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Brassica Allelopathy: A Potential Approach for Sustainable Agriculture

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Abstract

Intensive agriculture has dominated the world's food production through the use of synthetic fertilizers, pesticides, irrigation technology, chemical herbicides, and improved crop varieties. Even though these developments expand food grain production, but they also contributing to the habitat destruction, land degradation and environmental depletion, as they remain available in the environment for a longer period leading to soil and environmental pollution. Therefore, allelopathic potential of various crop species is one of the novel approaches to enhance the crop production and to minimize the adverse impact of synthetic chemicals.

Keywords: Alleolochemicals, Allelopathy, Brassinosteroids, Glucosinalates

Introduction

The volatile organic compounds or allelochemicals are the chemical substances which are produced from plants to defend from several biotic and abiotic stresses to enhance the crop production. All the brassica species produce allelochemicals in the form of secondary metabolites; only some species have shown promising allelopathic effect. Allelopathy is a process that involves either direct or indirect effect, and either beneficial or adverse effect of plants on another plant through the environmental impact of chemical releases. The term allelopathy was first coined by the expert Dr. Hans Molisch during 1937 and defined it as a chemical interaction among plants. Allelopathy is a Greek word, where '*allelon*' means each other and '*Pathos*' means to suffer that is injurious effects of one plant upon the another (Rehman *et al*., 2019).

Brassica: An Allelopathic

This family's members growing as vegetables, herbs or oil seed crops and another important character brassica species is allelopathic activity. All Brassicaceae family members possess allelopathic effect, the family comprising around 375 genera and over 3200 species. Out of those Rapeseed/ Canola (*Brassica napus*), Indian mustard (*B. juncea*) and Ethiopian mustard (*Brassica carinata*) are highly allelopathic together with two additional family members *i.e.*, *Sinapis alba* L. and *Raphanus sativus* L. (Jabran *et al*., 2017). These species endogenously produce plant allelochemicals which substantially control the target plant growth and development by releasing chemicals like Glucosinolates, Phenolic compounds, Allyl isothiocyanates and Brassinosteroides. Some Brassica plants contain these compounds that aid in crop growth called Brassinosteroides. These allelochemicals are expelled from various parts like roots, stem, flower, pollen grains, seeds and leaves.

Modes of Allelochemicals Action

1. Decomposition: Brassica plant litters, which are found on the ground, started to decompose by microbial action and release the allelochemicals. These allelopathic compounds either stimulate or neutralize by the micro-organisms, its depending on which type of interaction occurs between the microorganism and transformation of parent compounds.

2. Exudation: The roots are the main source of exudation, which secrete chemicals that are mostly carbon based. Root exudation typically has a lower concentration, which

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stimulates growth.

3. Leeching: The rain grounds leaching of the chemicals from various chunks that either falls on the ground or on next to the plants. The plant's component when used on the soil surface, through the process of leaching, the chemicals reach the target tissues which increase the membrane permeability, further destabilize the plasma membrane and cause cell death.

4. Volatilization: The chemical compounds or secondary metabolites are volatilized through the stomata, which are then taken up by the neighbouring plant's stomata.

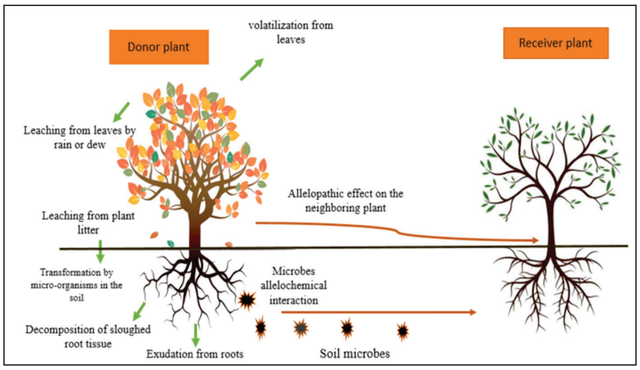


Figure 1: Ways of release of allelochemicals and effect on other plants (Nguyen *et al.*, 2020)

Glucosinolates (GSL)

These are secondary metabolites which build up in whole plants, but are then discharged when plants are injured by the myrosinase enzyme. These exert biocidal effects on various species, including plants, nematodes, insects, and fungus (Rehman *et al.*, 2019), when discharged into the rhizosphere. Depending on the substrate and reaction circumstances, the by-products of the hydrolysis of glucosinolates include glucose, sulphates, and certain active phytochemicals, such isothiocyanates, thiocyanates, cyanides, and nitriles (Rehman *et al.*, 2019).

Glucosinolate content of some Brassica crops are: *Brassica carinata*: 35-170 µmol g^{-1}, *Brassica juncea*: 15.7-127.6 µmol g^{-1} and *Raphanus sativus*: 1.0-145.5 µmol g^{-1} (Nguyen *et al.*, 2020).

Brassinosteroids

Wide variety of Brassica species contains interrelated compounds called brassinosteroides. It was first time extracted from the pollen of rapeseed plant (*Brassica napus* L.). They also boost defences against various abiotic stressors, including heavy metal, temperature, drought, and salinity. Brassica water extract containing brassinosteroides is known as brassinolide where an increase in crop yield upto 20-60% is noticed.

Synthesis of Allelochemicals

In plants "Shikimic acid pathway" considered as the major locale for the synthesis of very important allelochemicals like Phosphoenol pyruvate chorismate (precursor of allelochemicals), the process occurs in cytosol which is known to be an anabolic process.

Mechanism of Allelopathy

• Allelochemicals have various effects on a plant's growth and development. They show impact on a various physiological process, which are important for a plant's healthy growth and development. Although the modes of action of several allelochemicals vary and major effects on plant growth and physiology are still noticeable.

• Cell division.

• Nutrient uptake.

• Biosynthesis of certain proteins and hormones.

• Water relations.

• Membrane permeability.

• Stomatal conductance.

• Photosynthesis and respiration.

• Lipid peroxidation.

Membrane Permeability: Phenolic chemicals disrupt the ion fluctuation and hydraulic conductivity of the cell membrane, rendering it non-specifically permeable. Variations in plant membranes have the potential in affecting transpiration, photosynthesis, and water relations.

Respiration: Interfering in various phases, including electron transport, oxidative photophosphorylation, Carbon dioxide generation and the ATP enzyme activity (Rehman *et al.*, 2019).

Photosynthesis: Impairment to the photosynthetic machinery and the pigments caused by the breakdown of the chlorophyll production pathway.

Extraction of Allelochemicals

i) Conventional Methods

• *Solvent extraction*: Method helpful for separating the compounds based on their relative solubility usually in two diverse immiscible liquids.

• *Solvents*: methanol, Ethanol, Acetone and Ether.

• *Maceration*: This method is used for the volatile and thermolabile compounds. Here the powdered plant material is placed in a container having liquid solvent for a defined period of time to attain equilibrium under room temperature.

• *Percolation*: In this procedure, the herbal material is allowed to absorb a certain amount of solvent before the collected solvent is collected.

• *Decoction/ Infusion*: In decoction plant material is poached for about 15-30 min. in water. It is not appropriate for chemicals that are thermolabile and in infusion method, hot water is added to the plant material.

ii) Non-Conventional Methods

• *Ultrasonic-assisted extraction*: Being assisted by ultrasonic waves with the frequency of > 20 kHz. These ultrasounds are producing the cavitation from the extracting solvent which enhances the solute dissolution and diffuse together thus improving extraction efficiency.

• *Solid-phase microextraction*: A non-solvent extraction method that separates different compounds based on physical and chemical different qualities from those that are suspended or dissolved in liquid. Here, the compatibility of liquid-dissolved solutes with the solid that a sample is passing (Stashenko and Martínez, 2007).

Brassica Allelopathy in Crop Production

The Brassica allelopathy can be used to manage weeds, nematodes, fungus, and abiotic stress in an efficient manner.

Weed Management

The various problems like resistance of herbicides over the weeds, environmental pollution and importance towards the organic agriculture, have emphasized the position of non-conventional methods of weed control (Jabran *et al*., 2017). The selective action of allelochemicals is primarily responsible for these species' suppressive effects. The weed suppressive effect of brassica species followed an order Rapeseed (*B. napus* L.) > Indian mustard (*B. juncea* L.) > Ethiopian mustard (*B. carinata* L.) (Rehman *et al.*, 2019). The following techniques can be used to take use of crops from the Brassicaceae family's allelopathic potential.

1. Cover Crops

Allelopathic crops along with weed management also gives a shield from erosion of soil and snow trapping and helps in nitrogen fixation and enhancement of soil fertility and structure.

- Discharge of allelochemicals over root exudates and leaf shedding by rain will help to decay the whole weed seed bank.
- Strong allelopathic crop will provide more efficient weed control.
- Herbicide resistant weeds are controlled by allelopathic cover crops.
- White mustard as the cover crop will be effective against *Chenopodium album* and *Amaranthus blitoides*.

2. Crop Rotation

These allelopathic crops when used in crop rotation have the potential to suppress the weeds and reduce the weed infestation in the following crop.

- Decomposing crop residues and root exudates are the major source of allelopathy in crop rotation that adding the allelochemicals to the soil which helps to reduce the weed pressure.
- Addition of Rapeseed in the crop rotation instigated about 40% of decrease in weed density.

3. Mulch and Residue Incorporation

Allelopathic residues as mulch, they release allelochemicals in rhizosphere to control weeds. Mustard crops (*B. napus*, *B. hirta*, *B. juncea*) when used as mulch known to exhibit a strong allelopathic effect against *A. retroflexus*, *Capsella bursapastoris*, *Setaria viridis* (green foxtail) (Jabran *et al.*, 2017).

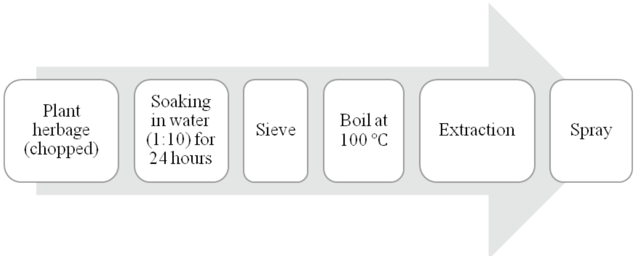
4. Allelopathic Cultivars

Brassicaceae family cultivars have significant potential of allelopathic activity in contradiction of weeds. Cultivars with solid allelopathic activity can support to reduce the weeds (Jabran *et al*., 2017) and this weed control process helps in non-conventional methods like organic farming.

5. Plant Water Extracts

Concentrated form of plant parts dissolved in the water. While the whole plant and root extractions of black mustard suppress weeds in alfalfa, lentil and onion, plant water extracts of white mustard and seed extract of Indian mustard significantly lower the biomass of redroot pigweed and *Chenopodium album* L.

Procedure of Plant Water Extracts (PWE)



Pest Management

The allelopathic water extractions of *Brassica napus* is effective in controlling cabbage aphid, *i.e.*, *Brevicoryne brassicae* at 8-16% (Pontoppidan *et al.*, 2003).

Advantages of Allelopathy

- Substitute for synthetic chemicals.
- Less environmental hazards.
- Cost-effective.
- Eco-friendly.
- No residual effect on crop and soil.

Conclusion

As an alternative to chemical control, the allelopathic effect of Brassica crops can be used to manage weeds, nematodes, and soil-borne illnesses. This can be utilized as a component in integrated management and there is a need for development of innovative environmentally friendly and sustainable agricultural system using plant allelopathy.

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