

# Allelopathic Impacts of Invader Plant Species on Natural Herbaceous Vegetation of Sariska Region

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**ABSTRACT:** Allelopathy is a biological phenomenon by which an organism produces one or more biochemicals that influence the germination, growth, survival, and reproduction of other organisms. These biochemicals are known as allelochemicals and can have beneficial (positive allelopathy) or detrimental (negative allelopathy) effects on the target organisms and the community. Allelopathy is often used narrowly to describe chemically-mediated competition between plants; however, it is sometimes defined more broadly as chemically-mediated competition between any type of organisms. Allelochemicals are a subset of secondary metabolites,<sup>[1]</sup> which are not directly required for metabolism (i.e. growth, development and reproduction) of the allelopathic organism. In Sariska, allelopathic impacts of invader plant species on natural herbaceous vegetation was recorded.

**KEYWORDS:** allelopathic, chemicals, detrimental, beneficial, secondary metabolites, reproduction, organism, growth

## I. INTRODUCTION

Allelopathic interactions are an important factor in determining species distribution and abundance within plant communities, and are also thought to be important in the success of many invasive plants. For specific examples, in Sariska, see black walnut (*Juglans nigra*), tree of heaven (*Ailanthus altissima*), black crowberry (*Empetrum nigrum*), spotted knapweed (*Centaurea stoebe*), garlic mustard (*Alliaria petiolata*), Casuarina/*Allocasuarina* spp., and nutsedge.

It can often be difficult in practice to distinguish allelopathy from resource competition. While the former is caused by the addition of a harmful chemical agent to the environment, the latter is caused by the removal of essential nutrients (or water). Often, both mechanisms can act simultaneously. Moreover, some allelochemicals may function by reducing nutrient availability. Further confounding the issue, the production of allelochemicals can itself be affected by environmental factors such as nutrient availability, temperature and pH. Today, most ecologists recognize the existence of allelopathy, however many particular cases remain controversial.

In Sariska, many invasive plant species interfere with native plants through allelopathy.<sup>[19][20]</sup> A famous case of purported allelopathy is in desert shrubs. One of the most widely known early examples was *Salvia leucophylla*, because it was on the cover of the journal *Science* in 1964.<sup>[21]</sup> Bare zones around the shrubs were hypothesized to be caused by volatile terpenes emitted by the shrubs. However, like many allelopathy studies, it was based on artificial lab experiments and unwarranted extrapolations to natural ecosystems. In 1970, *Science* published a study where caging the shrubs to exclude rodents and birds allowed grass to grow in the bare zones.<sup>[22]</sup> A detailed history of this story can be found in Halsey 2004.<sup>[23]</sup>

Garlic mustard is another invasive plant species that may owe its success partly to allelopathy. Its success in North American temperate forests may be partly due to its excretion of glucosinolates like sinigrin that can interfere with mutualisms between native tree roots and their mycorrhizal fungi.<sup>[24][25]</sup>

Allelopathy has been shown to play a crucial role in forests, influencing the composition of the vegetation growth, and also provides an explanation for the patterns of forest regeneration.<sup>[26]</sup> The black walnut (*Juglans nigra*) produces the allelochemical juglone, which affects some species greatly while others not at all. However, most of the evidence for allelopathic effects of juglone come from laboratory assays and it thus remains controversial to what extent juglone affects the growth of competitors under field conditions.<sup>[27]</sup> The leaf litter and root exudates of some *Eucalyptus* species are allelopathic for certain soil microbes and plant species.<sup>[28]</sup> The tree of heaven, *Ailanthus altissima*, produces allelochemicals in its roots that inhibit the growth of many plants. Spotted knapweed (*Centaurea*) is considered an invasive plant that also utilizes allelopathy.<sup>[29]</sup>



Another example of allelopathy is seen in *Leucaena leucocephala*, known as the miracle tree. This plant contains toxic amino acids that inhibit other plants' growth but not its own species growth. Different crops react differently to these allelochemicals, so wheat yield decreases, while rice increases in the presence of *L. leucocephala*.<sup>[30]</sup>

Capsaicin is an allelochemical found in many peppers that are cultivated by humans as a spice/food source.<sup>[31]</sup> It is considered an allelochemical because it is not required for plant growth and survival, but instead deters herbivores and prevents other plants from sprouting in its immediate vicinity.<sup>[32]</sup> Among the plants it has been studied on are grasses, lettuce, and alfalfa, and on average, it will inhibit the growth of these plants by about 50%.<sup>[32]</sup> Capsaicin has been shown to deter both herbivores and certain parasites' performance.<sup>[33]</sup> Herbivores such as caterpillars show decreased development when fed a diet high in capsaicin.

## II.DISCUSSION

Allelochemicals are a useful tool in sustainable farming due to their ability to control weeds.<sup>[34]</sup> The possible application of allelopathy in agriculture is the subject of much research.<sup>[35]</sup> Using allelochemical producing plants in agriculture results in significant suppression of weeds and various pests. Some plants will even reduce the germination rate of other plants by 50%.<sup>[32]</sup> Current research is focused on the effects of weeds on crops, crops on weeds, and crops on crops.<sup>[36][37]</sup> This research furthers the possibility of using allelochemicals as growth regulators and natural herbicides, to promote sustainable agriculture.<sup>[38]</sup> Agricultural practices may be enhanced through the utilization of allelochemical producing plants.<sup>[39]</sup> When used correctly, these plants can provide pesticide, herbicide, and antimicrobial qualities to crops.<sup>[40]</sup> number of such allelochemicals are commercially available or in the process of large-scale manufacture. For example, leptospermon is an allelochemical in lemon bottlebrush (*Callistemon citrinus*). Although it was found to be too weak as a commercial herbicide, a chemical analog of it, mesotrione (tradename Callisto), was found to be effective.<sup>[41]</sup> It is sold to control broadleaf weeds in corn but also seems to be an effective control for crabgrass in lawns. Sheeja (1993) reported the allelopathic interaction of the weeds *Chromolaena odorata* (*Eupatorium odoratum*) and *Lantana camara* on selected major crops.

Many crop cultivars show strong allelopathic properties, of which rice (*Oryza sativa*) has been most studied.<sup>[42][43][44]</sup> Rice allelopathy depends on variety and origin: Japonica rice is more allelopathic than Indica and Japonica-Indica hybrid. More recently, critical review on rice allelopathy and the possibility for weed management reported that allelopathic characteristics in rice are quantitatively inherited and several allelopathy-involved traits have been identified.<sup>[45]</sup> The use of allelochemicals in agriculture provide for a more environmentally friendly approach to weed control, as they do not leave behind residues.<sup>[34]</sup> Currently used pesticides and herbicides leak into waterways and result in unsafe water qualities. This problem could be eliminated or significantly reduced by using allelochemicals instead of harsh herbicides. The use of cover crops also results in less soil erosion and lessens the need for nitrogen heavy fertilizers.<sup>[46]</sup>

## III.RESULTS AND CONCLUSIONS

The term allelopathy from the Greek-derived compounds allilon- (meaning "mutual harm" or "suffering"), was first used in 1937 by the Austrian professor Hans Molisch in the book *Der Einfluss einer Pflanze auf die andere - Allelopathie* (The Effect of Plants on Each Other - Allelopathy) published in German.<sup>[2]</sup> He used the term to describe biochemical interactions by means of which a plant inhibits the growth of neighbouring plants.<sup>[3] [4]</sup> In 1971, Whittaker and Feeny published a review in the journal *Science*, which proposed an expanded definition of allelochemical interactions that would incorporate all chemical interactions among organisms.<sup>[2][5]</sup> In 1984, Elroy Leon Rice in his monograph on allelopathy enlarged the definition to include all direct positive or negative effects of a plant on another plant or on micro-organisms by the liberation of biochemicals into the natural environment.<sup>[6]</sup> Over the next ten years, the term was used by other researchers to describe broader chemical interactions between organisms, and by 1996 the International Allelopathy Society (IAS) defined allelopathy as "Any process involving secondary metabolites produced by plants, algae, bacteria and fungi that influences the growth and development of agriculture and biological systems."<sup>[7]</sup> In more recent times, plant researchers have begun to switch back to the original definition of substances that are produced by one plant that inhibit another plant.<sup>[2]</sup> Confusing the issue more, zoologists have borrowed the term to describe chemical interactions between invertebrates like corals and sponges.<sup>[2]</sup>

Long before the term allelopathy was used, people observed the negative effects that one plant could have on another. Theophrastus, who lived around 300 BC noticed the inhibitory effects of pigweed on alfalfa. In China around the first century CE, the author of *Shennong Ben Cao Jing*, a book on agriculture and medicinal plants, described 267 plants that had pesticidal abilities, including those with allelopathic effects.<sup>[8]</sup> In 1832, the Swiss botanist De Candolle suggested that crop plant exudates were responsible for an agriculture problem called soil sickness.

Allelopathy is not universally accepted among ecologists. Many have argued that its effects cannot be distinguished from the exploitation competition that occurs when two (or more) organisms attempt to use the same limited resource,



to the detriment of one or both. In the 1970s, great effort went into distinguishing competitive and allelopathic effects by some researchers, while in the 1990s others argued that the effects were often interdependent and could not readily be distinguished.<sup>[2]</sup> However, by 1994, D. L. Liu and J. V. Lovett at the Department of Agronomy and Soil Science, University of New England in Armidale, New South Wales, Australia, wrote two papers<sup>[9][10]</sup> in the Journal of Chemical Ecology that developed methods to separate the allelochemical effects from other competitive effects, using barley plants and inventing a process to examine the allelochemicals directly. In 1994, M.C. Nilsson at the Swedish University of Agricultural Sciences in Umeå showed in a field study that allelopathy exerted by *Empetrum hermaphroditum* reduced growth of Scots pine seedlings by ~ 40%, and that below-ground resource competition by *E. hermaphroditum* accounted for the remaining growth reduction.<sup>[11]</sup> For this work she inserted PVC-tubes into the ground to reduce below-ground competition or added charcoal to soil surface to reduce the impact of allelopathy, as well as a treatment combining the two methods. However, the use of activated carbon to make inferences about allelopathy has itself been criticized because of the potential for the charcoal to directly affect plant growth by altering nutrient availability.<sup>[12]</sup>

Some high profile work on allelopathy has been mired in controversy. For example, the discovery that (-)-catechin was purportedly responsible for the allelopathic effects of the invasive weed *Centaurea stoebe* was greeted with much fanfare after being published in *Science* in 2003.<sup>[13]</sup> One scientist, Dr. Alastair Fitter, was quoted as saying that this study was "so convincing that it will now place allelopathy firmly back on center stage."<sup>[13]</sup> However, many of the key papers associated with these findings were later retracted or majorly corrected, after it was found that they contained fabricated data showing unnaturally high levels of catechin in soils surrounding *C. stoebe*.<sup>[14][15][16]</sup> Subsequent studies from the original lab have not been able to replicate the results from these retracted studies, nor have most independent studies conducted in other laboratories.<sup>[17][18]</sup> Thus, it is doubtful whether the levels of (-)-catechin found in soils are high enough to affect competition with neighboring plants. The proposed mechanism of action (acidification of the cytoplasm through oxidative damage) has also been criticized, on the basis that (-)-catechin is actually an antioxidant.<sup>[18]</sup>

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