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Research Article

Main Challenges of Allelopathy Field

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Abstract

The inhibition of plant growth due to the release of chemicals from other plants into the environment is called allelopathy. The term "allelopathy" was initially used to describe the effects of ethylene on fruit ripening. However, it has been challenging to identify allelopathy as a potential cause of vegetation patterns due to the complex interactions of soils with ecosystems. Phytotoxic chemicals from plants can enter the environment through various ways such as volatilization, leaf leaching, root leaching, residue decomposition, or leaching from plant leaf litter. Allelopathy refers to the processes involving secondary metabolites produced by plants, microorganisms, viruses, and fungi that affect the growth and development of agricultural and biological systems. Soil microorganisms in the rhizosphere can contribute to the allelopathic potential of plants through positive feedback. Bacteria can enhance inhibition by activating nontoxic allelochemicals. For example, non-glycosylated compounds can become more toxic after being released from plants. Rye allelochemicals, known as benzoxazinoids, mainly lead to the production of phenoxazinones in the soil, which are degraded by specific fungi through the Fenton reaction. Benzoxazinoid residues are effective for weed control due to their selectivity, specific activity, and limited persistence in soil. The effects of allelochemicals on plant photosynthesis mainly include inhibiting or damaging the synthetic machinery and promoting the degradation of photosynthetic pigments. When exposed to allelochemicals, recipient plants in the contact area rapidly produce reactive oxygen species (ROS) and alter the activities of antioxidant enzymes such as superoxide dismutase, peroxidase, and ascorbate peroxidase to resist oxidative stress.

Keywords: Allelopathy; Aallelochemical; Agriculture

Introduction

Allelopathy is a subfield of chemical ecology that studies the effects of chemicals produced by plants and microorganisms on other plants and microorganisms in natural communities and agricultural systems [1]. Allelopathy increased in the 1970s and rapidly developed from the mid-1990s. In recent years, it has become a popular topic in botany, ecology, agriculture, soil science, horticulture, and other fields of research. Allelopathic interactions may be one of the major factors contributing to species distribution and abundance within plant communities and may be important for the success of invasive plants [2]. Such as water hyacinth (*Eichhornia crassipes* Mart. Solms) [3], spotted knapweed (*Centaurea stoebe* L. ssp. *micranthos*) [4] and garlic mustard (*Alliaria petiolate,* M. bieb). Allelopathy is also considered to be one of the indirect causes of persistent obstacles to cultivation in agriculture. Detailed studies on allelopathy, strategies for agricultural production management and ecosystem restoration using allelopathy and allelochemicals are being improved. The main objectives of this review are to present conclusions on the application of allelopathy in agricultural production, focus on the physiological and ecological mechanisms underlying plant allelopathy, explain the effects of allelopathy on soil microorganisms, and further research is to discuss important points.

The phenomenon in which plant growth is inhibited by the release of chemicals from other plants into the environment is generally defined as allelopathy [5]. Ethylene on fruit ripening from a physiological perspective. However, due to the dynamic nature of soils and their complex interactions with ecosystems, identifying allelopathy as a potential cause of vegetation patterns has proven difficult [6]. Zones of inhibition around shrubs such as *Salvia leucophylla, Artemisia californica* and *Adenostoma fasciculatum* were likely due to volatile chemicals released by these shrubs.

Two problems related to both field and laboratory research conducted on allelopathy

- The utilization of inadequate methodology with regards to chemical extraction and subsequent identification.
- The lack of clear evidence of allelopathy in field settings contribute to the inability of researchers to address key points raised in the ecological literature.

While elaborating criteria that could be utilized to further demonstrate the occurrence of allelopathy [7], stressed the importance of

- A pattern of inhibition of one species or plant by another,
- Phytotoxin production by the aggressive plant,
- Knowledge of the mode of toxin release from the plant into the environment,
- Toxin transport
- Toxin uptake,
- Exclusion of physical or biotic factors influencing plant interference.

Importance of the mode of allelochemical release from the plant into the environment

Phytotoxic chemicals from plants can enter the environment either through volatilization, leaf leaching, root leaching, residue decomposition, or leaching from plant leaf litter [8]. Root exudates are important because they introduce chemicals directly into the rhizosphere environment [5]. The possibility of chemicals leaching from above-ground plant tissues should a component of the root exudate of cornflower (*Centaurea maculosa*) and major allelochemical associated with the invasion success of cornflower [9]. However, recent studies have questioned the activity and availability of catechins as plant inhibitors in the soil rhizosphere [10].

For example, Actinidia (Nepeta × faasennii) is an ornamental ground cover with numerous secretory glands on the abaxial surface of its leaves. The volatile mixture emitted by this plant over time contains a number of derivative products, including three related nepetalactones that occur in high concentrations. Volatile substances effectively inhibit seedling growth and germination in closed bioassays [11,12]. *Artemisia vulgaris* binds to soil particles in a closed soil bioassay and also produces a cocktail of volatiles that can affect plant growth and germination. The leaf tissues of many plants disperse large amounts of volatile mixtures and can be observed on warm, sunny days in and around established stands of certain perennials. Furthermore, in a three-year field trial, weed growth under established Actinidia and Ragweed plantings was negligible compared to other ground covers and mixed vegetation [11].

By improving the ability to collect and detect trace amounts of allelochemicals in plant leaf surface mixtures in the form of oils associated with trichomes, glands, or waxes, or in conjunction with the use of GC or HPLC. Using mass spectrometry by collecting trace amounts of root exudate from the roots, we can characterize the sites of allelochemical production in plant structures and organelles and determine the potential for release over time. The use of microscopy, such as scanning electron microscopy or transmission electron microscopy, is also useful for studying root exudates and glandular release of allelochemicals [11]. By localizing the production of allelochemicals, we can determine whether the genes and enzymes for biochemical production are specific to particular cells, tissues, and organs, and whether they are related to plant growth and development.

This is the case when allelochemical production increases in the early stages of plant development, as seen in the production of during or other related phenolics by Sorghum, chemicals may play an important defensive role in situations where immature plants have to colonize difficult environments. If the production of allelochemicals increases with increasing plant maturity, the defensive role of allelochemicals in promoting the ability of higher plants to successfully reproduce and disseminate seeds and propagules becomes more likely. Relatively few, if any, studies have examined in detail the ability of plants to produce and diffuse allelochemicals through living plant parts or residues throughout their life cycle. Studies conducted generally suggest that changes in the production of some compounds or allelochemicals occur during plant development and in response to environmental and biological stimuli, sometimes in both roots and leaves.

Soil characteristics influence allelopathic activity

All plants synthesize a variety of chemicals, many of which can be phytotoxic in soil-free bioassays. Nevertheless, these chemicals may not be involved in allelopathic suppression in plant species. The fate of many allelochemicals in the soil environment is relatively unknown. Once released, allelochemicals are exposed to physical (e.g. adsorption), chemical (e.g. direct oxidation or oxidation by metal ions), and biological (e.g. microbial degradation) soil factors [13].

The best synthetic herbicides applied to soil, such as trifluralin [2,6-dinitro-N, N-dipropyl-4-(trifluoromethyl) benzamine], are highly lipophilic. These compounds attach to soil particles and are not easily removed from the root zone of the target weed. Even at very low concentrations in soil water, herbicides flow from soil particles through soil water to lipophilic areas such as: B. Root cell membranes develop rapidly, leading to the accumulation of phytotoxic amounts of compounds [14]. The use of lipophilic-treated fibers and tubing to absorb lipophilic substances from soil solutions shows that lipophilic allelochemicals, such as Sorgoleone, function in a similar manner to synthetic herbicides applied to the soil. Understanding the dynamics of allelochemicals in the rhizosphere is important for understanding the mechanisms of allelopathy and assessing the importance of allelopathic processes in plant communities.

In another example, pigweed, a weed native to Europe, has invaded cultivated fields, roadsides, abandoned soils, and wastelands in northern India. The leaves of *C. murale* are incorporated into the soil during tillage, and water-soluble substances are released after the fields are flooded before cultivation of lowland rice [15]. The allelopathic activities of *C. murale* rhizosphere soil and soil amended with its leaves [16]. Carbon could not completely eliminate the inhibitory effect of soil amended with large amounts of *C. murale* exudate, but after the addition of nitrogen fertilizer, the phytotoxic effects were largely eliminated. The phytotoxicity of *C. murare* leaf exudates may be related to the fixation of inorganic nitrogen by microbial activity, and this reaction may be misinterpreted as an allelopathic effect. Soil properties and edaphic effects may play an important role in influencing the extent of allelopathic interactions over time. To further assess the ecological importance of secondary products in plant interactions, allelonomic effects are (i) time-limited or long-lasting, and (ii) present at the species and/or community level. or (iii) Over time, allelochemical equilibrium between release, decomposition, settling, inflow and outflow is constantly achieved in the rhizosphere. Further research on allelochemicals in the soil rhizosphere will require targeted collaboration with soil chemists and soil microbiologists.

Allelopathy and allelochemicals

The definition of allelopathy was first used by Morrish in 1937 to mean all effects resulting directly and indirectly from the transfer of biochemicals from one plant to another [17]. After almost half a century, algae, fungi, and various microorganisms are recognized as targets for allelochemicals in the plant kingdom. "Direct or indirect harmful or beneficial effects that one plant (including microorganisms) has on another through the production of compounds that are released into the environment" [18]. In 1996, the International Allelopathy Association expanded the definition of allelopathy to now include processes involving secondary metabolites produced by plants, microorganisms, viruses, and fungi that affect the growth and development of agricultural and biological systems. Now you can point to it. Furthermore, allelopathy donors and recipients should also include animals [19].

Allelochemicals are non-nutritive substances mainly formed as secondary metabolites of plants or degradation products of microorganisms and are the active media of allelopathy. Allelochemicals are comprised of various chemical families and are divided into 14 categories based on chemical similarities [20]: Water-soluble organic acids, straight chain alcohols, aliphatic aldehydes and ketones. Monounsaturated lactone. Long chain fatty acids and polyacetylene. Benzoquinones, anthraquinones and complex quinones. Simple phenol, benzoic acid and its derivatives. Cinnamic acid and its derivatives. Coumarins; flavonoids; tannins. Terpenoids and steroids. Amino acids and peptides. alkaloids and cyanohydrin. Sulfides and glycosylates. and purines and nucleosides. The rapid progress of analysis technology in recent years has made it possible to isolate and identify even minute amounts of allelochemicals and to perform sophisticated structural analyses of these molecules.

Management of plant allelopathy in agriculture

Allelochemicals stimulate or inhibit plant germination and growth, enable the development of crops with low levels of phytotoxic residues in water and soil, and facilitate wastewater treatment and recycling [21]. Although the potency and specificity of many allelochemicals is limited, allelochemicals have no residual potency or toxic effects, making them suitable alternatives to synthetic herbicides [22]. Agricultural production, reducing the use of chemical pesticides and the resulting environmental pollution, and for the sustainable development of agricultural production and ecosystems [23]. The use of allelopathic crops in agriculture is currently realized, for example, as part of crop rotations, in the cultivation of fish crops, as fish crops or as green manure [24,25]. Application of allelopathy to improve plant productivity and environmental protection through environmentally friendly control of weeds, pests and plant diseases, nitrogen conservation in agricultural land, synthesis of new pesticides based on allelopathy, etc., is involved in allelopathy research.

Arrangement of cropping systems

The ability of a plant to suppress weeds is determined by the plant's allelopathy and competitive ability. Crop allelopathy can be effectively used for weed control in fields to reduce the autotoxicity of allelopathy and reduce the inhibitory effects of allelopathy crops [26,27]. Crop rotation and intercropping systems will improve land utilization and increase annual soil production [28]. The relative abundance and population suppression of plant-parasitic nematodes in *Chromolaena odorata* (L.) (*Asteraceae*) fallow land in a 2-year field study, and *C. odorata* and shrub fallow land It was suggested that this method has the potential to become an integrated management method in management. Survey of pest nematodes in crop production in southwestern Nigeria. Intercropping is commonly practiced among farmers in developing countries to maximize land resources and reduce the risk of single crop failure. Crop rotation and cover crop cultivation systems can significantly reduce weed population density and biomass production [23]. Intercropping cotton fields (*Gossypium hirsutum* L.) with sorghum (*Sorghum bicolour* L.), sesame (*Sesamum indicum* L.), and soybean (*Glycine max* L.) results in higher net profits and increases the net income of cotton fields (*Gossypium hirsutum* L.) significantly suppressed compared to cotton alone in a 2-year experiment [26,29]. Intercropping of eggplant and garlic is a beneficial cultivation method to achieve stronger growth and higher yield of eggplant. However, allelopathy between different species may have promoting or suppressing effects [30]. Rotating cultivation with tobacco (*Nicotiana tabacum* L.) improved stand establishment and growth of maize (*Zea mays* L.) compared to mung bean (*Vigna radiata* L.), whereas stand establishment and growth of mung bean improved. was reported to be suppressed. became. Therefore, the allelopathic nature of the crop should be considered during crop rotation, cover crops, and stem mulching [31].

Straw mulching

In conventional agriculture, weed control with herbicides is not only expensive; It is also harmful to the environment. Allelopathic applications such as straw mulch ensure sustainable weed control [23]. Using allelopathic plant life as floor cowl species presents an environmentally pleasant option [32]. Allelochemicals released from decomposed straw can suppress the growth of weeds in agricultural fields and reduce the incidence of pests and diseases. Additionally, straw mulch can improve soil organic matter content and increase soil fertility. However, increasing the soil C:N ratio may also have negative effects. Green wheat (*Triticum aestivum* L.) straw suppresses the growth of Ipomoea weeds in corn (*Zea mays* L.) and soybean fields, thereby reducing the need for herbicide applications. Rye mulch (*Secale cereale* L.) significantly reduced the germination and growth of several problematic agricultural grasses and broadleaf weeds [33]. Conversion reactions of rye allelochemicals, namely H. Benzoxazinoids in soil mainly lead to the production of phenoxazinones, which are degraded by some special fungi through the Fenton reaction. Benzoxazinoids or rye residues are suitable agents for weed control due to their selectivity, specific activity, and possibly limited persistence in soil [33,34]. The allelopathic suppression effect on weeds varied depending on the type of rye straw used for mulching [35]. Allelopathic plant material at 1-2 tons/ha reduced weed biomass in rice fields (1998-2003) by about 70% and increased rice (*Oryza sativa* L.) yield by about 20%. In the southeastern region of Brazil, coffee (*Coffea arabica*) fruit peel, which contains allelochemicals such as phenols, flavonoids, and caffeine, is widely used as an organic supplement in agricultural practices for weed control [36]. Switchgrass (*Panicum virgatum* L.) plants and residues reduced the biomass and density of associated weeds, and their research provided weed management strategies in agroecosystems and important information for the introduction of switchgrass into new ecosystems. Water extracts of *Conyza bonariensis* (L.) Cronquist, *Trianthema portulacastrum* L., and *Pulicaria undulata* (L.) C. A. Mey can be applied at a concentration of 10 g L^{-1} to manage the weed *Brassica tournefortiil,* Gouan by inhibiting germination and seedling growth [37]. Additionally, some soybeans induce the germination of the noxious parasitic weed, spring rapeseed (*Orobanche spp.*), suggesting that soybean may be used as a cover crop to reduce the spring rapeseed seed bank [38].

Figure 1: Field experimental on rye mulch previous a tomato crop.

Developing environmentally friendly agrochemical and microbial pesticides

The technology modifies allelochemicals for the product of environmentally friendly fungicides and factory growth controllers allows the effective operation of agrarian product and confers many environmental problems in the soil due to the fairly high degradability of allelochemicals [39,40]. Sorgoleone, a hydrophobic compound present in the root exudate of *Sorghum bicolor* (L.), inhibits weed growth more effectively after being formulated as a wettable powder, while crop species are resistant to Sorgoleone. Some microorganisms can use sorgoleon as a carbon source. Sorgoleone is completely decomposed into CO_2 and mineralized in the soil, but the various chemical groups of the molecule are not mineralized in the same way [41]. The powerful weed-suppressing ability of formulated Sorgoleone has sparked interest as an effective, natural and environmentally friendly approach to weed control. Plant growth-promoting rhizobia (PGPR) includes a wide range of beneficial bacteria that have beneficial effects on plants, such as Causing induced systemic resistance (ISR), promoting plant growth and reducing susceptibility to diseases caused by plant pathogens [42]. Allelopathic bacteria perform the same function in bacterial mixtures with PGPR properties and activity against allelopathic weeds, thereby reducing the inhibitory effect on susceptible plants caused by allelopathic weeds [43]. There are several organic herbicides or plant growth inhibitors made from allelopathic plant material to control weed growth in fields [44,45]. A type of herbicide has been prepared and put into practical use by mixing ingredients extracted from pine, cypress, and cedar with bamboo vinegar (*Poaceae*), Utilizing plant allelopathy in rice fields.

Reduction of nitrogen leaching and environmental pollution

Due to water pollution, nitrogen leaching has become a serious ecological problem, and mineralization of soil organic nitrogen, especially nitrification of nitrogen fertilizers, is one of the main causes of nitrogen accumulation in soil. Recent studies have shown that plant-produced nitrification inhibitors (NIS) are the first choice for soil nitrification management. For example, biological nitrification inhibitors (BNIS) are allelochemicals that can inhibit soil nitrification. Wheat allelochemicals such as ferulic acid, p-hydroxybenzoic acid, and hydroxamic acid act on soil microorganisms to suppress soil nitrification, reduce N_2O emissions, improve the utilization rate of nitrogen fertilizers, and reduce environmental pollution. Reduces [46]. Allelopathic plantain (*Plantago lanceolata* L.) had an inhibitory effect on nitrogen mineralization in soil, suggesting that plantain can be used to reduce nitrogen leaching in soil.

Breeding of Allelopathic Cultivars

Allelopathic kinds have great eventuality to minimize the preface of refractory chemicals and effectively control weeds in agroecosystems, making them the most promising operation of allelopathy [47]. When breeding allelopathic kinds, both conventional parentage styles and breeding styles developed using transgenic technology can be used. Successful kinds must combine weed repression capability with high-yield eventuality, complaint resistance, early development, and quality characteristics. Rondo is a rice variety that combines high yield potential with blast resistance and weed suppression ability, grown on a commercial organic rice farm in Texas, and has better weed suppression ability than many commercial varieties [48]. Huagan 3 is a particularly promising F8 generation line derived from a cross between local rice cultivars N9S and PI 312777, and is considered the first commercially acceptable weed-suppressing variety in China [19,49]. Wheat to improve its allelopathic potential through conventional breeding. The material used was created from a cross between a Swedish variety with low allelopathic activity and a Tunisian variety with high allelopathic activity. Field studies showed that weed biomass was reduced by an average of 19% in highly allelopathic lines. However, the negative effect was a 9% reduction in grain yield in the highly allelopathic lines. In this study, highly allelopathic lines showed lower initial biomass compared to controls [50]. Identification of quantitative trait loci reveals putative genes related to weed competitive ability in wheat on chromosomes 1A, 2B, and 5D, which may be useful for allelopathic wheat breeding.

Conclusion

Allelopathy has been used and recognized in agriculture for thousands of years, but its use is rare today. Allelopathy is of great importance for researching effective farming practices, controlling weeds, diseases and insects, removing barriers to continued crop production, and breeding allelopathic varieties. In addition, allelochemicals are of great use in sustainable agriculture as environmentally friendly insecticides, fungicides and plant growth regulators. Allelochemicals have been studied for many years as environmentally friendly herbicides, but there are not many natural herbicides made from allelochemicals on the market. However, some studies have looked at herbicides from natural products. Allelopathy is gaining more attention as organic farming and environmental protection gain more attention and more attention is paid to the physiological and ecological mechanisms of allelopathy. In addition, advances have also been made in the study of relevant molecular signalling pathways. Allelopathy clearly needs further research before it can be used in agricultural production worldwide.

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