Allelopathy

1-Introduction

Allelopathy is a secondary metabolites created by plants, fungi, viruses and microorganisms , effect biological and agricultural, which may be either "stimulatory or inhibitory" from the release of compound known as "Allelochemicals" are released to the environment from all plant organs roots, leaves, stems etc. The Allelopathy is a chemical war between plants; which is carry out by one plant to prevent the latter from benefiting from oppression.

allelopathy is one of the modes of interaction between receptor and donor plants and may use either positive effects (e.g.for agricultural management, such as weed control, crop protection) or negative effects (e.g., autotoxicity, soil sickness, or biological invasion).

Competition has been considered to be the main factor, Competition is defined as" the process in which two or more organisms try to utilize the same resource. Thus competition is viewed as a type of negative interaction, or interference, in which the level of some product, be it a nutrient, water, light, or simply space.

Generally, competition is important in plant interrelationships, as it affects primary metabolism. Allelopathy differs that it operates through the input of substances, commonly secondary metabolites, into the environment, which then affect other organisms.

2-History of allelopathy

Allelopathy, in theory, dates back well over two thousand years, but the term itself was create relatively in 1937. The word “Allelopathie” was coined in German by the eminent Austrian plant physiologist Hans Molisch, published shortly before his death in 1937. The word originates from the Greek roots, allelon, meaning ‘among each other’, and pathos, meaning ‘suffering’. The definition of allelopathy was first used by **Molish in 1937** to "indicate all of the effects that directly and indirectly result from biochemical substances transferred from one plant to another".

In 1968, a subcommittee of the International Biological Program (IBP) They recognized that allelopathy was commonly take to mean as referring to negative interactions, and thus recommended a more global term to include stimulatory effects, “allelochemicals ”.The Subcommittee adopted the view that allelopathy pertained to substances of plant origin that could affect both plants and animals.

However, the ground shifted again, as in 1971 an influential paper on allelochemicals by Whittaker and Feeny (1971) decreed that allelochemicals was the domain of all chemical interactions among organisms, a view which has largely continued.

Almost half a century later, the accepted targets of allelochemicals in the plant kingdom include algae, fungi and various microorganisms. In 1984, Rice, redefined ‘allelopathy’, in light of the dual inhibitory and stimulatory effects of substances, as “any direct or indirect harmful or beneficial effect by one plant (including microorganisms) on another through production of chemical compounds that released into the environment.”

In 1996, the International Allelopathy Society broadened its definition of allelopathy to refer to "any process involving secondary metabolites produced by plants, microorganisms, viruses and fungi that influence the growth and development of agricultural and biological systems". In addition, the allelopathic donor and receiver should include animals.

Stage of allelopathy history

The historical backdrop of allelopathy could be divided into 3 periods of its growth :

1. DeCandolle Phase

The period spanning late eighteenth to early nineteenth century, particularly between 1785 and 1845.

2. Pre-Molisch Phase

The period of the early twentieth century extending from 1900 to 1920, known by the work of Pickering and Scheiner.

3. Post-Molisch Phase

1937 onwards, which actually showed progress ever since 1960.In communities, distinct plant species may associate in a positive, neutral, or negative way. It is only once in a while the living organisms in a community stay neutral. Negative interactions, however, are more common between the organisms.

The negative effect of a neighboring plant in an affiliation is known as interference (Muller, 1969), Putnam and Tang (1986) have classified interference as:

1. Allelospoly

More commonly called competition, which included consumption of one or more resources attained for the growth and development of living organisms in environmental.

2. Allelo-Mediation

Discerning harbouring of herbivore that might choose to feed on some plant species, thus lending an advantage to another.

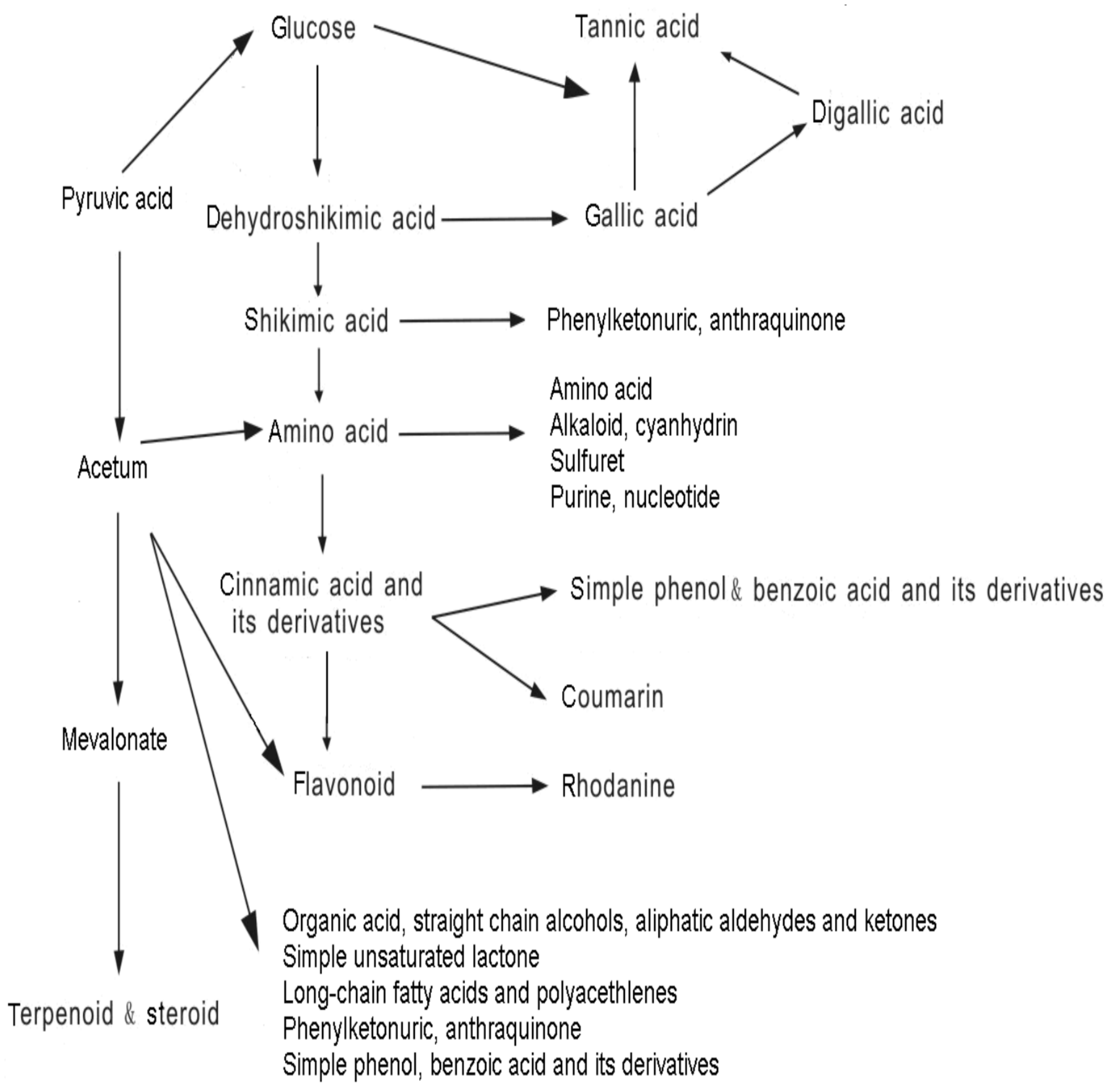
3. Allelopathy

Allelopathy, the chemical mechanism of interspecific plant interference, characterized by a negative effect on plant performance in the association.

Allelochemicals

Allelochemicals are secondary substances, biosynthesized from the metabolism of carbohydrates, fats and amino acids and arise from acetate or the shikimic acid pathway.

These are biosynthesized and stored in the plant cells and do not affect in the cell activities. However, after their release from the plant cells (through volatilization, leaching root exudates and decomposition of biomass), these allelochemicals start influencing the organisms (plants, pathogens, insect,etc.), when they come in contact.



Nature of Allelochemicals

Allelochemicals based on their structural differences and properties, Rice (1984) has divided these compounds into 14 chemical categories: (a) cinnamic acid derivatives, (b) coumarins, (c) simple phenols, benzoic acid derivatives, gallicacid and protocatechuicacid, (d) flavonoids,

(e) Tannins,(f)Terpenoids and steroids, (g) water soluble organic acids, straight chain alcohols, aliphatic aldehydes and ketones, (h) simple unsaturated lactones, (i) long chain fatty acids, (j) naphthoquinones, anthraquinones and complex quinones, (k) amino acids and polypeptides, (l) alkaloids and cyanohydrins, (m) sulfides and mustard oil glycosides and (n) purines and nucleotides.

Putnam and Tang (1986) grouped these chemicals into 11 classes: (a) toxic gases, (b) organic acids and aldehydes, (c) aromatic acids , (d) simple unsaturated lactones, (e) coumarins, (f)quinines, (g) flavonoids, (h) tannins, (i) alkaloids, (j) terpenoids and steroids, and (k) miscellaneous and unknown.

Factors affecting in production of allelochemicals:

1. . amount of produced allelochemicals compounds influence by long-day photoperiods, Growing seasons , plant growth stage .
2. Mineral deficiency: Mineral deficiency leads to increases in allelochemicals.
3. Drought stress: enhanced the production of allelochemicals under these conditions.
4. Temperature: allelochemicals are production in larger amounts in Cooler temperatures .

5. Plant tissue type and the age: allelochemicals production different within species and between species, a result of the unequal spreading of compounds in plants.
6. Plant diseases, predator can influence allelopathy.

As will as there are many factors effect on allelochemicals amount produced that: radiation, water stress, temperature, Allelopathic agents and age of plant organs .

Types of Alelochemicals

1- Aromatic Compounds

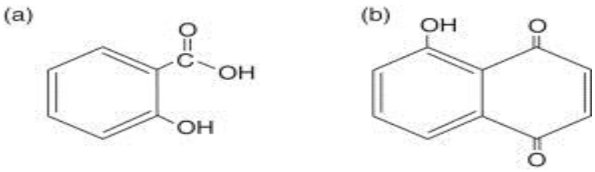
This group includes(phenolic acide, phenols, flavonoids, coumarins, Tannins) Phenolic compounds occur in plants ,these consist of:

a) Simple phenols

simple phenolic acids, such as the benzoic acid and cinnamic acid derivatives and assist a variety of plant and ecosystem ,are widespread in higher plants .

b) Phenolic acide

They are synthesized in response to stress conditions such as infection, wounding and UV radiation, etc. These compounds are a very varied group of phytochemicals derived from phenylalanine and tyrosine Like most allelochemicals, phenolic acids are secondary plant compounds typified by a hydroxylated aromatic ring structure. Species which have been noted to produce phenolic acids include: rice , wheat . contain multiple phenolic compounds along with other allelopathic compounds. however, it is not clear to what degree individual allelochemicals interact to produce plant inhibition, Early research with phenolic acids indicated that some phenolic acids could function though increasing cell membrane permeability, thus affecting ion transport and metabolism.



Figure(1) a-salisylic acid b-juglone, an allelopathic phenolic produced by walnut.

c) Flavonoids

Flavonoids are a plant pigments, they contribute to colour by acting as co-pigments, basic structural elements, namely the 2-phenylchromane, accumulate in vacuoles and depending on the species, are either concentrated in the epidermis of the leaves or spread in both the epidermis and the mesophyll. In flowers, they are concentrated in epidermal cells, Whenever flavonoids are present in the leaf cuticle.

d) Quinones

Quinones can be divided into four groups: benzoquinones, naphthoquinones, anthraquinones and isoprenoid quinones. Naphthoquinones and anthraquinones are among the most widely distributed natural quinones.

2-Alkaloids

Alkaloids are a very large and heterogeneous subgroup of nitrogenous

Compounds, They are basic compounds containing one or more nitrogen atoms in their chemical structures, alkaloids have been

classified in three main groups:

(i) **True alkaloids:** These are derived from amino acids and have a heterocyclic ring, which includes a nitrogen atom Ex: Lupinus alkaloids derived from lysine, by cadaverine, and Senecio alkaloids derived from ornithine, are examples of true alkaloids containing one or more nitrogen atoms from the first step of their biosynthesis.

(ii) **Proto-alkaloids:** These are also derived from amino acids but the nitrogen atom is not contained a heterocyclic ring.

(iii) **Pseudo-alkaloids:** These are not derived from amino acids but from terpenoids (solanine) or purines (caffeine) and have a heterocyclic ring with a nitrogen atom in their chemical structures.

(iv) 3-Glycosides

glycosides, made even more lipophilic by the partial or total methylation of their hydroxyl groups As a general rule, glycosides are water-soluble and soluble in alcohols, includes(benzaldehyde ,hydroxybenzaldhyde)

4-Tannins

Tannins are water-soluble phenolics of molecular weight between 500 and 3,000,which, Two main groups of tannins are generally distinguished, which differ by their structure, as well as their biogenetic origin:

hydrolysable tannins and condensed tannins. They are distributed unevenly throughout the plant kingdom,The amount and type of tannins synthesized by plants varies considerably depending on plant species, cultivars, tissues, stage of development and environmental conditions.

The name proanthocyanidins is used to designate the condensed tannins because the anthocyanidin is released after hydrolysis.

5-Terpenoids and steroids

They constitute the largest known group of plant secondary metabolites. Common of them are specific to the plant kingdom, but they also occur in animals, e.g. sesquiterpenoid insect pheromones, diterpenes of marine organisms . Triterpenes are specific to the plant kingdom and like steroids, arise from mevalonate. The mechanism of formation of these last compounds is a little different from that of triterpenes, but their structure is perfectly specific to a plant group; this is true for cardenolides, steroidal alkamines, saponins, and phytosterols.

Terpenoids and steroids are formed by units of five carbons derived from 2-methylbutadiene

6-Organic compounds (organic acids)

Aqueous extracts of plant tissues contain large amounts of organic acids. Citric, malic, tartaric, succinic and oxalic. These acids accumulate in plant cell vacuoles, where high quantities of malic, citric and isocitric acids are accumulated in the vacuoles during the day.

Plant organic acids can contain a variable number of carboxylic groups, Organic acids are water-soluble, colourless liquids with relatively low melting points. In general, they are non-volatile compounds.

ALLELOPATHY

(Lecture 3) ا.م. ايمان رضا جاسم

Modes of release allelochemicals into environment

Allelochemicals can be found in all parts of the plant, the greatest amounts are most often located in the roots and leaves. Plants release their allelochemicals in several different ways(Figure 1):

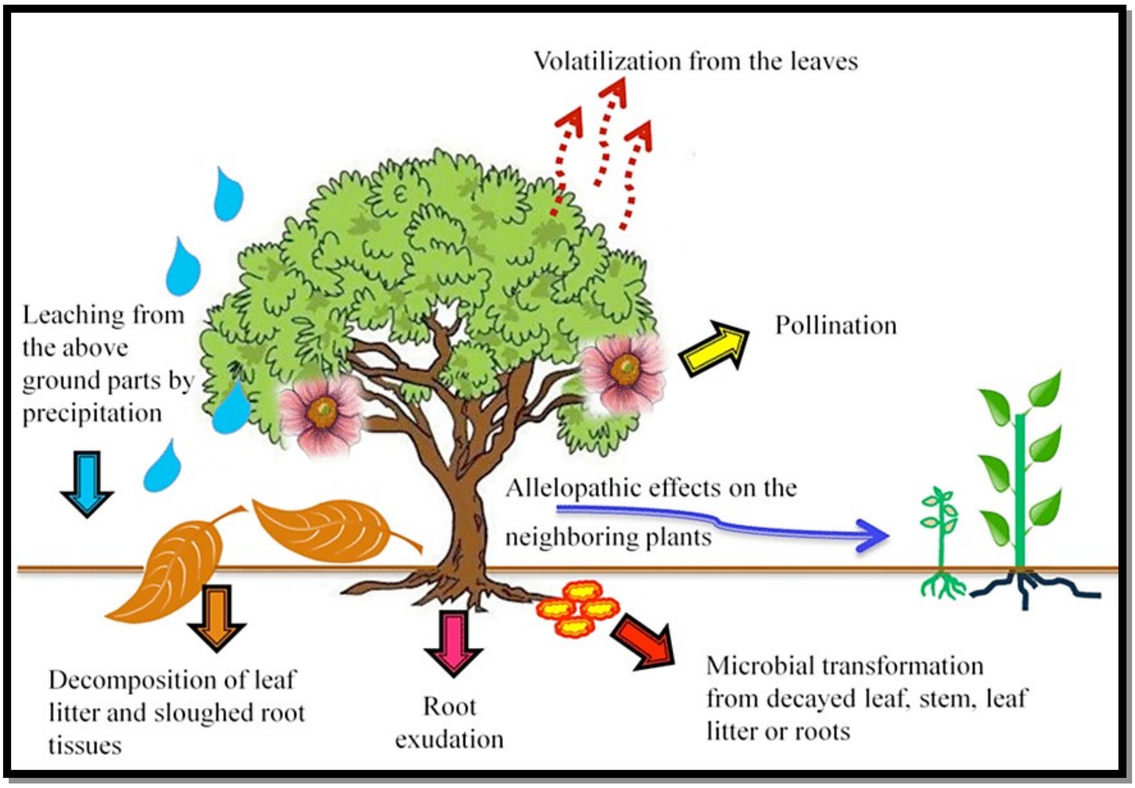


Figure 1: Release of allelochemicals from plant to the environment

1.Volatilization

The toxic chemicals are released as a gas from opening in their leaves and then are absorbed by another plant. Higher plants regularly release organic compounds by volatilization from their surfaces of leaf. The release of volatile compounds from plants may also be regulated by specific transport processes.

bioassays under controlled conditions in a growth chamber showed that germination and seedling growth of Lactuca sativa and growth of Vitis were reduced when grown near tomato plants .In contrast, volatile phytotoxic monoterpenes such as cineole, piene, and camphor have long been reported as allelopathic inhibitors.

2**- Leaching:-**

All plants lose leaves. When leaves fall on the ground, they decompose and give off chemicals that protect the plant. In leaching, the chemicals that are stored in the plant's leaves seep into the soil, via rain, fog, or dew that comes into contact with the leaves.

Examples of plant species that exhibit allelopathy include, many trees (eucalyptus, and oak), shrubs, agricultural crops (tobacco and rice),and various grasses, Each releases its own type of allelochemical. the vegetable seeds examined that are known to be sensitive to allelopathic toxins were tomato (Solanum lycopersicum), cabbage (Brassica oleracea), and The seeds that are known to be resistant to allelopathic toxins, bean (Phaseolus vulgaris) and corn (Zea mays)were compared with the sensitive plants, in order to test the phenomena of allelopathy.

One of the most well-known allelopathic chemical toxins is known as juglone , Juglone is the compound release from Black walnut trees , negatively affects the growth of many plants, including pine, blueberry, and tomato, often times killing very sensitive species. The study of Allelopathic effects of Squash (Cucurbita pepo L.)on certain common weed species in Jordan, showed that even 1ml of squash extract caused reduced germination and growth all of the weeds, and these effects were amplified with increased concentrations of squash extracts . Other studies have investigated the allelopathic effects of a variety of other plants, such as sour orange, red maple, eucalyptus, mango, wheat, and broccoli; each of these allelopathic plants interfered with the growth of surrounding plants.

3- **Decomposition of the residues in the soil :**

A large number of plants impose inhibitory effects on the germination and growth of neighboring or successional plants by releasing allelopathic chemicals into the soil, either as exudates from living tissues or by decomposition of plant residues , These decomposition products are often added to the soil matrix. Some are volatile compounds that permeate the air environment of the soil as well as having some solubility in the aqueous phase. Wheat residues have been reported to:

1- Inhibit growth of certain weeds, crops that follow wheat crop in crop rotation

2. Affected the soil nitrification and biological nitrogen fixation**.**

Thus crop production can be enhanced by the inhibitory effects. In Some studies reported that aqueous extracts of *Eucalyptus camaldulensis L.* inhibited seed germination, fresh and dry weight of wheat seedlings. Other reported that the leaf extract of *Helianthus annus* inhibited the rate of germination of wheat seedlings.Toxic releases are the mechanisms of action of many fungal pathogens, antibiotic zones improve the success of certain bacteria, the chemical constituents of all organisms are released to the environment through the processes of decomposition.

4-Exudation of roots:-

Some plants release defensive chemicals into the soil through their roots ,absorbed by the roots of nearby plants that tend to inhibit or exhibit development. In ecological terms, the rooting zone and rhizo-sphere is a very competitive environment where roots of neighboring species and microorganisms compete for space, water, nutrients, and gases, In addition to providing mechanical support . water and nutrients in roots also rely on the synthesis and exudation of metabolites . The rhizosphere is specifically defined as:- a narrow region of soil surrounding the living root that is influenced by root secretions and contains associated soil microorganisms.

Many bacteria thrive in this location because of the physical environment in this zone (e.g. pH and moisture) and because they can feed on sloughed-off decomposing root cells and metabolites released by living plant roots, Other soil microbes, protozoa, nematodes, and fungi also contribute to the significant nutrient cycling occurring in the rhizo-sphere. As a result, exudates can repel herbivores and microbes, stimulate symbiotic relationships, alter soil properties, and inhibit the growth of competing species .

Exudates of all plant roots can also include:-

A- low molecular mass constituents such as amino acids, organic acids, sugars, phenolics, and other secondary metabolites comprise of root secretions.

B- high-molecular-mass root constituents proteins , many of which serve as metabolic substrates .

When roots are under stress they often react by releasing low molecular mass compounds, including amino acids, organic acids, and phenolics as well as proteins. These secretions can protect the plant, these exudates can elicit symbiotic responses that initiate legume Rhizobium nitrogen fixation or attract common soil microbes, which are positive forms of communication. Some studies concluded that the rice root exudates had anti-fungal properties while that from watermelon promoted pathogen growth(Figure 2).

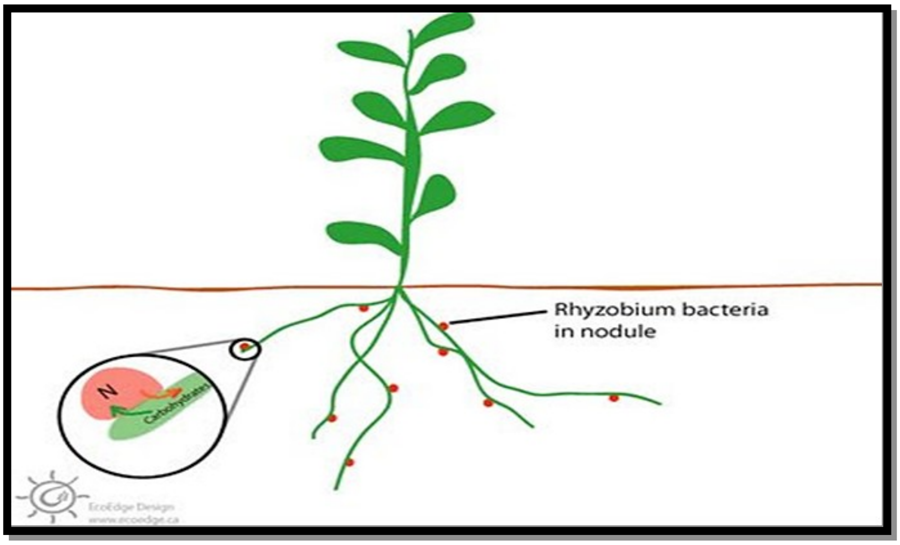


Figure 2 : Relationship of soil microbiota with plants.

Allelochemicals can act on plants in a variety of ways:-

1-Inhibiting germination by disrupting cell division.

2- Interfering with mechanisms of energy transfer such as respiration.

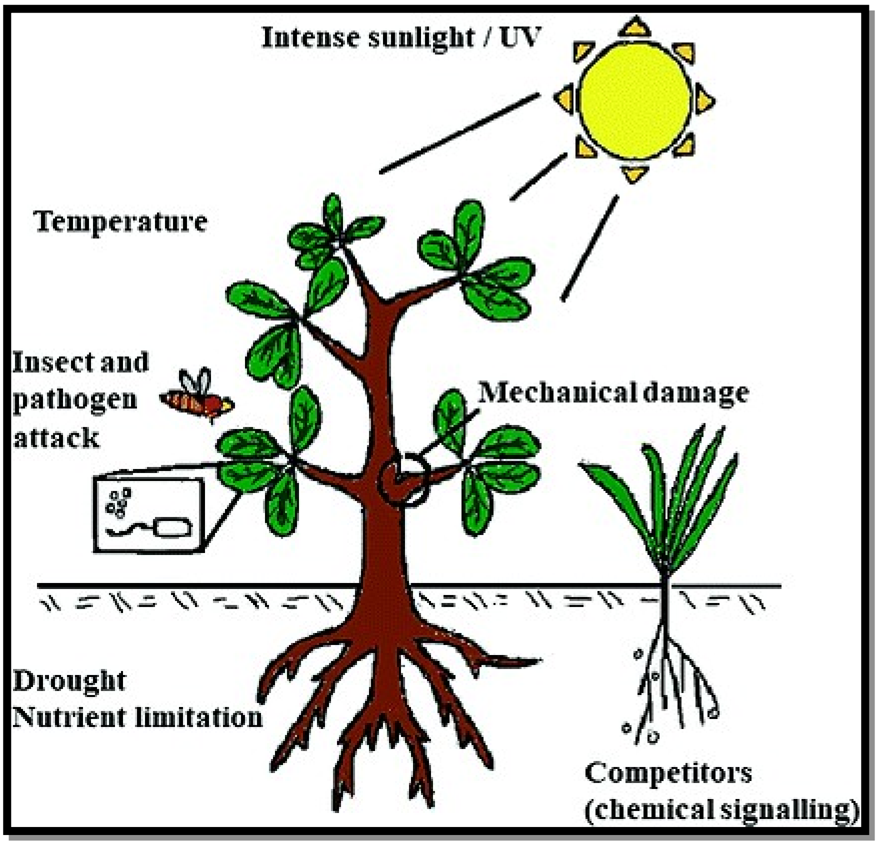
3- Limiting water and nutrient uptake.

The overall effect is to severely impede the growth of the plant.

REGULATORY FACTORS

Factors influencing the release of allelochemicals are normally abiotic, such as high radiation, low humidity, unsuitable pH, ultraviolet light, temperature, nutrient deficiency, pollution or contamination (including pesticides). The higher is the stress caused by this factors to the plant, highest is the allelochemicals amount released from secondary metabolic routes.This is important for research and pharmacy: for generating relevant oils many plants are grown under stressful conditions, as it is thanks to the production of these secondary metabolites that they can survive.

Biotic factors also take part, such as insects, herbivores or competition with other plant species. These activate the plant defenses and then the organism is stimulated to secrete bitter substances, or substances that harden the tissues, that are toxic or give off unpleasant odors, etc. Finally, each plant has its own genome and this makes synthesize those or other substances. But, they are also determined by the phenology (life stages) and the development (if the size of the plant is bigger, it can release more allelochemicals.



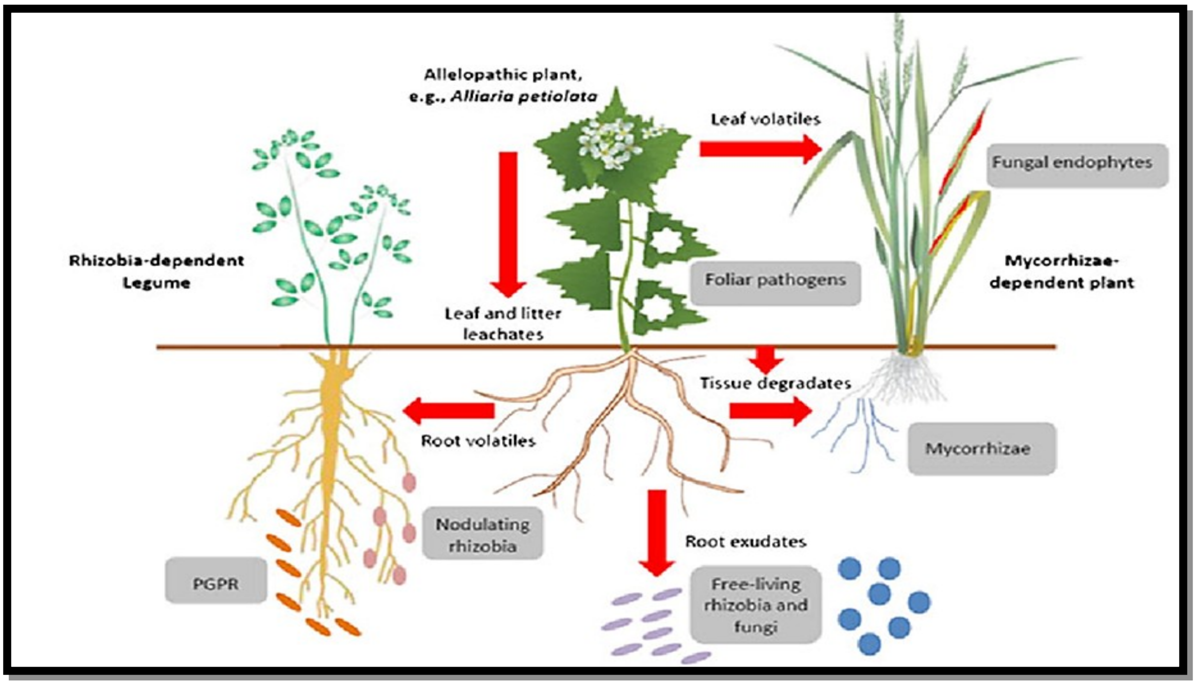
. **Figure (3)** : Effect of abiotic factors on plant

Allelopathy ا.م أيمان رضا الراوي

(lecture 4)

Allelopathic effect in agro-ecosystem

Crops, weeds and even the trees are the integral visible biotic components of agro-ecosystems. In addition, a diversity of invisible microbes also plays an important role.



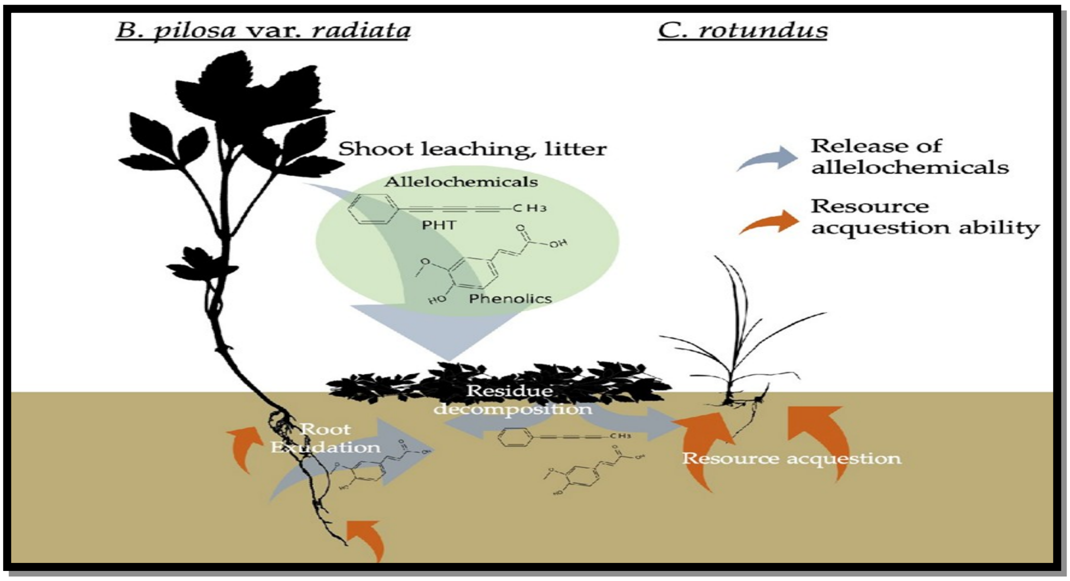
.**Figure (1)** : allelopathic effect in agroecosystem

1. Allelopathic weeds

Weeds are an integral and ecologically important components of agroecosystems., weeds continue to pose threat to crops . They have a number of physiological, agronomic and reproductive characteristics, which make them successful compared to the other plants that further make them competitively stronger and thus adversely affecting crops. (Kohli *et al*., 2004).

They compete with the crop plants for resources, reduce crop yield and deteriorate their quality and thus resulting in huge financial loss. Nearly 12% of the total loss of crop yields has been attributed to the weeds alone. Qasem and Foy (2001) reported nearly 240 weeds to be allelopathic , Parthenium hysterophorus commonly has caused much harm to plants in India, Australia and other parts of the world. All parts of this weed including the dried residues contributing a major fraction of allelochemicals in the environment.

Some of the allelochemicals of *P. hysterophorus* are water-soluble while others are water-insoluble and are mainly released through microbial decomposition and root exudates. In fact, *parthenium* provides several properties, including allelopathy, to the weed and can also help in weed management by suppressing growth of the noxious weeds.Among the phenolic acids, caffeic, ferulic, p-coumaric, p-hydroxybenzoic and flavonoids ,volatile essential oils have been reported in the areas infested by it. Even the soil collected from the *Ageratum* infested area was found to be phytotoxic to crops and this was attributed to the presence of water soluble phenolics in it released from the weed.

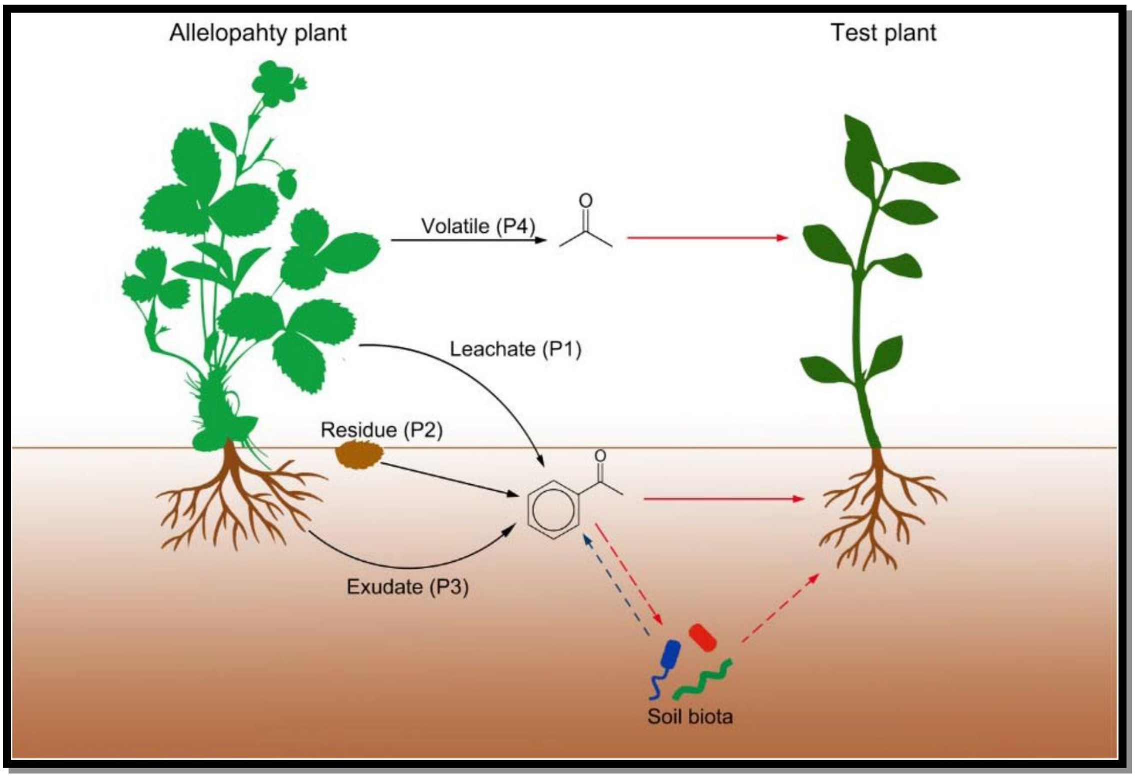


.Figure (2) : Allelopathic relationship between plant and weed

2.Allelopathic crops

A number of crops have also been observed to exhibit allelopathic effects on other crops and weeds, besides being autotoxic . Crop auto-toxicity in agroecosystems is significant. This problem is commonly known as soil sickness. In Agroecosystems 469 residues of old roots in soil releasing phytotoxins, which may directly affect the succeeding crops and may cause

1-microbial imbalance 2- change organic matter of soil 3.increase ion leakage 4-disturb nutrient uptake.



. **Figure (3)** : Allelopathic relationship between plant and plant

Some of important crops exhibiting autotoxicity include rice, wheat, maize, sugarcane, alfalfa and vegetable crops like, cucumber, carrot, fennel, eggplant, tomato. A variety of water-soluble or insoluble or volatile phytotoxins are released by the crops and their residues. These accumulate in the soil and affect the germinating of another crops. Some of the major agronomic crops produce allelochemicals which can affect weed growth, result in autotoxicity, or influence growth of the next crop. Sunflower (*Helianthus annum),* Sorghum crops, and rye (*Secale cereale)* are perhaps the better documented examples of allelopathy .Some accessions of oats produced three times as much scopoletin as a standard cultivar and the former provided better weed control. Grain sorghum and sunflower yields show a marked decline when these crops are replanted year after year, seen with wheat (*Triticum aestivum*), rice (*Oryza sativa*), corn, and several others, production of alfalfa and other perennial legumes diminishes due to autotoxicity. The concentration of allelochemicals varies with :-

1.Age of crop 2.Cultivar 3. Plant organ, 4. Their amount is often enhanced by various biotic and abiotic stress factors .

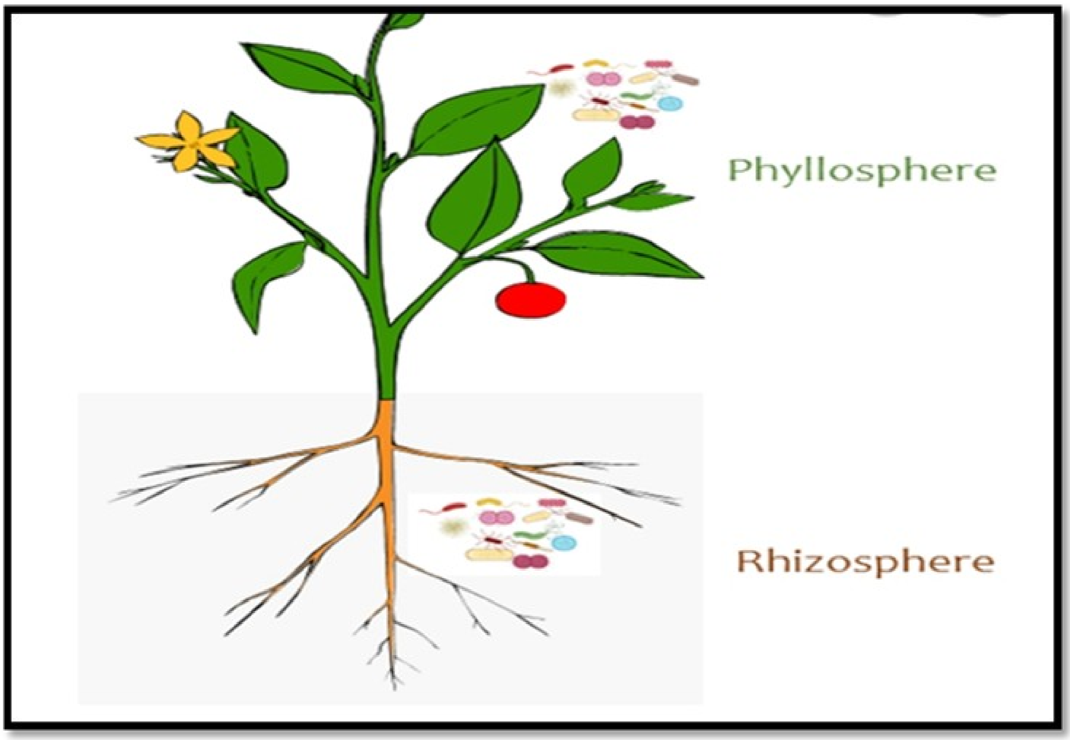
3.Allelopathic trees

In addition to weeds and crops, trees are also an integral part of the agriculture. In fact, Several studies show that this practice increases productivity, improves soil quality and nutrient cycling, conserves soil, manages weeds and increases overall sustainability though a number of negative interactions (including allelopathic) have also been recognized .In most of the instances, the litter from the tree interferes with the growth of the adjoining crop plants. A number of volatile and non-volatile allelochemicals have been identified from the tree.

Among the volatile oils, various monoterpenes like cineole, limonene, citronellol, citronellal, grandinol and α-pinene have been identified and found to be very toxic to the germination and growth of other plants .The volatile oils rich in monoterpenes diffuse through the leaves, travel downwards as they are heavier than air and get adsorbed to the soil particles and affect vegetation. The aqueous extracts prepared from the leaves of the tree and litter mulched in soil are observed to have deleterious effects on a number of plant species including crops like sorghum, cowpea and sunflower .Allelochemicals from trees can be used for controlling the weeds, e.g. volatile oils from Eucalyptus sp., mimosine from *Leucaena* spp.

4. Microbes and allelopathy

Microbes have a greater effect on the allelopathic activity of higher plants as they are known to alter or transform the amount of allelochemicals, particularly the phenolics. ,their role depends upon the available carbon source and other environmental factors. The microbes may affect allelochemicals by addition or deletion of side groups, polymerization, production of other organic molecules and / or incorporation of carbon from other phenolic compounds into microbial biomass.



. **Figure (4)** : Soil biomass effect on plant

The allelochemicals from microorganisms are generally non-specific and inhibit the growth of several annual and perennial species, allelochemicals may influence the growth of microbes positively or negatively, thereby indirectly interfering with the availability of nutrients, particularly nitrogen and phosphorus, in the soil. Besides, phenolic compounds released in soil from decomposing residues may cause microbial imbalance . In orchards microbes play an important role in replant problem besides the autotoxicity, Presence of *Penicillium expansum* in apple orchards facilitates the release of allelochemicals . In Asparagus, it has been observed that allelochemicals synergist with fungal pathogens, thereby increasing the disease incidence.

The differences among allelopathic effects (trees, crops, weeds)

1- According to type and part of plants, many studies showed that leaves are the most effectives parts caused allelopathic effect do to forming secondary metabolism and relation metabolic product for it.

2- Growth stage of the affected(recipient) plant like germination, flowering and elongation .3- The concentrations of allelochemicals .

4 The effect of allelochemicals either alone or additive(synergistic).

5-Sensitivity of plant’s roots are the most affected part due to direct contact with surrounding environment(soil).

6- The remaining period of allelopathic effect.

7- The nature of allelochemical of plant, e.g. phenolic acids reduced the germination and growth other compound caused synergic effect.

Mechanisms of action Allelopathic compounds :

A series of physiological and biochemical changes in plants induced by allelochemicals are detailed as follows:

A. Structural level .
B. Molecular and biochemical level.
C. Physiological level

A. Structural level .

1-Changes in the Ultra-Structure of Cells

The shape and structure of plant cells are affected by allelochemicals. that effect on the cell ultra-structure such as, vacuoles, chloroplasts , mitochondria, thickening the cell wall and reducing intercellular communication and the formation of root hairs, in one study they found Upon exposure to hordenine and gramine, which are allelochemicals from barley (*Hordeum vulgare*) roots, the radicle tips of white mustard (*Sinapis alba* L.) exhibited damaged cell walls, increases in both the size and number of vacuoles, disorganization of organelles, and they found Cinnamic acid significantly deformed the ultrastructure of cucumber chloroplasts and mitochondria.

- Cell Division and Elongation2

Allelochemical monoterpenoids affected cell propagation and DNA synthesis in plant meristems cell division in root tips ,the Phase factor index , for example benzoxazolinone (BOA) inhibited the mitotic procession lettuce significantly inhibited the regeneration of cucumber root cap cells and thus inhibited growth.

3-Anatomy of plant

Allelopathy effect in plant anatomy of leaf ,stem ,and root study effect by Wheat residues caused reeducation in stem diameter section, and caused the greatest inhibition root diameter section in *sonchus oleraceus* L. ,While remarked increases in vascular calendar diameter for *Lolium rigidum* L

B-Molecular and biochemical level.

1-Effect on the Functions and Activities of Various Enzymes

Allelochemicals use different effects on the synthesis, functions, contents and activities of various enzymes. Previous studies have shown that the key enzyme λ-phosphorylase involved in seed germination might be inhibited by chlorogenic acid, caffeic acid and catechol. In addition, protease can be suppressed by allelochemicals.

2-Influence on Protein and Nucleic Acid Synthesis and Metabolism

Most alkaloids show allelopathic potential. Some can closely integrate with DNA and increase the temperature of DNA cleavage, while some can inhibit DNA polymerase and prevent the transcription and translation of DNA, whereas others can inhibit protein biosynthesis , Allelochemicals can also inhibit amino acid absorption, in addition to transport, thus interfering with protein synthesis, which affects cell growth , All phenolic acids can affect the integrity of DNA and RNA. Ferulic acid

C. Physiological level

1-Cell Membrane Permeability

Many studies have shown that allelochemicals significantly inhibit the activity of antioxidant enzymes and increase free radical levels, resulting in greater membrane lipid peroxidation and membrane potential alteration, which diminish the scavenging effect on activated oxygen and damage the whole membrane system of plants. The growth of *Avena ludoviciana*, and *wild mustard* seedlings were found to be inhibited by an aqueous extract of barley aerial parts through increasing lipid peroxidation

2-Effect on the Plant Growth Regulator System

Allelochemicals can alter the contents of plant growth regulators or induce imbalances in various phytohormones, which inhibits the growth and development of plants, for example, with respect to seed germination and seedling growth. Most phenolic allelochemicals can stimulate IAA oxidase activity and ABA content in the roots .

3-Influence on Respiration

Allelochemicals affect plant growth by influencing different stages of respiration, such as electron transfer in the mitochondria, oxidative phosphorylation, CO_2 generation and ATP enzyme activity. These chemicals can reduce oxygen intake, which prevents NADH oxidation, inhibits ATP synthesis enzyme activity, reduces ATP formation in mitochondria, disturbs plant oxidative phosphorylation and ultimately inhibits respiration; on the other hand, they can stimulate the release of CO_2, which promotes respiration.

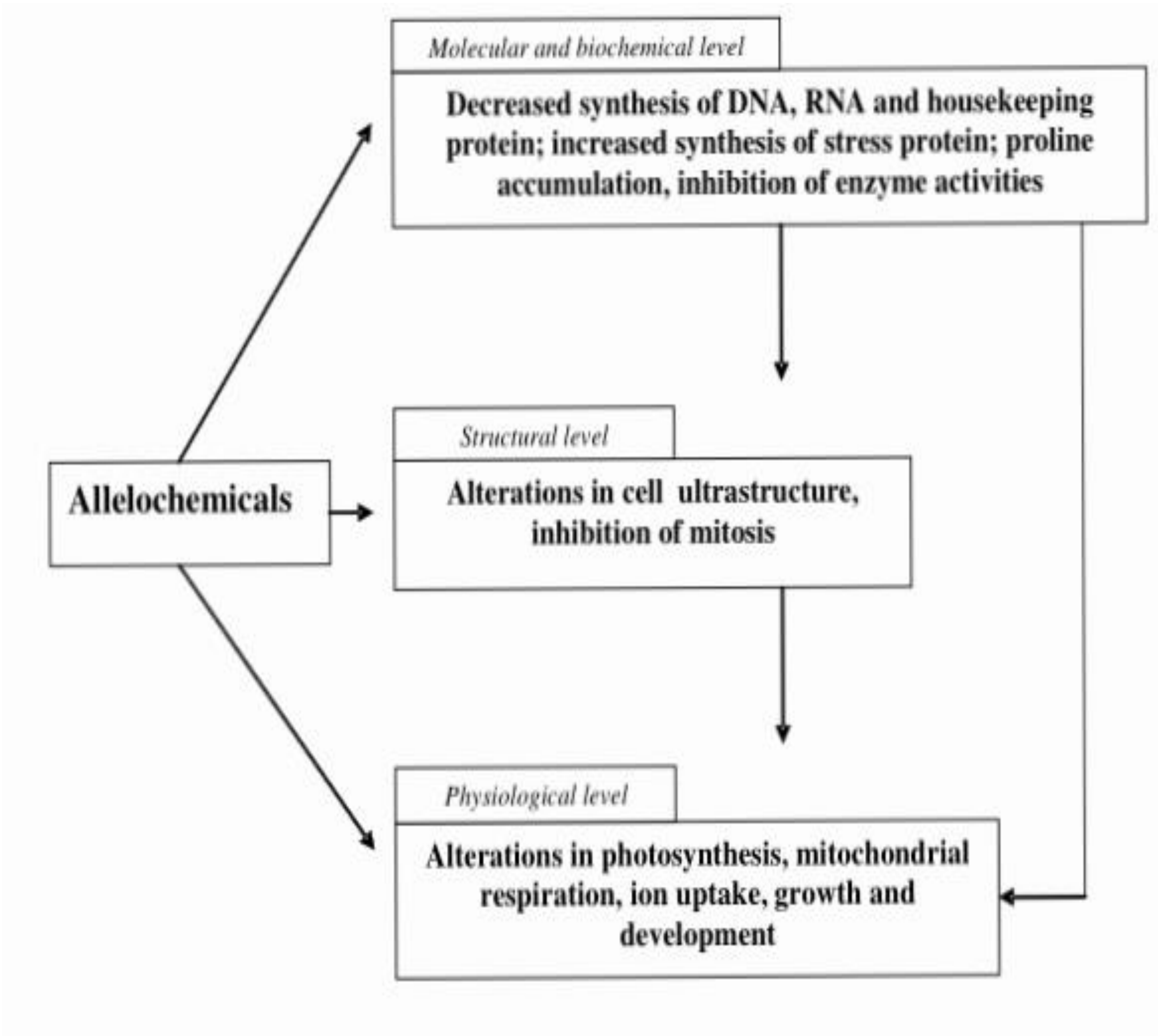
4-Effect on Plant Photosynthesis

The impacts of allelochemicals on plant photosynthesis mainly involve inhibition of or damage to the synthesis machinery and acceleration of the decomposition of photosynthetic pigments. which effect in energy and electron transfer, ATP synthesis, enzyme activity, and affects stomatal conductance and transpiration, which effect in the photosynthetic process . example: aqueous extracts of leaves from *Trema micrantha* (Ulmaceae), an allelopathic plant, did not lead to inhibition of the synthesis of photosynthetic pigments in radish (*Raphanus sativus* L.)

5-Influence on Water and Nutrient Uptake

Many allelochemicals affect nutrient absorption in plant roots or induce water stress through long-term inhibition of water utilization. Allelochemicals can inhibit the activities of Na^+/K^+-ATPase involved in the absorption and transport of ions at the cell plasma membrane, which suppresses the cellular absorption of K^+, Na^+, or other ions.

found that ferulic acid (250 μM) inhibited ammonium and NO_3^- uptake in corn seedlings, although ammonium uptake was less sensitive to this treatment than NO_3^-.



Mechanisms of action Allelopathic compounds

Importance of allelopathy in breeding new cultivars:

Allelopathy is defined as the direct influence from a chemical released from one plant on the development and growth of another. It is known that allelopathic substances are induced by environmental stresses, as Allelopathic compounds may be released into the environment from plants by means of root exudation, leaching, volatilization and decomposition of plant residues in the soil .

Although a breeding approach alone cannot overcome weed problems, an increase in the allelopathic potential of plant varieties will likely have a great impact on cropping systems. Moreover, allelopathy-based technology is also more easily transferable to farmers in low-input management systems than those in high-input management systems, which use herbicide. There are strategies to enhance weed control by engineered Allelochemical production

IMPORTANCE OF ALLELOPATHY IN BREEDING NEW CROPS

Recent research on plant allelopathy has advanced the possibility of breeding allelopathic crops for the following reasons:

1. A variation in allelopathy among cultivars .
2. Allelopathy plays a role under field conditions.
3. Allelopathic is effective on both mono- and dicot weeds.
4. Identification of allelochemicals has progressed remarkably.
5. Quantitative trait loci (QTL) correlated with allelopathy have been determined.

Ecological Importance

In all ecosystems, herbicides have become one of the most important components in weed control. There are two reasons to explain the increased use of herbicides:

First being the widespread adoption of high-yielding varieties which created economic incentives for farmers to reduce weed infestation. **Second** is the availability of cheap herbicides .

All the recommended herbicides used are known to be not safe for humans and animals, but also for the environment when they are used properly. However, intensive and repeated application of this type of herbicide has resulted in **several negative effects, as follows**:

•evolving resistant weeds

• residual effects on the following crops;

• disappearance of some susceptible weeds such as Brasenia schreberi and Sagittaria aginashi, which affects weed biodiversity.

Putative allelochemicals

There are a number of studies indicating that common putative allelopathic substances found in plant are phenolic compounds ,sterols, benzaldehydes, benzene derivatives, long-chain fatty acid esters, aldehydes, ketones and amines from fractions with biological activity. Among the allelopathic substances identified, p-coumaric acid, a known allelochemical, inhibited the germination of lettuce (Lactuca sativa L.) seedlings at 1mM, but was active against barnyard grass only at concentrations higher than 3 mM .

STRATEGIES FOR BREEDING ALLELOPATHIC CROPS

The three approaches to create more allelopathic crops are :

1. Traditional breeding method.
2. Incorporation of allelopathic properties to hybrid plant
3. Genetic engineering.

Traditional breeding method

If a high number of Quantitative trait loci QTLs with little effect are involved, a traditional breeding method can be a reasonable alternative. The principle of traditional breeding for the genetic studies is simple.

Two parents with contrasting behaviour are crossed and recombinant inbred lines

Incorporation of allelopathic properties to hybrid plant

The three-line hybrid rice that is popularly cultivated in China is a good competitor because of its rapid and profuse vegetative growth in comparison with an inbred line. It will be worthwhile if allelopathic traits can be introduced into an elite restorer line in developing three-line hybrid rice. Lin et al. (2000)

attempted simultaneous backcrossing and selfing breeding method to develop hybrid rice with allelopathic activity and its counterpart, isogenic hybrid rice with a non-allelopathic effect on weeds. Three lines of rice, Kouketsumochi, Rexmont and IR24 were used as the donors of allelopathy, non-allelopathy

Genetic engineering.

Two methods for creating more allelopathic crops have been suggested: (1) the regulation of gene expression related to allelochemicals biosynthesis;

(2) the insertion of genes to produce allelochemicals that are not found in the crop.

Aim of breeding allelopathic crop cultivars

1. An improvement in allelopathic potential in crop varieties will have a great impact on management systems.
2. Allelopathy may be reduced use of herbicide will be a significant economical benefit to farmers and will also reduce the ecological impact on the environment.
3. At present, no commercial cultivars carrying allelopathic properties are available, but there is the possibility of breeding new allelopathic crops by regulating their capacity to produce

allelopathic substances. identification of specific allelochemicals and related genes that can be applicable in breeding programs.

Environmental changes caused by allelochemicals

1. Environmental changes can include modifications at the plant community level, with species inclusion and exclusion and also, at the ecosystem level, via influences on abiotic factors.
2. Some soil modifications, especially those related to nutrient concentration, can be explained by allelochemical action. It is known, for example, that allelochemicals such as phenolic acids can form complexes with nutrients and toxic substances in the soil, which change their availability to plants. Thus, phenolic acids can increase the availability of phosphorus to plants by competition with the sites of this nutrient in the soil organic matter, clay particles, soluble aluminum, iron or manganese.
3. Allelochemical-producing plants can also affect the presence of mycorrhizal fungi, nitrogen-fixing bacteria and pathogens in the soil. these chemicals can impact the associations among plants or between plants and microorganisms .
4. When released into the soil, these allelochemicals can also inhibit the germination of spores, as well as the symbiotic association between mycorrhizal fungi and surrounding host plants.
5. Allelochemicals can also have an impact on populations of species that are potentially harmful to crop plants.

Use of Plant Allelopathy in Agriculture and the Physiological and Ecological Mechanisms of Allelopathy

Allelopathy is a common biological phenomenon by which one organism produces biochemicals that influence the growthand reproduction of other organisms. These biochemicals are known as allelochemicals and have beneficial or detrimental effects on target organisms.

Plant allelopathy is one of the modes of interaction between receptor and donor plants and may exert either positive effects (Allelochemicals can potentially be used as growth regulators, herbicides, insecticides, and antimicrobial crop protection products. Here, Here, can use plant allelopathy management practices applied in agriculture

The major points we can study in these filed are as follows:

(1) Description of related to allelopathy and allelochemicals in agriculture.

(2) Discussion of the progress regarding the mode of action of allelochemicals and the physiological mechanisms of allelopathy, consisting of the influence on cell micro- and ultra-structure, cell division and elongation, membrane permeability, oxidative and antioxidant systems, growth regulation systems, respiration, enzyme synthesis and metabolism, photosynthesis, mineral ion uptake, protein and nucleic acid synthesis.

(3) Evaluation of the effect of ecological mechanisms exerted by allelopathy on microorganisms and the ecological environment.

(4) Discussion of problems and proposal for future research directions in this field to provide a useful reference for future studies on plant allelopathy.

Effect of plants on microorganisms

The first written suggestions that higher plants may produce chemical inhibitors of microorganisms.

The expression "higher plants" has been used with many meanings, but using it here to refer to all plants , all algae(including species of the following phyla: Bryophyta, Psilophyta, Lycophyta, Sphenophyta, Filicophyta, and Spermatophyta) fungi (including molds),and bacteria(cyanobacteria) considering as lower plants and microorganisms.

reported low nitrification under perennial grass, in India, indicating an inhibition of the nitrifying bacteria by certain perennial grass species.

Another study found that suggested that root exudates of plants may be important to the biological balance of organisms in the soil.

McKnight and Lindegren (1936) and Walton et al. (1936) reported that vapors from crushed garlic, *Allium sativum*, are bactericidal to *Mycobacterium cepae*. Later, isolated and identified the active toxin as allicin.

Thorne and Brown (1937) found that most legume-nodule bacteria (Rhizobium) investigated by them were able to grow in freshly expressed juices of their host plants, but such juices were bactericidal to other species of root-nodule bacteria.

Effect of Microorganisms on Higher Plants

Only a relatively small amount of research has been done on the chemical inhibition of higher plants by microorganisms, except for the specialized field of plant pathology.

There is no question that many (if not most) pathogenic microorganisms bring about abnormal signs in the host plants through the production of toxins, but this topic will not be discussed to any appreciable extent.

When Konishi (1931) used 4-week-old liquid cultures of the alfalfa **Rhizobium and Bacterium coli (apparently Escherichia coli) which were grown together to inoculate tubes containing alfalfa, Medicago sativa, plants in agar, the Bacterium coli inhibited or completely prevented nodule formation, The design of the experiments was such that it was not possible to tell whether the inhibition of nodulation was due to the inhibition of Rhizobium, or to direct effect on the nodulation process, or to both.**

MICROORGANISMS VERSUS MICROORGANISMS

There is much published material on this subject of antibiotics, but most of it is related to medical applications and will not be discussed here. There is a rather limited amount of research on this subject related to agriculture, or basic ecology;

Greig-Smith (1912, 1917) studied the relationship between microorganisms in the soil and soil fertility. In the course of his investigations, he demonstrated that certain microorganisms in the soil were inhibitory to some of the soil bacteria. In a study of Conn and Bright (1919) found certain microorganisms in the soil which were.

Konishi (1931) isolated several bacteria from soil which were inhibitory to various species of Rhizobium, and generally these were aerobic rod-shaped, gram positive, and non-spore-forming. He experimented with several species of known bacteria also and found that two common soil bacteria, *Bacillus subtilis* and *Bacillus megaterium*, inhibited Rhizobium from both alfalfa (Medicago) and pea (Pisum) nodules.

Rice (1954) found that *Chlorella vulgaris* (Chlorophyceae) produce antibiotics that inhibit themselves.

Later, Proctor (1957) grew five common species of freshwater algae and found that no two species grew as well together as each did alone.

Types of allelopathy

Allelopathy includes both positive and negative effects of one plant on th e other through environment, It plays a key role in both natural and ma naged ecosystems. In agroecosystems, several weeds, crops, have be en shown to exert allelopathic influence on the crops, thus,affecting th eir germination and growth adversely. there are two types of allelopathy: Autotoxicity and heterotoxicity.

1-Heterotoxicity

Many crops have alellopathic effects on other crops through the release of allopathic compounds by decomposing plant residues, root secretions or by leaf and volatilisation that is Known heterotoxicity

There have been several studies the effect of crops on other crops (heterotoxicity),

(Mzori, 1996) identified some crops that have Allelopathic effect such as maize.

Alfalfa (Medicago sativa L.) has been investigated as both an autotoxic and heterotoxic species. Many plants species have shown heterotoxicity, both between plants species and weed species.

Various plants and some weed species have demonstrated allelopathic effects on alfalfa, and alfalfa has allelopathic effects on some weed species. This alone may provide an insight for herbicide studies in alfalfa production(Miller ,2016).

Autotoxicity

Autotoxicity in crops was described as the repressive effect of same crop, Autotoxicity is an interspecific form of allelopathy that occurs when a plant releases chemicals harmful to its growth and development (Miller, 1996). Sterilized leachates from soils where sugarcane was previously grown inhibited the growth of sugarcane test plants.

Barley that found have autotoxic effect which described as an intraspecific form of allelopathy, by decreasing its seed germination or seedling development These studies concluded that barley is prone to a high 'allelopathic risk' in barley–barley cropping sequences, and have been identified as potential allelochemicals that contribute to the allelopathic effectiveness of barley(Kremer and Ben–Hammouda 2009) . Autotoxicity is thought to be the result of natural selection, in which an older plant avoids competing with younger individuals for resources (light, water, nutrients, etc.) in which plants tend to be evenly spaced. From the agronomic point of view, the interest in autotoxicity resides in the possible problems for reseeding or overseeding crops (Chon et al., 2006). Autotoxicity has been studied in members of the Cucurbitaceae family, revealing considerable genetic variations, example in cucumber that was found the cucumber root residues caused an autotoxin to cucumber roots that followed it in the cultiver the reason may be it has cinnamic acid.

How Allelopathy Works

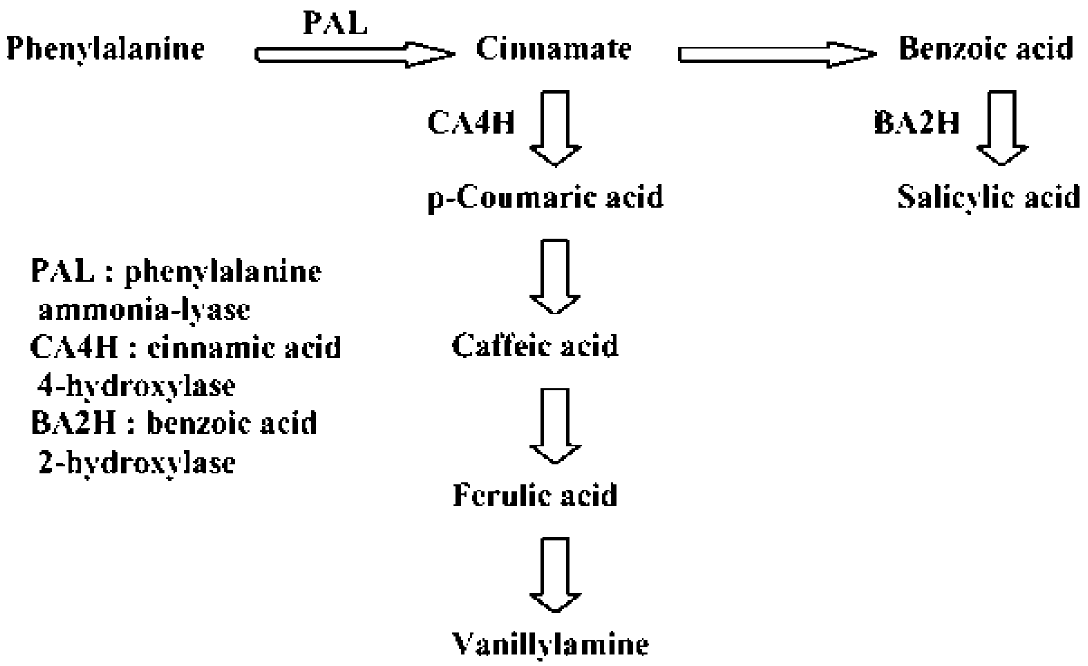
Competition is a very common phenomenon in the Earth’s Biosphere. Like other living organisms, plants also compete for sunlight, nutrients, water, space etc. and this competition is the basis for allelopathy. Some plants, known as allelopathic plants, use their chemical tools to win the competition and use the available resources more efficiently.

Allelopathy can be carried out by allelopathic plants by the following processes-

1. Allelopathic plants release chemical compounds from their roots into the soil, and these chemicals suppress or even kill the neighboring plants when they are absorbed by the plants. The harmful chemicals released by allelopathic plants are known as allelochemicals. Some allelochemicals change the amount of chlorophyll production in a plant and thus, they slow down or stop the photosynthesis process of that plant which ultimately leads to the suppression or death of that plant.
2. Many allelopathic plants release allelochemicals in gaseous forms. These gaseous allelochemicals are released from the small pores of their leaves. When the neighboring plants absorb these gasses, they are suppressed or killed.
3. When leaves drop from the allelopathic plants to the ground, they are subjected to decomposition; when the leaves decompose they release their noxious chemicals as a way to inhibit the growth of other neighboring plants.

Allelochemical synthesis affected by environmental stresses

Until recently, many studies verified the mechanisms of a self-defence system, including allelopathy in plants, particularly phenylpropanoid and isoterpenoid metabolism . Plants respond to environmental stress through a variety of biochemical reactions, which may provide protection against casual agents. The increase of allelopathic phenolic and terpenoid compounds under environmental stresses has been well documented. For example, enhanced UV-B light induces the accumulation of phenylpropanoids and flavonoids in different plant species, such as bean, parsley, potato, tomato, maize, rye, barley and rice.



Scheme of phenylpropanoid pathway.

Advantages of Allelopathy

Allelopathic plants can be introduced in agroecosystems to get some advantages from that

1. selectively allelopathic plant will suppress certain weeds and will not disturb the growth of the main crop. The introduction of a number of crop species such as- corn, lupin, oats, beets, wheat, peas, millet, barley, rye etc. in companion cropping has been proved effective in suppressing a number of weeds.

2. The allelopathic characteristics of wild types plants can be transferred into the commercial crops to boost up their allelopathic traits for weed suppression.

3. Allelopathy can be used for beneficial purpose through using allelochemicals as natural herbicides or pesticides. Various allelochemicals classes including alkaloids, flavonoids, cyanogenic compounds, cinnamic acid derivatives, benzoxazines, and ethylene and some other seed germination stimulants can be isolated from various families of terrestrial and aquatic plants.

Caution

Allelopathic plants sometimes create some problems to the soil. For example, the residues of allelochemicals may exist in the soil for a long time after the plant is removed; which results makes some soil unsuitable for general plant growing.

Nature of Allelopathic Compounds

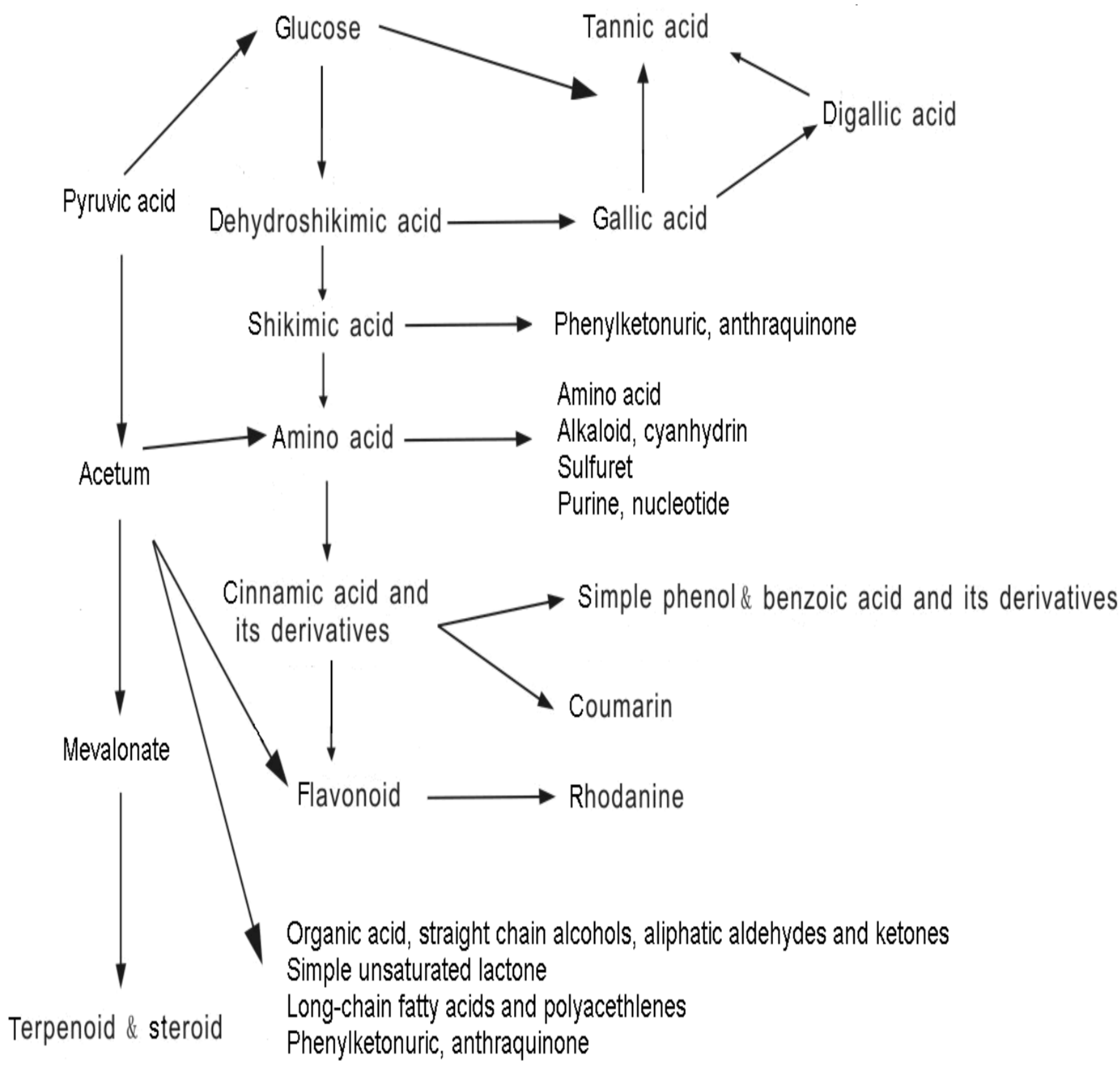
Allelopathic compounds are secondary metabolites synthesized by fungi, viruses, microorganisms and plants influence biological and agricultural systems, In order to have any effect on the target plant the allelochemicals have to be released from the donor plant, This can be **released into environment through four methods**:

1. Runoff and leachate from leaves and stem of plants. As for example, the allelochemicals in the leaves of *Black walnut, Juglans nigra*, which are washed off with rain can inhibit the growth of the vegetation under the walnut tree (Bode, 1958).
2. Volatile phytotoxic compounds from the green parts of a plant, e.g. *Salvia leucophylla* and (Halligan, 1973).
3. Phytotoxic compounds from decomposing plant material, such as Rye (*Secale cereale*) when used as a mulching material. Apart from shading and keeping the soil moist, rye mulch also inhibits both germination and growth of weeds through release of phytotoxins (Barnes and Putnam, 1986).
4. Phytotoxic compounds released from the plant roots, Rice is an example, where living Rice plants are able to suppress weed growth selectively (Navarez and Olofsdotter, 1996; Olofsdotter et al., 1997).

Allelochemicals

Allelochemicals are secondary substances, biosynthesized from the metabolism of carbohydrates, fats and amino acids and arise from acetate or the shikimic acid pathway.

These are biosynthesized and stored in the plant cells and do not affect in the cell activities. However, after their release from the plant cells (through volatilization, leaching root exudates and decomposition of biomass), these allelochemicals start influencing the organisms (plants, pathogens, insect,etc.), when they come in contact.



Nature of Allelochemicals

Rice (1984) has divided these compounds into 14 chemical categories: (a) cinnamic acid derivatives, (b) coumarins, (c) simple phenols, benzoic acid derivatives, gallicacid and protocatechuicacid, (d) flavonoids,

(e) Tannins,(f)Terpenoids and steroids, (g) water soluble organic acids, straight chain alcohols, aliphatic aldehydes and ketones, (h) simple unsaturated lactones, (i) long chain fatty acids, (j) naphthoquinones, anthraquinones and complex quinones, (k) amino acids and polypeptides, (l) alkaloids and cyanohydrins, (m) sulfides and mustard oil glycosides and (n) purines and nucleotides. However, Putnam and Tang (1986) grouped these chemicals into 11 classes: (a) toxic gases, (b) organic acids and aldehydes, (c) aromatic acids , (d) simple unsaturated lactones, (e) coumarins, (f)quinines, (g) flavonoids, (h) tannins, (i) alkaloids, (j) terpenoids and steroids, and (k) miscellaneous and unknown.

Rice (1984) outlined the following factors which affect the amount of allelochemicals produced: (a) radiation, (b) mineral deficiencies, (c) water stress,(d) temperature, (e) Allelopathic agents, (f) age of plant organs, (g) genetics, (h) pathogens and predators.

Allelopathy (Lec.10)

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Application of Allelopathy in Crop Production

Increasing global population is a threat to food security and agricultural sustainability. Allelopathy has emerged to solve multiple issues in modern agriculture. There are many challenge for scientists, like certain application in the farming community.

1.Allelopathy and Weed Management

Weeds are the most stubborn competitors of crops causing substantial reduction in yield by sharing light, air, water, nutrients and space.

Application of allelopathic by added water extracts at high concentrations suppress the weed **density** and **biomass** reduction. Sorghum is one of the most widely crop used water extracts as natural herbicide , controlled *Chenopodium album* in wheat crop, and has been used against weeds of cotton and sunflower , which increased the yield of these crops by 3-59% depending upon the **type of crop**, **frequency of application and time of application**.

Allelochemicals are interfere with the following :

1-Cell division, 2-Hormone biosynthesis , 3-Mineral uptake and transport 4-Membrane permeability 5- Stomatal oscillations 6- Photosynthesis 7- Respiration 8- Protein metabolism and plant water relations.

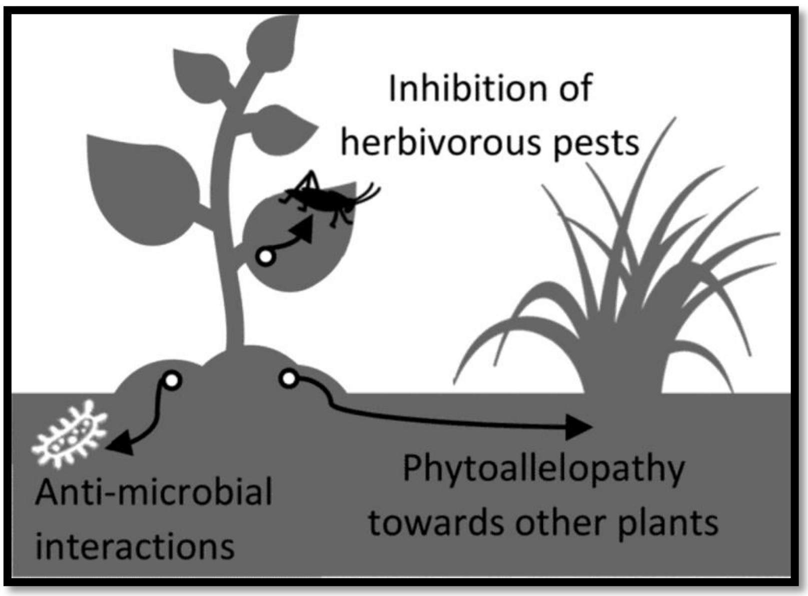
2. Allelopathy and Insect Management

Insects cause substantial losses to **food grains**, **legumes**, **fiber crops** and vegetables. they have developed resistance against **chemical insecticides** due to

repeated use. chemical insecticides have detrimental effects on environment beside to cause health and hygienic problems

Natural compounds have been identified as potent weapons against certain insect pests .They have the advantages of **1. biodegradation, 2. economic affordability, 3. environmental safety 4. easy handling.**

Many plants have natural defense mechanism against insect pests. As e.g Neem produces allelochemicals like **salannin and nimbin**, which inhibit growth of different insect-pests, such as green cicadellid and white fly .



3. Allelopathy and Diseases Management

Plant diseases are cause of growth reduction. Bacteria, fungi, viruses and some nematode are causal agents of different seed and soil borne diseases.

Two potent allelochemicals of rice; **momilactone A** and **momilactone B** have shown antifungal, antibacterial and antioxidant activities *in vitro*. Some of the flavanoids from rice have suppressing potential against spore formation of *Rhizoctonia solani*.

4-Allelopathy and Resistance against Abiotic Stresses

Allelopathy may be effectively employed for improving resistance against abiotic stresses. This effect of allelopathy is given in the following lines:

A. **Biosynthesis of allelochemicals**: Their production at higher rates induces plants resistance against stresses and helps them to grow under such conditions.

Allelochemical production is influenced by 1. **age of plant**, 2. **type and intensity of stress and ambient surroundings,** as e.g cucumber produced phenolics and flavanoids at **dry** conditions. Temperature were shown to **increase** biosynthesis of allelochemicals, e.g production of chlorogenic acid is enhanced with temperature just **above freezing point in case of tobacco.**

B. **Role of allelopathy in stress signaling:**

1. Plants use secondary metabolites as messenger to trigger the defense mechanism, by production of phytochemicals and hormones are necessary to defend plant ultra-structures from heat, drought or salinity stress.
2. allelochemicals play a vital role in reactive oxygen species (ROS) production initially and then activation of antioxidant defense system.

5- Allelopathy in Crop Nutrition

It`s an essential aspect in crop production. Soil is the basic medium for the provision of almost all necessary nutrients for plant growth. Nutrients are taken up in the form of **solution from roots.** Dynamics and activity of allelochemicals are defined by **amount**, **form** and **balance** of soil nutrients.

Allelochemicals affect the availability and uptake status of nutrients for plants in vicinity of source plant. Plants may release allelochemicals under stress conditions to facilitate **1. their nutrition by altering nutrient forms, 2. microbial populations and activities, 3. availability modes and uptake channels** .

Growth Promotion Potential of Plant Water Extracts

Many arable crops have been identified as potential allelopathic crops. Recent research has shown that water extracts of sorghum, brassica, sunflower, rice, wheat, barley and moringa having promotory allelochemicals, improve growth of different arable crops and vegetables, when applied at low concentrations.

These promotory effects are due to regulation of different physiological events Application **as seed treatment**: One of the most important and critical stage in plant growth is germination. Germination percentage, germination power, germination index, radical length, plumule length, fresh weight and dry weight are greatly affected by allelochemicals depending upon their concentration.

Low concentrations of allelopathic water extracts as seed treatment before sowing or planting can improve all these parameters which later on decide the rate of plant growth Maize plant produces several secondary metabolites like **benzoic acid**, **4-phenylbutyric**, and **coumaric acids** having growth inhibition potential at high concentrations but can promote growth and yield of crops at low levels.

Exogenous application:

Exogenous application of allelochemicals as foliar spray is an effective method for growth improvement. It works equally well as seed pretreatments. Foliar application improves plant growth directly or indirectly. ***Moringa*** water extract increased sorghum germination, maize radical length and wheat hypocotyl length by 29, 77.8 and 14.5%, respectively when applied on plant foliage at low concentration

This growth promotion is attributed to different secondary metabolites and allelochemicals like phenols, ascorbates in moringa leaf extracts. Sorghum is the most studied allelopathic crop regarding water extract application and other implications of its allelochemicals

.**Root application**:

Root is important plant organ, absorbing water and nutrients for growth. Allelochemicals released as root exudates affect the root growth of nearby growing plants. Allelopathic water extracts applied to the roots as soil application have the potential of growth improvement.

Soil application of *Nicotiana plumbagmifolia* leachate (25%) in maize field improved root and shoot length 4.15% and 18% respectively. It improved cell division and cellular regulation under chilling conditions to acclimatize the plant roots. Root tip of wheat plant was swelled under the application of Coumarins at low concentration. It increased the root surface area and helped in more nitrate uptake.