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Biodiversity 2016: Diversified natural products in Rhododendron formosanum reveal allelochemical and pharmaceutical properties

Chang-Hung Chou, Tzong-Der Way, Shang-Jie Tsai, Yun-Lian Jhan and Chao-Min Wang

China Medical University, Taiwan

E-mail: changHung@gmail.com

Abstract

Rhododendron formosanum, an endemic plant in subtropical region of Taiwan, possesses diversity of natural products such as phenolic acids, flavonoids and terpenoids in leaves and other plant parts. Underneath the vegetation, there is almost lacking understory species which turns out to be an allelopathic phenomenon. We have already demonstrated the unique pattern of allelopathy which was due to the allelopathic substances released from the plant leaves. The responsible allelopathic substances are water soluble phenolic acids, namely, p-hydroxybenzoic, methyl-ferulate, syringic acid, vanillic acid, coumarin, and protocatechuic acid. On the other hand, cinnamtannin D1, a trimer of catechin, from the plant induces autophagy via the inhibition of Akt/mTOR activation of ERK1/2 non-small cell lung carcinoma cells.

Rice defined allelopathy as the effect of one plant on growth of another plant through release of chemical compounds into the environment. In 1996, the International Allelopathy Society recommended the following, more wide definition of allelopathy: "any process involving the secondary metabolites produced by plants, microorganisms, viruses, and fungi that influence the growth and development of agricultural and biological system (excluding animals), including positive and negative effects". However, negative effects are observed more often than positive ones. Allelopathy plays a significant role in forest ecosystems for the following reasons: (1) trees release allelochemicals for long periods, and they may accumulate in soil to toxic levels, (2) one or only a few species dominate in the forest plantations, (3) allelochemicals affect the understory, and for some species they can affect the undergrowth, and in some cases can even cause problems in natural regeneration, and (4) introduced highly productive exotic trees may increase accumulation of allelochemicals in soil due to the inability of the local microflora to degrade them.

Allelochemicals are the products of secondary metabolism and have no nutritional value. According to the different structures and properties, allelochemicals can be classified into the 10 categories: (1) water-soluble organic acids, straight-chain alcohols, aliphatic aldehydes, and ketones; (2) simple unsaturated lactones; (3) long-chain fatty acids and polyacetylenes; (4) quinines (benzoquinone, anthraquinone, and complex quinines); (5) phenolics; (6) cinnamic acid and its derivatives; (7) coumarins; (8) flavonoids; (9) tannins; and (10) steroids and terpenoids (sesquiterpene lactones, diterpenes, and triterpenoids). Plant secondary metabolites include about 200,000 compounds, among which the most diverse are terpenoids (30,000), alkaloids (21,000), and phenolic compounds (8000). In allelochemical trees, the most common are the terpenoids and phenolics.

Reigosa described five ways by which allelochemicals can be released into the environment from trees: stem flow, root exudation, leachates from aerial parts during rain, dew, and fog, volatiles from leaves or other plant parts, and litter decomposition. It is interesting to note that the greatest Russian poet Alexander Pushkin in his poem Anchar (1828) described all abovementioned ways of extracting poison from the Antiaris toxicaria tree except for litter decomposition. Studies have shown that various nutrients deficiency, as well as water stress, UV radiation, physical damage by herbivores or interspecific competition can enhance the production of allelochemicals and the sensitivity to allelochemicals.

For effective action, allelochemicals must reach a certain concentration. Their release is influenced by such environmental factors as temperature, duration and intensity of rainfall, type of soil and soil humidity. Degradation by soil microorganisms also plays an important role in the accumulation of allelochemicals. Most allelochemicals are rapidly biodegraded in the soil, especially phenolics. The term ''phytotoxicity'' was introduced to distinguish allelopathy (as interactions occurring in natural environment) from studies of plant extracts or allelochemicals (purified or synthetized) under controlled conditions. The most common method for assessing phytotoxicity is the Petri dish bioassay of extracts (leachates) on seed germination and seedling growth. Such studies are usually carried out on model plants, for example, Lactuca sativa, because of their rapid germination and genetic homogeneity. It allows comparing the results among different studies. Evaluation of plants in the soil, in the greenhouse, is rare and even less often in field conditions. Evaluation in natural conditions is especially important for the reason that allelochemicals mainly act through the soil. For a short period of time, a contact exposure through leachates during rain or dew may be possible. In some species, it may be

conducted directly through volatile compounds. It was proved that some volatiles (e.g., terpenoids in the eucalypt species) can be dissolved and absorbed by soil. This is especially important for woody plants which grow and accumulate allelochemicals in soil for a long period of time.

Various biological, chemical, and environmental factors can influence the allelochemical effectiveness for a particular species, such as: (1) specific plant toxins affect only particular species; (2) time or plant density required to reach toxic concentrations; (3) seasonal variation in toxicity; (4) synergistic effects of several allelochemicals; and (5) adsorption, leaching, and degradation in soils. Coder and Warnell described more than a hundred tree species with allelopathic activity. The strongest allelopathic effects were found in representatives of the genera Acacia, Ailanthus, Eucalyptus, Juglans, Leucaena and some conifer species. Most examples of allelopathy in trees are associated with exotic species that are rapidly becoming dominant in new ecosystems, such as Tree of Heaven (Ailanthus altissima (Mill.) Swingle), which is considered as one of the worst invasive plant species in Europe and also listed as an invasive plant in North America and many other countries. At the global level, the invasion of alien organisms is considered the second largest threat to biodiversity after habitat destruction. Nowadays, allelopathy is considered to be the most important factor influencing invasion and spread of exotic plants. The ‘‘novel weapons hypothesis’’ suggests that an introduced species may have strong allelopathic effects on neighbouring plant species in a novel environment, because native vegetation has not evolved resistance to unique allelochemicals produced by the invader. Rabotnov hypothesized earlier that allelopathy is more significant between plants that have not co-evolved together for a long time. This hypothesis is especially important in forestry, because allelopathy could be one of the important factors influencing the successful introduction of tree species in new regions. Some trees that belong to the widespread plantation species are also invasive, such as eucalypts. As a result, due to the large areas occupied by these trees and because of their dominance, the significance of allelopathy of woody plants can reach the level of ecosystems.

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