the surface liberally with an antiseptic such as 70 percent alcohol or shellac; the use of a commercial tree wound dressing (tree paint) is of questionable value since it does not check the invasion of wood by decay fungi. The barrier zone of cells formed by the cambium effectively confines the decay within the tissues present at the time the tree is wounded. The use of tree wound dressings is largely cosmetic and their usefulness in preventing Wood-decay is questionable.

- Control discoloration and decay in lumber and other wood products by drying the wood in a kiln or by treating with a recommended wood-preserving fungicide. Wood likely to be in contact with soil or moist surface should be treated with a wood preservative.

- It can be very hard to prevent and control heart-rot, but may be avoided, if a tree is carefully monitored over its entire lifetime.

Table 1. Wood-decay fungi associate trees

Fungal pathogen	Common hosts	Symptoms
Inonotus dryophilus  	*Larix*, *Abies*, *Tsuga* and *Picea* spp., oak, and other broadleaved woody species: highly susceptible.	Decay is a white pocket rot of the heartwood of living trees, usually in the upper bole and large branches (unlike inonotus root and butt rot, which always occurs near ground level). Annual conks appear on upper bole usually near knots, broken branches or pruning wounds. Conks are large (3.5 to 12 inches in diameter), thick, usually shelf-shaped, light brown initially, then dark brown. The decay consists of long white pockets (pipes) separated by darker and more solid wood. Conks deteriorate during winter to a very dark-brown color, and usually fall from tree within a year of formation.
Cytospora spp.  	Wide variety of forest trees including *Populus alba*, *Juglans regia*, *Salix pyrunus*, eucalyptus, and pine.	*Cytospora* species cause branch dieback and cankers on trees. Bark often splits along the canker margin as the tree is protecting itself and callus formation occurs. The fungus may quickly girdle and kill twigs without forming cankers .Bark above infected cambium may appear sunken and yellow, brown, reddish-brown, gray, or black. Diseased inner-bark and cambium turns reddish-brown to black, and becomes watery and odorous as it deteriorates. Liquid-ooze on aspen and gummy-ooze on *Populus*, *Salix*, *Juglans* spp. and *cherry* are common. Cankers, sunken dead areas of bark with black pinhead-sized speckling or pimples, may be evident. Species differentiation in Cytospora has relied mainly on conidiomata/ ascomata morphological characters, including locule shape/organization and spore dimensions (Wang *et al*., 2011).

Monilinia fructicola 	Numerous ornamental plants and fruit trees including peach, apple, cherry, citrus, maple, oak, and olive.	Brown rot is an economically important fungal disease especially on peaches, apple and cherry. Symptoms-infected flower parts turn light brown, and may develop areas of buff-color or gray spores. Infected petals may look water soaked, which can be mistaken for frost injury (Gell *et al*. 2008). Flowers generally collapse as the fungus invades through the pedicel. Infected flowers often adhere to twigs and spurs during the harvesting season. This pathogen is a major yield limiting factor of many orchards and natural forest and is very active in wet season. On peach, the disease continues into twigs or spurs. Lesions may remain discrete or may girdle the twig, causing all distal portions to die. Profuse gumming also may occur in these areas. Again, buff or gray spores may develop on these necrotic twigs (Burnett *et al*. 2010). Fruit symptoms begin as small, dark spots that enlarge rapidly. Fruit remains fairly firm and dry relative to a watery-rot caused by *Rhizopus* spp. Production of masses of buff-colored spores is equally rapid in the necrotic area. Peaches may have concentric rings of gray sporulation as the rot takes a few days to encompass the entire fruit.
Phytophthora alni 	Alder	All alder (*Alnus* spp.) species are threatened by a lethal disease, which was first discovered in 1993 in Britain. The causal agent is a formerly unknown species of *Phytophthora*, named *P. alni*, which is highly specific to alder. The disease is now considered to be one of the most important diseases of natural forest. Infected trees possess small, yellow and sparse summer leaves, thin and sparse crowns. Trees that have suffered infection for several years have dead twigs and branches in the crown. Heavy cone production and bleeding visible as tarry or rusty spots at the base of the tree.
Laetiporus gilbertsonii 	*Acacia* spp., birch, cherry, chestnut, elm, eucalyptus, fir, oak, sissoo, pepper tree, pine, poplar, spruce, and walnut.	The fungus causes a brown heart-rot on living trees but also will decay dead trees. It is one of the few brown rot fungi of hardwood trees. It can enter trees through bark wounds and dead branch stubs. This fungus is one of the most serious causes of decay in oaks and eucalyptus. The soft, fleshy, moist conks range from 2 inches to over 20 inches wide, and are bright orange yellow above and red yellow below. Conks are produced annually and appear singly or in clusters, usually in fall; they become hard, brittle, and white with age. Conks do not appear until many years after the onset of decay and indicate extensive internal damage.

Pleurotus ostreatus 	*Acacia* spp., alder, ash, beech, birch, chestnut, elm, eucalyptus, sissoo, maple, oak, *Albizzia* sp., walnut, and teak.	This fungus decays heartwood and sapwood, causing a white, flaky rot. Infections occur through open wounds, and decay is most extreme when wounds are large. A bunch of shelf-like mushrooms, each 2–8 inches wide, is produced annually and can indicate localized decay or heart-rot that extends up to10 feet in either direction. The mushrooms are smooth on the upper surface with gills that characteristically extend down along the stalk on the lower surface.
Schizophyllum commune 	Many species of trees including *Acacia* spp., birch, eucalyptus, juniper, laurel, teak, magnolia, oak, pine, poplar, walnut, and sissoo.	This fungus causes a white rot of sapwood and produces annual fruiting bodies that are hairy and white to pale brown when young but darken with age. The stalk-less brackets are tough, leathery, about 1–4 inches wide, and usually found in clusters. The pale gills on the underside have the appearance of being longitudinally split, hence the common name. The fungus colonizes trees stressed by heat, sunburn, drought or major wounds. It generally grows on cut and fallen wood and dead parts of living trees.
***Stereum* species** 	*Acacia* spp., alder, birch, catalpa, cherry, chestnut, elm, eucalyptus, fir, juniper, magnolia, maple, oak, pine, sequoia, spruce, and willow.	This group of fungi are commonly found on dead trees, branches, and stumps but rarely cause serious decay in living trees. They can cause heart-rot on trees wounded by pruning or bark injury. The annual fruiting bodies are thin, leathery, and bracket-like, lack stalks, and are 1 inch or more across. The upper surface is gray brown whereas the lower side is buff to brown and smooth, lacking tubes or pores.
Trametes hirsuta 	Alder, ash, birch, catalpa, cherry, chestnut, citrus, elm, eucalyptus, fir, ginkgo, holly, juniper, maple, oak, pine, poplar, and walnut.	This fungus, which causes white rot, can enter a tree through dead wood exposed by fire scarring; decay begins as a sap-rot and can continue as a heart-rot on some woody species. It often produces fruiting bodies on the dead portions of live hardwoods; fruiting bodies are tough, leathery, usually stalk-less, shelf-like, and 1–10 inches wide. The outer surface is dry, velvety, and has concentric zones whereas the under surface is poroid.

Trametes versicolor 	Alder, apple, birch, cherry, chestnut, crape myrtle, elm, eucalyptus. gingko, blackberry, juniper, maple, nectarine, oak, poplar, walnut, and willow.	This fungus is commonly found on cut and fallen wood and on wounded areas of living trees; also, it is capable of colonizing sapwood of trees and shrubs stressed by water shortage, sun-burn, freeze damage, or wounding. The fungus, which causes a white, spongy rot of wood, can actively invade and rapidly kill the cambium (the tissue between the bark and wood), causing cankers with papery bark and dieback. The annual conks are thin, leathery, stalk-less, bracket-like, 1–4 inches across, and often found in groups. The upper surface is velvety with concentric zones of various colors, and the lower surface is cream colored and minutely poroid (Gilbertson & Ryvarden, 1986).
Phellinus igniarius 	Apple, birch, elm, cottonwood, lilac, poplar, pear, walnut, oak, and teak.	*Phellinus* produce perennial conks with a "hoof" like appearance- dark and cracked above and tan or ochre below, with small pores. A new hymenium or spore bearing layer is added each year. These are white rotting fungi common on various species of hardwoods and softwoods. These cause heart-rots on intact trunks.
Biscogniauxia mediterranea 	Mango, oaks, maple, pecan, golden raintree, and walnut.	*Biscogniauxia* is an Ascomycete fungus that resides in trees as a latent infection not causing symptoms. When trees are stressed by drought, the fungus invades the sapwood, decaying it extensively and cutting water supplies to the canopy. Fruiting bodies are long sheets of charcoal-like stroma that emerge through and from under the bark of affected hardwoods. Conidia proceed the dark charcoal sexual fruiting bodies.
***Annulohypoxylon* spp.** 	*Syzygium cumini*, oak, maple, alder, birch, apple, cottonwood, and elm.	*Annulohypoxylon* spp. are in the same group as *Biscogniauxia*, but fruiting bodies form on the surface of bark in a concentric- or globe-shaped stroma. They only form on dead wood and indicate that the sap-rot fungus has killed that portion of the standing tree. The young fruiting bodies are cream-colored and covered in asexual spores called conidia in early summer or late spring. These later darken into structures that contain the sexual ascospores.

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