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Allelopathy in Crop-Weed Interaction: A Tool for Sustainable Weed Management

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In the face of yield losses caused by weeds, specially, in low-input agricultural systems and environmental pollution due to the excessive use of synthetic herbicides, sustainable weed management has become mandatory. To address these issues allelopathy is Gaining popularity. Although many important crops are known for their allelopathic potential, farmers are still reluctant to use such knowledge practically. Allelopathy, the biochemical interaction between plants, is emerging as a crucial factor in crop-weed interactions, offering potential solutions for sustainable weed management. This phenomenon involves the release of allelopathic compounds by plants that inhibit the germination, growth or development of nearby weeds, thereby reducing their crop competitive pressure on crops. In the context of modern agriculture, where chemical herbicides pose environmental and health risks, allelopathy provides an eco-friendly and cost-effective alternative. This article explores the mechanism of allelopathy in crop-weed interactions, highlighting its role in suppressing weed populations and improving crop yield. Additionally, it examines the potential of incorporating allelopathic crops or plant species into integrated weed management systems. The benefits and challenges of utilising allelopathy as a tool for sustainable weed control are discussed. The adoption of allelopathy-based weed management could significantly contribute to reducing reliance on synthetic herbicides, promoting biodiversity and enhancing the sustainability of crop production systems.

Keywords: Allelopathy, sustainable weed management, integrated weed management and biodiversity

Introduction

The term allelopathy derives from two Greek words i.e, "allelos" which means "of each other", and "pathos" means "to suffer". The term allelopathy was first defined by Hans Molisch in 1937 by Austrian scientist to indicate effects resulted from biochemical substances transferred from plant to plant, including micro-organisms on another through production of chemical compounds that escapes into the environment to influence the growth and development of neighbouring plants. Weed management remains one of the most significant challenges in modern agriculture. Traditional methods, such as chemical herbicides, have been widely used to control weeds, but concern about environmental pollution, resistance and human health risks have sparked interest in alternative, more sustainable solutions. As a result, alternative, eco-friendly methods are Increasingly being explored. One such promising approach is the use of allelopathy, a natural phenomenon where plants release chemicals that affect the growth and development of neighbouring plants.

Understanding Allelopathy

Allelopathy is a biological phenomenon in which an organism produces one or more biomolecules that affect the growth, survival and/or reproduction of other organisms. It is an important mechanism of plant interference by the addition of plant-produced Phytotoxins to the environment. Many of the phototoxic substance suspected of causing germination and growth inhibition have been identified from plant tissue and soil, these substances are termed allele-chemics or allelochemicals. A large Number of plant species are known to possess allelopathic properties, mainly weed. The latest estimate found ~240 allelopathic weeds but many other weed species were found in the past 20 years to show allelopathic effects. In addition to weeds, many herbaceous and woody crops have allelopathic traits both on other crops and weeds. Most allelopathic crops belong to the Asteraceae and Poaceae families, but Brassicaceae and Fabaceae are also well-represented. Some allelochemicals are accumulated at various stages of growth while accumulation of some compounds depends upon time of day and season. Allelopathic inhibition is complex and can involve the interaction of different classes of chemicals, such as phenolic compounds, flavonoids, terpenoids, alkaloids, steroids, carbohydrates and amino acids with mixture of different compounds sometimes have a greater allelopathic effect that individual compounds alone. Allelopathy is characteristics of certain plants, algae, bacteria and fungi. Allelopathic interactions are an important factor in determining species distribution and abundance within plant communities.

Types of Allelopathy

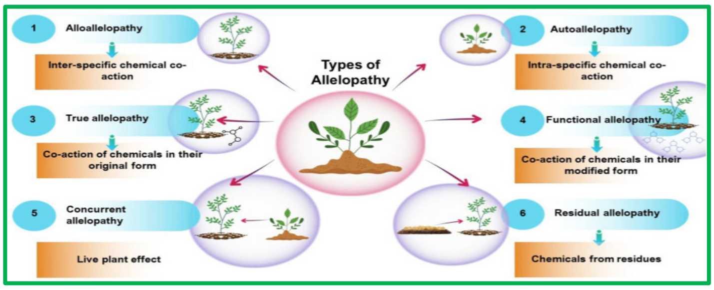
Allo-allelopathy: It is Inter-specific chemical co-action. Allelochemicals are toxic to other species, other than which release it. E.g. maize (Zea mays) is allelopathic for Chenopodium and Amaranthus.

Auto-allelopathy: It is intra-specific chemical co-action. Allelochemicals are toxic to same species from which they are released. E.g. Wheat (Triticum aestivum), Alfalfa (Medicago sativa), Cowpea (Vigna unguiculata), Rice (Oryza sativa) and Apple (Malus domestica).

True allelopathy: It refers to the release into the environment of chemical compound that are toxic the form they are produced by the plant.

Functional allelopathy: It refers to the release into the environment of chemical compound that are toxic after chemical modification by microorganisms.

Concurrent/ direct allelopathy: It refers to the Instantaneous direct effect of released toxin from the living plant to another growing in vicinity. It is also called ‘living plant effect’. E.g. Sorghum (Sorghum bicolour) suppresses many weeds growing in the vicinity.



Residual allelopathy: It is the effect obtained on the plants growing in succession from the decaying residues, leaf litters, stem and roots of the previous plants. E.g. sorghum is allelopathic to wheat and Phalaris minor and Sweet potato (Ipomea batatas) to cowpea.

Allelopathic Interaction

Allelopathic interactions between crops and weeds in agroecosystems can be of four types as describes below:

WEED ON CROPS

Weeds	Effects on	Cause/source	Effects
Quack grass (*Agropyron repens*)	Maize, potato (Solanum tuberosum)	Ethylene produced by the activity of microorganisms on rhizomes	Decrease uptake of manures (N,K) followed by yield reduction

Wild oat (*Avena fatua*)	Wheat, barley (Hordeum vulgare), oat (Avena sativa)	Root exudates	Growth of leaves and roots of Wheat
Bermuda grass (*Cynodon dactylon*)	Barley	Decayed grass residues	Seed germination, root and op growth
Yellow nut sedge (*Cyperus esculentus*)	Grain crops, soybean (Glycine max), orchard	Vanillic acid, hydrobenzoic acid in sedge extract	Root and Shoot growth of maize and soybean
Johnson grass (*Sorghum halepense*)	Sugarcane (Saccharum officinarum), maize, soybean	Root exudates and decaying residues	Root and shoot growth

WEED ON ANOTHER WEED

WEEDS	EFFECT ON	CAUSE/SOURCE	EFFECT
Cogon grass	Button weed (*Borreria hispada*)	Exudates of inhibitory substances through rhizomes	Inhibits the emergence and growth
Johnson grass	Giant foxtail (*Setaria faberi*), Large crabgrass (*D. sanguinlis*)	Living and decaying rhizomes and leaves	Inhibit growth

CROP ON WEED

CROPS	EFFECT ON	CAUSE/SOURCE	EFFECT
Coffee (*Coffea Arabica*)	Spiny Amaranthus (*Amaranthus spinosus*)	1,3,7- trimethylxanthin	Inhibit germination
Maize	Associated weeds	Increased Catalase and Peroxidase activity by root extract	Inhibit growth
Oat, Wheat, Pea (*Setaria faberi*)	Lams quarter (*Chenopodium album*)	Root exudates	Suppress growth

Mechanisms of Allelopathy

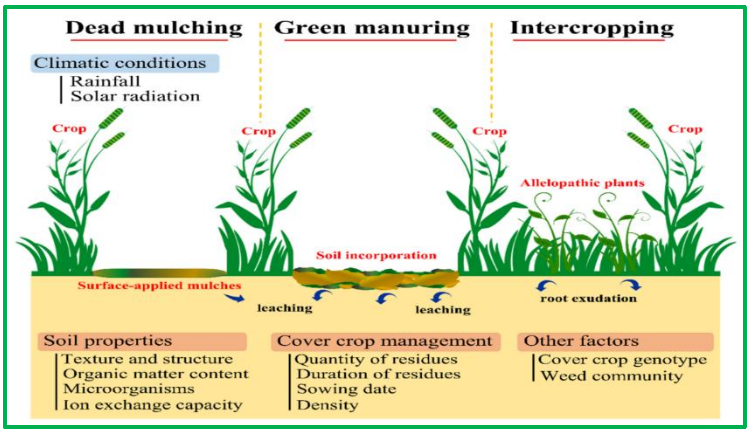
Root Exudates: Chemicals released from the roots of plants can directly affect soil chemistry and disrupt the growth of weeds.

Volatile Compounds: Some plants release gaseous allelochemicals into the air, which can affect weeds growing in proximity.

Decomposition of Plants Residues: Plant material left on the soil surface can release allelochemicals during decomposition, inhibiting weed seed germination or seedling growth.

Allelopathic Compounds

1. Simple water-soluble organic acids
2. Simple unsaturated lactones
3. Long-chain fatty acids and polyacetylenes
4. Simple phenols
5. Naphthoquinone, anthroquinones and complex quinones
6. Flavonoids
7. Benzoic acid and derivates



8. Steroids
9. Cinnamic acid and derivates
10. Tannins
11. Amino acids and polypeptides
12. Coumarins
13. Sulphides and glucosides
14. Purines and nucleotides
15. Alkaloids and cyanohydrins
16. Thiocyanates
17. Lactones
18. Actogenins

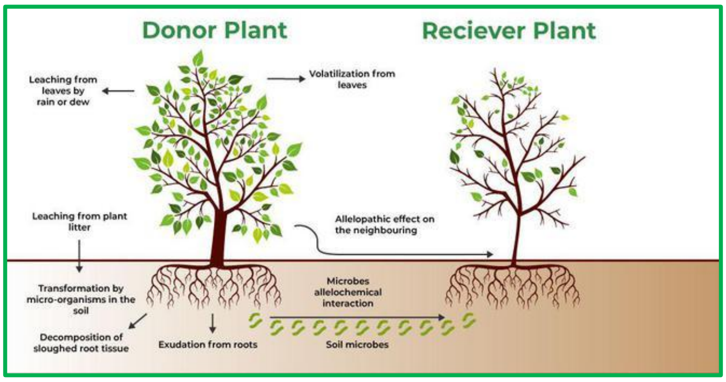
Mode of Allelochemicals

1. Root Exudation: One of the most common methods for the release of allelochemicals is through the roots of plants. These chemicals are exuded directly into the soil through the root system. Roots actively release allelochemical into the rhizosphere via passive diffusion or active diffusion transport mechanism. E.g. Black walnut, eucalyptus release compounds through their roots that inhibit the growth of nearby plants.

2. Volatilization: Some plants release allelochemicals into the atmosphere as volatile organic compounds. These chemicals are emitted from plant surfaces, especially leaves and stems, into the air. E.g. Volatile compounds like Terpenes and Phenolics released by plants such as Eucalyptus or Sagebrush can inhibit the growth of nearby plants.

3. Leaching: Allelochemicals can be released through rain or irrigation water, which washes chemicals off the plant surfaces (Primarily leaves). Water that comes in contact with the plant's leaves, stems or flowers can leach allelochemicals from these surfaces into the soil or surrounding environment. Plants like Eucalyptus and black walnut can release allelopathic compounds into the surrounding soil when rain or dew washes their leaves.

4. Decomposition of residues: When plant materials (Such as leaves, stems or roots) decompose, they can release allelochemicals into the soil. As plant matter decomposes, the breakdown of organic compounds can lead to the gradual release of allelopathic substances into the surrounding soil, which can affect the growth of nearby plants. E.g. Black walnut and Sorghum release allelochemicals from decaying leaves, stems or root fragments.



Need of Allelopathy in Weed Control

Allelopathy refers to the biochemical interactions between plants in which one plant releases chemicals that influences the growth, survival and reproduction of other plants. Allelopathy provides a natural way for plants to suppress the growth of unwanted weeds. Certain plants can produce allelochemicals that inhibit the germination, growth and development of competing weed species. This can reduce the need of chemical herbicides, which may be harmful to the environment and human health. Allelopathy offers a potential alternative to chemical herbicides, which can have negative effects on the environment, human health and non-target species. The use of allelopathic plants to suppress weeds can promote the growth of more desirable plant species in agricultural fields or gardens. This encourages biodiversity by allowing crops or other beneficial plants to thrive, without the interference of competitive weed species. Unlike synthetic herbicides, which may degrade soil quality over time, allelopathic plants often improve soil health. These plants can enrich the soil with organic matter, which contributes to soil fertility. Additionally, the root exudates from some allelopathic plants may promote beneficial soil microbial activity, enhancing soil structure and nutrient cycling. Allelopathic plants may be able to target specific weed species while leaving desirable plants unaffected. This selective inhibition is particularly useful in agricultural and horticultural settings where farmers need to control particular weeds without harming crops. By inhibiting seed germination, allelopathic plants can reduce the weed seed bank in the soil. This can be especially helpful in fields where weed pressure is high and in situations where weed seeds are persistent in the soil for long periods. Allelopathy can be incorporated into an integrated pest management (IPM) strategy, which combines, biological, cultural and chemical control methods to manage weeds. By using allelopathic plants, farmers can integrate this natural method into their IPM programs, reducing their dependency on chemical herbicides while enhancing the overall sustainability of their operations. Allelopathic plants can be grown as part of mulching or cover cropping systems. These systems provide additional benefits like moisture retention, erosion control and improved soil structure. Allelopathic weed control methods are generally safer for humans and wildlife compared to chemical herbicides, which may pose toxicity risks. Allelopathy can offer an eco-friendly option for controlling weeds in public spaces, gardens and around agricultural fields without the adverse side effects of chemicals.

Challenges and Limitations

Not all crops produce allelochemicals with strong or consistent effects on weeds. The effectiveness of allelopathy can vary depending on the crop variety, environmental conditions and weed species. Allelochemicals might not only affect weeds but could also harm non-target plants, including beneficial crops or neighbouring plants in a field. Much of the research on allelopathy remains theoretical and more studies are needed to understand the mechanism involved, identify the most effective allelochemicals and evaluate the long-term impact. Implementing allelopathy on a large scale in commercial agriculture requires careful planning and integration into existing farming systems. The cost of developing new allelopathic crop varieties and the need for specialized management techniques may limit widespread adoption.

Conclusion

In summary, allelopathy has important promise for sustainable weed management and plays a big part in crop-weed interactions. Farmers can create more efficient and ecologically friendly methods of weed management without largely depending on synthetic herbicides by comprehending and utilizing the chemical interactions between crops and weeds. Allelopathic crops or plants can minimize the adverse effects on ecosystems while promoting biodiversity, increasing crop output, and decreasing weed competition. Nonetheless, further investigation is required to maximize the use of allelopathy in farming methods, including comprehending the underlying mechanisms, choosing appropriate crops, and figuring out how to control allelopathic effects in many environmental settings. Allelopathy's use into integrated weed management methods ultimately has the potential to improve agricultural sustainability and lower.