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Mitigation of Weed Stress in Crops through Phytoherbicides

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Introduction:

Phytoherbicides are plant origin products having herbicidal property and can be used directly as a natural herbicide or act as lead molecules for the synthesis of new synthetic herbicides. Weeds are the hidden competitors for crop plants, interfering with their functions and suppressing the growth and development of crops. Weeds alone are responsible for 1/3rd of total estimated losses caused in production of crops. Effective weed management is critical to maintaining agricultural productivity. Any plant origin products having herbicidal property and can be used directly as a natural herbicide or act as lead molecules for the synthesis of new synthetic herbicides are called "Phytoherbicides". It is directly synthesized from plant extracts. Ex: *Sorgaab, sunfaag*, corn gluten meal, botanically extracted oils. It is indirectly synthesized from templates for new synthetic herbicides. Ex: 1,8-cineole, leptospermone. Weeds are the hidden competitors for crop plants, interfering with their functions and suppressing the growth and development. Weeds alone are responsible for 1/3rd of total estimated losses caused in production by pests in the world. Weeds compete with crops for water, nutrients, light, and space, and thus reduce the crop yields. An estimate shows that weeds can deprive the crop's 47% N, 42% P, 50% K, 39% Ca and 24% Mg from their nutrient uptake. Weeds also act as alternate hosts that harbor insects, pests, diseases and other micro-organisms. Weeds reduce the quality of marketable agricultural produce. Contamination of weed seeds of *Datura*, *Argemone*, *Brassica species* etc., is harmful to human health and weed seeds present in the produce cause odd odour sometimes. Weeds not only reduce yield but also interfere with agricultural operations. Hence, weed management in field crops is an important practice for obtaining optimum yields.

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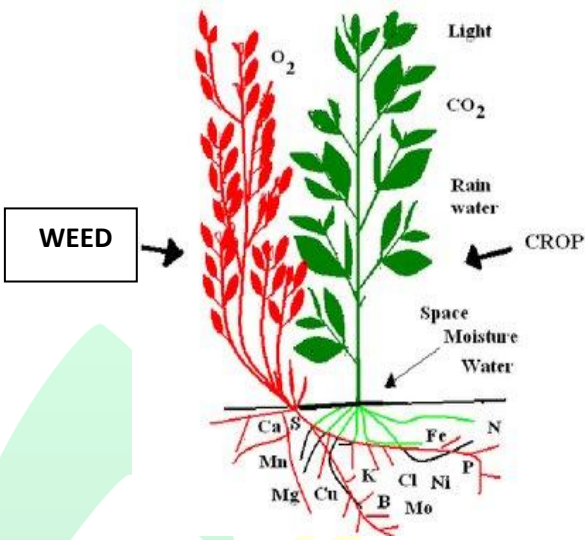

Crop-weed competition

Need of phytoherbicide:

The need for current sustainable and organic agricultural production system has generated demand for effective and alternate plant based natural herbicides to combat the weed problem from natural product data base. Therefore, plant derived organic substances can be a possible alternative for synthetic herbicides. Many plant products are found to inhibit germination and growth of weeds, which have some herbicidal properties.

Basis for phytoherbicides:

Any direct or indirect inhibitory effect by one plant on another through production of chemical compounds that escape into the environment is known as "*Allelopathy"*. The chemical compounds released by the plants are commonly called as allelochemicals.

Thousands of allelopathic substances have been isolated from plants and their chemical structure has been determined. However, the mode-of-action (MOA) has only been

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elucidated for a limited number of allelochemicals (Vyvyan 2002). Some of the allelochemicals such as allyl isothiocyanate (Brassica sp., black mustard), fatty acids (Polygonum spp.), isoflavonoids and phenolics (Trifolium spp., Melilotus spp.), phenolic acids and scopoletin (Avena sativa), hydroxamic acids (Triticum sp.), phenolic acids, dhurrin, and sorgoleone (Sorghum bicolor) have been reported for weed control (Duke *et al*. 2002). Allelopathic chemicals are released from the plants as: 1. Vapour – from root and leaf (through stomata) 2. Foliar leachate 3. Root exudate 4. Breakdown/ decomposition product of dead plant parts 5. Seed extract. In volatilization allelopathic trees release a chemical in a gas form through small openings in their leaves. Other plants absorb the toxic chemical and die. In leaching all plants lose leaves. Some plants store protective chemicals in the leaves they drop. When the leaves fall to the ground, they decompose and give off chemicals that protect the plant. Fall foliage tends to release more potent allelochemicals than fresh, spring foliage. Water-soluble phytotoxins may be leached from roots or aboveground plant parts or they may be actively exuded from living roots. Rye and quackgrass release allelopathic chemicals from rhizomes or cut leaves. In Exudation some plants release defensive chemicals into the soil through their roots. The released chemicals are absorbed by the roots of nearby trees. Exuding compounds are selectively toxic to other plants. Exudates are usually various phenolic compounds (e.g., coumarins) that tend to inhibit development.

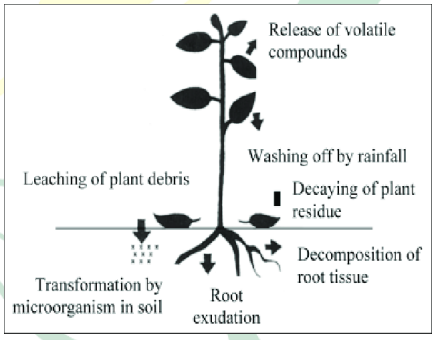

Figure 1: Sources of allelopathy

Characters of Allelochemicals:

Allelochemicals are complex carbon skeletons. Having higher molecular weight, rich in oxygen and nitrogen atoms. Allelochemicals are having number of chiral centres and SP3 hybridized carbons with ring structures. These are rapidly degraded in the natural environment. These are having short half-life period and with low amount of heavy atoms.

Different types of allelopathy observed in plants are:

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1. **Weed on Crop:** *Agropyron repens* (Quack grass) is an important weed of field crops, which causes serious decreases in yield of maize and potato. It interferes with uptake of manures, particularly nitrogen and potassium by maize. Ethylene is generated in quack grass rhizomes due to microbial activity in soil, which is responsible for allelopathic effects of the weed resulting in decrease uptake of mineral by associated crops. *Avena fatua* (Wild oat) is a serious weed of winter annuals like wheat, barley and oats. Wild oat residues inhibit germination of certain herbaceous species in shrubs stand due to an allelopathic mechanism. Growth of leaves and roots of wheat is significantly reduces by root exudate of wild oat. *Cynodon dactylon* (Bermuda grass) found on cultivated lands. Decayed Bermuda grass residues remain in the field inhibits seed germination, root and top growth of barley due to allelopathic effect. *Cyperus esculentus* (Yellow Nut sedge) is a perennial nut sedge infesting grain crops, soybean, orchards etc. It inhibits root and shoot growth of maize and soybean. The effect of soybean is due to the allelopathic compounds like vanillic acid, hydroxybenzoic acid in the yellow nut sedge extract. *Sorghum halepense* (Johnson grass) is a persistent perennial weed in sugarcane, maize, soybean etc. Root exudates and decaying residues of Johnson grass can inhibit both root and shoot growth. *Setaria viridis* (Giant foxtail) yield reduction in corn is due to the inhibitory effect of exudates of mature giant foxtail roots and leachates of dead roots. *Impereta cylindrica* (Cogon grass) inhibits the growth tomato and cucumber. Field bindweed, *Canada Thistle* release root exudates that affect seedling growth of many crops e.g. cabbage, carrot, tomato, radish etc.
2. **Weed on Weed:** *Impereta cylindrica* (Cogon grass) inhibits the emergence and growth of an annual broadleaf weed i.e. *Borreria hispada* (Button weed) by exudating inhibitory substances through rhizomes. *Sorghum halepense* (Johnson grass) living and decaying rhizomes and leaves inhibit the growth of *Setaria viridis* (Giant foxtail), *Digitaria sanguinalis* (Large crabgrass), and *Amaranthus spinosus* (Spiny amaranth).
3. **Crop on Weed:** *Coffea arabica* (Coffee) release 1,3,7-trimethylxanthin which inhibts germination of *Amaranthus spinosus* (Spiny amaranth). *Zea mays* (Maize) root extracts increase catalase and peroxidase activity of the weeds which inhibit their growth. Oat, pea, wheat suppress the growth of *Chenopodium album* (Lamsquarter).

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Recently some rice genotypes have already been identified which have allelopathic effects on weeds. Allelopathic effect of crops and weeds on other weeds may be applied to develop natural herbicides.

Factors affecting Allelopathic effect:

Allelopathic effects might also depend on a number of other factors that might be important in any given situation:

a. **Varieties:** There can be a great deal of difference in the strength of allelopathic effects between different crop varieties.

b. **Specificity:** There is a significant degree of specificity in allelopathic effects. Thus, a crop which is strongly allelopathic against one weed may show little or no effect against another.

c. **Autotoxicity:** Allelopathic chemicals may not only suppress the growth of other plant species, they can also suppress the germination or growth of seeds and plants of the same species. Lucerne is particularly well known for this and has been well researched. The toxic effect of wheat straw on following wheat crops is also well known.

d. **Crop on crop effects:** Residues from allelopathic crops can hinder germination and growth of following crops as well as weeds. A sufficient gap must be left before the following crop is sown. Larger seeded crops are effected less and transplants are not affected.

e. **Environmental factors:** Several factors impact on the strength of the allelopathic effect. These include pests and disease and especially soil fertility. Low fertility increases the production of allelochemicals. After incorporation the alleopathic effect declines fastest in warm wet conditions and slowest in cold wet conditions.

Stimulatory Effects:

Plants also produce certain chemical compounds, which have stimulatory effects on the germination and growth of other plant species. Corn roots contain a complex of stimulatory substances. The water-soluble component of these substances promote the germination of Orobanche minor (parasitic weed), and the ethyl soluble fraction stimulate the germination of Striga hermonthica, (another parasitic weed). Sorghum root produces Kinetin

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and certain other aminopurines, which stimulate the germination of witch weed (Striga asiatica), a root parasite in Sorghum.

These allelochemicals are responsible for this herbicidal nature of the plants. Plant products in the form of aqueous extracts, oil extracts, plant residues, dry powders of crops and other plants used as natural herbicides directly to suppress the growth and development of weeds in different cropped and non-cropped areas. In sorghum crop 'sorgoleone' is the most important allelochemical that is synthesized in the sorghum roots. Aerial plant tissues of sorghum mostly contain phenolic compounds as allelochemicals. By spraying sorgoleone the Weeds that are controlled are *Rumex japonicus, Plantago asiatica and Amaranthus retroflexus* etc. The sorghum water extract is known as 'sorgaab'.

Advantages of Phytoherbicides:

The aqueous water extract/residues of diversified crops/weeds used as natural herbicides. Allelopathic plant extracts in combination with lower rates of commercial organic compounds are less expensive. Templates/lead for designing new synthetic herbicides with greater selectivity. Provide rapid clues for the discovery of new molecular target sites. Provide diversity of molecular structures unlikely to be discovered by traditional strategies. Develop the allelopathic crops/varieties based on molecular biology with higher concentration of allelomones and no auto toxicity.it has unique mode of action, short half life period, eco friendly in nature. Many of them are non-halogenated compounds.

Limitations of Phytoherbicides:

Simplification of highly evolved molecules often leads to loss of biological activity. Phytochemicals are not conducive to efficient plant uptake and translocation. It has relatively short environmental half life. It has faster microbial decomposition of allelopathic water extract under natural conditions. Synthetic derivatives of natural products have high phytotoxicity, limited crop selectivity, instability under field conditions. Allelochemicals are not toxic as synthetic herbicides, only toxic at higher concentrations. Transfer of allelochemical traits to crop cultivars may disturb its chemical balance.

Conclusion:

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Biologically active plant-derived chemicals can be expected to play an increasing role in the commercial development of new products. The increasing environmental pressure, toxicological concern and incidence of pesticide resistance are encouraging the need of plant-derived compounds being used in agricultural fields. Weeds are virtually abundant reservoir of unusual bioactive compounds and the extraction, isolation and characterization of the active constituents can serve as a commercially successful alternative. Aqueous water extracts/lead molecules of allelomones offer new opportunities for development of more cost-effective and environmentally safe methods for weed management. Finally, phytoherbicides are a virtually unexploited source of novel natural herbicides and a tool to discover new herbicide molecular sites.

Commercially developed herbicides based on natural products chemistry:

Natural products	Source	Herbicide	Manufacture & country
Plant products:			
Cineole	*Eucaluptus, Citrus,Salvia*	Cinmethylin	Shell, USA
Benzoquinones (Hydroxamic acids)	Rye, Wheat,Maize	Benzanin	BASF, Germany
Quinolinic acid	Tobacco plants	Quinclorac	BASF, Germany

Different commercial phytoherbicides available in the world market:

Corn gluten meal

Organic extract for crab grass control

Barley straw extract