**ALLELOPATHIC IMPLICATION IN WEED MANAGEMENT**

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**Introduction**

Traditional method of weed control such as crop rotation, manual hoeing, tractor drawn cultivator and costly labour have made the use of herbicide popular among Indian Farmers. There are many kinds of herbicides which are used for controlling the weeds. But these chemicals not only destroy the weeds but also get mixed with air, water, and soil, causing their pollution. Solution to the chemical weed control related problem could be found in the development of a weed control system with the principle of greening and Environmental protection simultaneously with increased weed control and saving energy (Stoimenova *et al.,* 2008). Diversity in weed management tools ensure sustainable weed control and reduce chances of herbicide resistance development in weeds. Allelopathy combats the challenges of environmental pollution and herbicide resistance development and can be alternative to herbicidal weed control.

**What is Allelopathy?**

The definition of Allelopathy was first used by **Molisch** in 1937 to indicate all of the effects that directly or indirectly result from biochemical substances transferred from one plant to another (Molisch, 1937). International Allelopathy Society broadened its definition of allelopathy to refer to ‘Any process involving secondary metabolites produced by plants, microorganism, virus, and fungi that influences the growth and development of agricultural and biological system.’

**Allelochemicals**:

Allelochemicals are bioactive compounds produced by plants that influence the growth, development, and behavior of other plants, microbes, and organisms in their vicinity. These compounds play a key role in allelopathy, the chemical interaction between plants. Allelochemicals can be categorized into several major types based on their chemical structures and modes of action:

1. Phenolic Compounds: Phenolic allelochemicals are among the most common and well-studied. They include compounds like phenolic acids, flavonoids, lignins, and tannins. These compounds can influence seed germination, root growth, and nutrient uptake in neighboring plants. For example, juglone from black walnut trees inhibits the growth of many plant species, and allelopathic phenolic acids released from the roots of certain crops can suppress weed germination.

2. Terpenoids: Terpenoids are a diverse group of allelochemicals found in many plant species. They include compounds like essential oils, monoterpenes, and sesquiterpenes. Terpenoids often exhibit antimicrobial and herbicidal properties, affecting the growth of nearby plants and microbes. For instance, eucalyptus trees release volatile terpenoids that inhibit the growth of competing vegetation.

3. Alkaloids: Alkaloids are nitrogen-containing compounds with diverse bioactivities. Some alkaloids can interfere with plant growth by affecting cellular processes such as enzyme activity and membrane integrity. Nicotine, found in tobacco plants, is a well-known alkaloid with allelopathic effects that can suppress the growth of certain weeds.

4. Fatty Acids and Lipids: Some fatty acids and lipid-derived compounds can exhibit allelopathic properties. These compounds can interfere with cell membranes and disrupt physiological processes, affecting neighboring plants' growth. For example, allelopathic fatty acids released from some cover crops can inhibit weed germination.

5. Glycosides: Glycosides are compounds formed from the combination of a sugar molecule and another functional group. Some glycosides have allelopathic effects by inhibiting enzymes and disrupting cellular processes in target plants. For instance, allelopathic saponins, a type of glycoside, have been identified in various plant species and can affect weed growth.

6. Amino Acids and Peptides: Some amino acids and peptides can act as allelochemicals by interfering with nutrient uptake and metabolic processes in neighboring plants. L-tryptophan is an example of an allelopathic amino acid that can affect root development and seed germination.

7. Volatile Organic Compounds (VOCs): Certain plants release volatile organic compounds into the air, which can have allelopathic effects on nearby plants. These compounds can inhibit seed germination, root growth, and other physiological processes. VOCs released by pine trees, for example, have been shown to impact the growth of understory vegetation.

**The Application of Allelopathy in Weed Management:**

1. **Crop Rotation & Intercropping**

Intercropping of sorghum (*Sorghum bicolor* L.), sesame (*Sesamum indicum* L.) and soybean (*Glycine max* L.) in cotton (*Gossypium hirsutum* L.) field produced greater net benefits and a significant inhibition on purple nutsedge (*Cyperus rotundus* L.) in comparison with the cotton alone in a 2-year experiment ([Iqbal *et al.,* 2007](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4647110/#B89)).

1. **Straw Mulching**:

The allelochemicals from decomposed straw can suppress weed growth in farmlands, and reduce the incidence of pests and diseases. Moreover, straw mulch can improve the soil organic matter content and increase soil fertility. Research has shown that green wheat (*Triticum aestivum* L.) straw inhibits the growth of *Ipomoea* weeds in corn (*Zea mays* L.) and soybean fields, thereby reducing the need for herbicide application ([Schulz *et al.,* 2013](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4647110/#B149)).

1. **Aqueous Extracts:**

Aqueous extacts of *melilotus indica* shows strong phytotoxicity against *Phalaris minor* in Wheat field. *Medicago denticulata* and *chenopodium album* also possess weed suppressing ability (Chilwal A., 2017).

1. **Breeding of Allelopathic Cultivars**:

Both conventional breeding methods and those developed using transgenic technology can be applied in the breeding of allelopathic cultivars. Successful cultivars must also combine a weed suppression ability with high yield potential, disease resistance, early maturity and quality traits ([Gealy and Yan, 2012](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4647110/" \l "B60)) eg- Huagan 3, a particularly promising F8 generation line derived from crosses between the local rice cultivars N9S and PI 312777, is considered to be the first commercially acceptable weed-suppressive cultivar in China ([Kong *et al.,* 2011](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4647110/#B100)).

**Problems:**

1. The activity of allelochemicals varies with research techniques and operational processes ([Peng](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4647110/" \l "B142) *[et al.,](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4647110/" \l "B142)* [2004](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4647110/" \l "B142)).
2. The natural state of allelochemicals may be changed somewhat during the process of extraction ([Li *et al.,* 2002](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4647110/#B106)).
3. Interactions such as synergy, antagonism and incremental effects between different allelochemicals should be evaluated ([Albuquerque *et al*., 2010](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4647110/#B6)).
4. Stress environment can increase the release of allelochemicals from allelopathic plants ([Albuquerque *et al*., 2010](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4647110/#B6)).

**Challenges and Considerations**

While allelopathy holds promise for sustainable weed management, there are challenges and considerations to address:

**Specificity**: Allelopathic effects can be non-specific, affecting both weeds and desired crops. Careful selection of allelopathic species and management practices is necessary to minimize negative impacts on crops.

**Variable Effects:** Allelopathic effects can vary based on environmental conditions, soil types, and other factors. Predicting consistent outcomes requires a nuanced understanding of local conditions.

**Inconsistent Allelochemical Release:** The release of allelochemicals from plants can be influenced by factors like plant growth stage and health. Timing and quantity of allelochemical release may impact their effectiveness.

**Future Prospects:**

1. There is no generic allelochemical, and we should certainly anticipate different mechanisms of action among allelopathic chemicals.
2. It should be investigated in future studies whether allelochemicals are absorbed through transport proteins or whether different allelochemicals have the same molecular targets in different species ([Weston and Mathesius, 2013](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4647110/#B179)).
3. The systematic study of allelochemical detoxification mechanisms in different species will help reveal the differences in detoxification mechanisms between plants and microbes.
4. Very little is known about the transportation and biodegradation of allelochemicals in soil or the population genetics of allelopathic species, the establishment of practical ways of using allelochemicals in the field.

**Conclusion:**

Allelopathy offers a sustainable approach to weed management that reduces the reliance on synthetic herbicides while promoting ecological balance. By understanding the mechanisms and potential applications of allelopathic interactions, farmers can harness this natural phenomenon to enhance weed suppression in agricultural systems. As research advances, optimizing allelopathic strategies and integrating them with other weed management techniques will contribute to more resilient and productive agricultural landscapes.

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