Allelopathy In Trees

by Dr. Kim D Coder, Daniel B. Warnell School of Forest Resources,
University of Georgia 4/99

Trees have developed in ecological systems filled with many other organisms. The environment, shared by all, contains limited resources and less-than-ideal growth conditions. All living things have strategies to thrive in this intense struggle for life. There are not a lot of clear winners or losers, but many survivors. Allelopathy is one strategy of life.

The study of allelopathy (allelochemics) has only become a major thrust in tree biology in the last 30 years. The term "allelopathy" is from Greek meaning "to suffer from each other." Allelopathy has traditionally been considered only the negative chemical warfare of one organism upon another. Modern research suggests that allelopathic effects can be both positive and negative, depending upon the dose and organism affected. Allelopathy is the active or passive effects of chemicals released into the environment which influences other organisms.

Tree Biology

In a tree's biological system, the economics of elements, nutrients, water, light, and metabolites control health and growth. If a tree existed in an environment containing only itself and the physical environment (without other organisms), the physiology of the tree, the dynamics of the physical environment, and the tree's genetic framework would dictate the upper limits of tree health and growth.

The addition of a host of other living things — trees, shrubs, understory plants, fungi, bacteria, round-worms, insects, lichens, etc. – would initiate changes in our one-tree model. Expanding the one-tree model to include many individuals, the problems of health and growth would include: control of physical space, competition for physiological inputs, and chemical modification of the site. Trees have developed a number of processes to gain and control the ecological volume needed for life.

Interference

For a tree to be biologically efficient and ecologically effective, it must interfere with other surrounding species. This interference has two primary components: competition and allelopathy. Competition is the control or removal from the common environment of essential resources needed for life. Allelopathy is the addition of materials to the common environment which changes life functions. Allelopathy is the biochemical modification of the environment to enhance tree survival and reproduction

Interference is the proper name for individual ecological interactions. The word "competition" is mis-used / over-used to describe species interactions. Rarely is allelopathy isolated or eliminated in competition studies, and so, the combined term "interference" is most accurate to use. Allelopathy is a defensive component of tree interference.

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Communicating Resource Control

Allelopathy is the biochemical interactions between individuals and an ecological communication system which is transmitted externally. There are many materials inside a tree that would be beneficial or damaging to other organisms if they were released. Some are quite toxic. Most of the compounds generated inside a tree can (and do) leak out of a tree in some form and at some concentration. Most of these materials do not have a significant allelopathic effect in the environment. A few chemicals do have an ecological effect and are called allelopathic chemicals or allelochemicals.

Terminology

Allelopathic materials inside a tree can produce major changes in the survival, growth, reproduction and behavior of other organisms if they escape into the environment. These effects can be positive or negative. The most famous of the allelopathic materials used by humans are anti-biotics — allelopathic agents conveyed by microorganisms to other microorganisms. There are four main allelopathic classes of chemical interactions: anti-biotics (microorganism to microorganism); kolines (plants to plants); marasmins (microorganisms to plants); and phytoncides (plants to microorganisms).

Allelopathic chemical can be conveyed by trees and affect seed germination, root growth, shoot growth, stem growth, symbiotic effectiveness, microorganism-based soil transformations, pathological infections, insect injury scope and scale, and environmental stress impacts. These allelopathic chemicals can be received and influence other species, as well as parts and properties of the same tree. In allelopathic terms, a chemical is “conveyed” to a “receiver” which can either be “impaired” or “assisted.”

Messing With Pathways

Within any organism, every enzymatic step of life can be influenced by internal health and external environment. The string of processes that propel life have been carefully balanced over time to be conservative of energy and physical resources. Small changes or disruptions in flow patterns and rates of change between internal pools of materials can lead to rapid health changes and death. Rates of change which are too fast or too slow, compared to ideal, can modify or stop an essential process, or change an associated pathway. It is the subtle changes in the stream of dynamic life processes which are affected by allelopathy.

Most allelopathic effects are broad spectrum, influencing many biological processes. The points of influence for most allelopathic compounds are at the cell membrane, the double-wall membranes of cell organelles, energy production steps, and energy use processes. A few allelopathic chemicals are specific to one enzymatic step. Usually, a number of allelopathic compounds are conveyed to influence a number of growth processes. Allelopathic chemicals can be damaging or stimulating depending upon dose – too much or too little can change growth.

Relative Impacts

Many organisms respond quickly to allelopathic attack by breaking-up the chemicals or transforming them into non-damaging forms. As a general rule, the longer species have lived together, the less allelopathy affects their interference. New species combinations, rapid successional changes, and introduced exotic species can generate a large allelopathic effect. Under good growing conditions, allelopathy usually can represent 5-10% of the total interference between species. As stress becomes great, allelopathy increases in importance. Allelopathy is an important consideration in the overall stress in any tree-containing landscape.

Once an allelopathic chemical is outside its producer (conveyor), the chemical is easily modified, torn-apart, reassembled, and/or used by other organisms. Allelopathic chemicals usually have short lives in the environment. Other living things, soil chemistry and physical processes, and organic matter decay rates all can change the form and concentration levels of any compound. The original materials produced in a tree may be modified into other active allelopathic compounds in the soil.

Chemical Location

Allelopathic chemicals can be released or escape from a tree by several means: evaporating into the air or from the soil surface; erosion or leaching from tree surfaces; exudation from roots; and, release by decaying dead organic materials. The chemicals released can be both water-soluble and oil-soluble. They can be absorbed to soil surfaces, coat plant residues, and be carried away in the wind.

Seeds, fruits, buds, and pollen all can have significant concentrations of allelopathic chemicals within. These defensive materials can prevent damage and decay of reproductive materials. Leaves, buds and phloem tissues can generate and concentrate allelopathic chemicals to minimize injury and consumption. Roots can be defended by several allelopathic chemicals to assure longer root survival, and prevention of injury and attack. Allelopathic materials can lengthen survival times in a hostile environment.

Best Offense Is Defense

Allelopathic materials can also be leached, eroded, leaked, or extruded from tissues into the environment. These materials can greatly influence plant, animal, and microorganism populations, species mixes, and growth. Allelopathic materials act as selective and general chemical warfare compounds outside the original producer. If no pathway or means exist to shield, tie-up, or destroy these chemicals in receiving organisms, growth changes will occur. Under high allelopathic chemical levels, even species that can modify the chemical, may spend tremendous amounts of energy minimizing this interference and be left with inadequate food reserves.

Species with large allelopathic components of interference usually modify their own rhizosphere and surrounding soils enough to act as a shield from other allelopathic species. A number of allelopathic species can be found growing together because they each are successfully controlling their own interface with the environment while protecting themselves from the allelopathic materials of others. Production and sequestering of allelopathic materials is energy expensive. Environments with large components of interference due to allelopathy are stressful areas to grow for both the conveyors and receivers.

Amplifying Stress

Allelopathic chemicals can also be produced when an organism is under stress. Nitrogen, phosphorus, water, and temperature extremes can all accelerate allelopathic chemical production. Injury and pests can also rapidly increase base-level concentrations of allelopathic chemicals. Allelopathic chemicals are not newly induced in the tree by stress, but are always present. Their concentrations change continually from day to day, (and from tree part to tree part), as their synthesis and degradation are enhanced or reduced.

Allelopathic chemicals are bundled or concentrated in many forms. Some are tied to sugar molecules which are inactive until bacteria split-off the sugar, releasing the chemical. Other allelopathic compounds are held in unoxidized forms inside cells and only produce an active agent when oxidized by injury or expulsion. Still other compounds are active, but kept sealed in special compartments or along transport corridors until needed. Allelopathic compounds can be made faster at the site of use or can be transported to the site, depending upon the chemical. These chemicals are a significant investment and biologically dangerous for an organism, and so carefully controlled.

Active and Passive

Allelopathic chemicals can be the invitation for mycorrhizal fungi infection while destroying neighboring mycorrhizae. These chemicals can disrupt soil microorganism associations while selecting for specialized beneficial or detrimental organisms. Allelopathic chemicals change the effective density and value of essential resources while allowing for the competitive disadvantaged species to thrive. Allelopathy is a stress generating strategy where food energy is used to produce chemicals for modifying the environment and controlling resource space, rather than using food energy to build structures and maintain transport systems in controlling resource space (as in competition).

Allelopathic actions can be through an active process or through passive means. Passive means include decay of organic matter. The organic matter from a tree may contain either free, bound, or reduced allelopathic chemicals. Another passive effect is found under water stress when many lateral roots are initiated. Many new roots have an increased surface area and proportionally more root exudation. Allelopathic chemical production may have been significantly increased in the tree because of water stress, and the chemical exudation increased because of increased root surface area.

In trees, allelopathy is one portion of the total stress that must be overcome to survive. In the past, allelopathy was often ignored.   As we continue to "fine tune" tree-literate management, allelopathy should be a consideration for tree health care and landscape management. The ecological modification of a site by the organisms present can have acute and chronic impacts on tree health and productivity. The chemical interactions between individuals and between species should be more carefully examined and used for generating the goods and services expected from tree-filled landscapes.

Additional publications:

Coder, Kim D. 1999. Potential Allelopathy In Different Tree Species. University of Georgia Daniel B. Warnell School of Forest Resources Extension publication FOR99-003. Pp.5.

Coder, Kim D. 1999. Tree Allelochemicals: Ways and Means. University of Georgia Daniel B. Warnell School of Forest Resources Extension publication FOR99-005. Pp.4.

Coder, Kim D. 1999. Allelopathy in Trees and Forests: A Selected Bibliography. University of Georgia Daniel B. Warnell School of Forest Resources Extension publication FOR99-002. Pp.7

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