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ALLELOPATHIC EFFECT OF SOME MEDICINAL PLANTS ON SEED GERMINATION AND GROWTH OF COMMON WEEDS

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ABSTRACT

Allelopathy is a natural phenomenon defined as "The biochemical interactions among all types of plants including microorganisms." In this process the inhibition of growth in one plant species by allelochemicals produced by other plants species. It is well known area of research in ecology and environment. However, its importance in agro-ecology is still underestimated. This overview introduces this developing field to a wider research to stimulate new arena of agro-ecology. The role of allelopathy and release of allelochemicals in crop production is of high significance as allelopathy related problems existing in crop production with suggestion for future research. It also describes the role of allelopathy in agriculture as well as horticulture. We hope that it will encourage more scientists to initiate research into this exciting field.

KEYWORDS: Allelopathy, Agro-ecology, Allelochemicals, Crop production and Plant Species.

INTRODUCTION

Definition

Allelopathy is a natural phenomenon, which may be defined as "The inhibition of the growth in one plant species by chemicals produced by other plant species" or can also be defined more widely, "The biochemical interactions among all types of plants, including microbes." The inhibitory chemicals are excreted into environment by one plant species which affects the growth and development of its neighboring plant species.

The term allelopathy is derived from two Greek words allelon and pathons means natural harm or suffering and was first coined by Austrain Scientist Hans Molisch (1937) in his book "Der Einfluss einer Pflanze auf de andere Allelopathie" the effect of plants on each other.
Wills 2010, studied the forestry systems regarded allelopathy may affect many aspects of plant ecology including plant succession, growth, dominance, diversity and plant productivity. Earlier many plant species evaluated, had allelopathic effects on food and fodder crop plants. It was investigated that several species had beneficial, neutral or selective effects on companion or neighboring crop plants (Table 1).

Allelopathy in question refers to the beneficial or harmful effects of one plant, on other neighboring plant, weeds species or crop. The allelochemicals released from the plant parts by leaching, root exudation, volatilization, residue-decomposition in both natural and agricultural system (Fig 1).

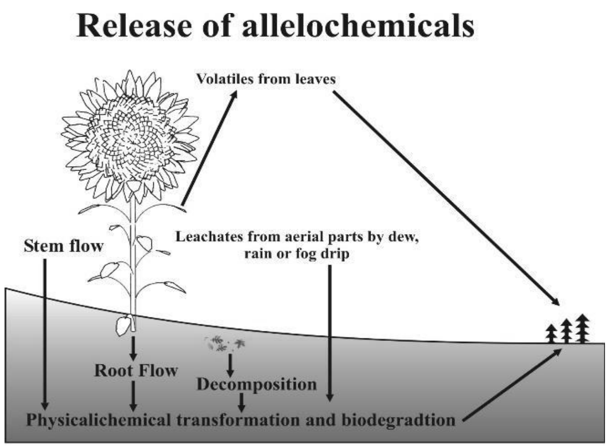

Figure 1: Possible routes of allelochemical release. (Kamal, 2020)

Allelochemicals are basically secondary metabolites not required for metabolism of the allelopathic plant. Allelopathic effects are an important part of plant defense against herbivory (Fraenkel, 1959; Stamp, 2003).

Our purpose here to explain allelopathy with specific examples and review potential applications as an alternative weed management strategy (Table 1) (Kamal, 2020).

Nature of Allelopathy

The effects of allelopathy include reduced seed germination and seedling growth as the spray of synthetic herbicides. There is no common mode of action or physiological target site of all the allelochemicals, although, known sites of action of some allelochemicals includes cell division, pollen germination, nutrient uptake, photosynthesis and specific enzyme function.

For example, the effect of an allelochemical known as velvet bean, 3-(3',4'-dihydroxyphenyl)-1-alanine(1-DOPA) indicated that the inhibition by this compound is due to adverse effects on amino acid metabolism and ion concentration equilibrium.

Allelopathic inhibition is a complex process, involve the interaction of different classes of chemicals, such as phenolic compounds flavonoids, terpenoids, alkaloids, steroids, carbohydrates and amino acids with mixtures of different compounds sometimes displayed a greater allelopathic effect than individual compound alone.

Further, it was observed that physiological and environmental stress, pests and diseases, solar radiation, herbicides and nutrient deficiency, moisture and temperature levels can also effect allelopathic weed suppression (Figure 2).

Various parts of a plant like flowers, leaves, leaf litter and leaf mulch, stems, bark, roots, soil and several their derived compounds can have allelopathic activity in different growing seasons. Allelochemicals also persist in soil affecting both neighboring plants, these chemical are biodegradable than traditional herbicides but allelochemicals may have undesirable effects on non-target species. Selective effect of tree allelochemicals on crops and other plants have earlier been reported. For example, *Leucaena leucocephala* a miracle tree promoted for re-vegetation, soil and water conservation and lives stock nutrition in India contains toxic amino acid in its leaves that inhibits the growth of other tress but not its own seedlings, it also shows reduce yield of wheat but increases yield of rice. One study in China found 25 highly noxious weeds screened had significant allelopathic potential, similarly Eucalyptus species is also more toxic for some food crops. The allelopathic effect of *Ipomoea cairica* is greater at higher environmental temperature.

One study indicated that the soil organism reduces the allelopathic potential *Agertina adenophora* (Table 1).

Allelopathic Research Strategies and Potential Applications

1. The basic approach used in allopathic research for agricultural crops in screening of crop plants and natural vegetation for their ability to suppress weeds.
2. To demonstrate allelopathy, the identification of allelochemicals must be established in the environment overtime in concentration efficient to affect plant species.
3. In the laboratory, plant extracts and leachates are commonly screened for their effects on seed germination.
4. Further, isolation, purification and identification of allelochemicals from green house tests and field soil confirming laboratory results.
5. Interactions among allelopathic plants host crops and other non-target must be considered.
6. Further-more allelochemistry may provide chemical structures and templates for developing new synthetic herbicides.
7. It was elucidated that certain allelochemicals involved in weed suppression like benzohexanoids in rye, diterpenoid momilactones in rice, tabanone in cogongrass, alkaloids and flavonoids in Fescue, anthratectone in teak (*Tectona grandis*) abscisic acid beta-d-glucopyranosyl ester in red pine and cyclopropane fatty acid in *Sterculia foetida*.
8. Incorporation of allelopathic traits from wild or cultivated plants into crop plants using breeding or genetic engineering methods which increase the synthesis and release of allelochemicals.
9. Genetic basis allelopathy has been demonstrated in winter wheat and rice by development of new cultivars.
10. An allelopathic crop can be used to manage weeds by planting a variety with allelopathic traits controls weed growth.
11. Application of allelopathic compounds / chemicals along or after synthetic herbicides could increase the overall affect or both materials there by reducing application rates of synthetic herbicides. It was recorded on application of aqueous extracts of allelopathic plants on crops weed suppression, for example extract of *Brassica napus*,

Sorghum and Sunflower was used on wheat crop to successfully reduce weed pressure.

When an allelopathic plant aqueous extract was mixed with atrazine, a significant degree of weed control was achieved.

Every living organism need certain resources to grow and develops, similarly plants require sunlight, nutrients, water and air. The roots absorb nutrients and water from soil to the plant, similarly leaves absorb sun radiant energy for obtaining food thus require space to fulfill their needs therefore plant uses allelopathic defenses to protect the space around them.

There are 4 major reasons that plants require their own space: fire, water, nutrients and sun radiations.

1. Plants need to protect themselves from harm and fire which is always a threat to the plant. If trees grow too close to each other the fire can spread easily therefore plants create more space in order to remain safe.

2. Water is in deficient supply in some areas thus, reducing the number of surrounding plants increases the water availability for roots.
3. Likewise, the nutrients in soil available for plant roots to grow and develop by reducing number of neighboring plants using allelopathic defense mechanism to kill the roots of surrounding plants.
4. Plants need sunlight in the form radiant energy to grow and develop but if many other plants are growing nearby all plants will be shaded and receive less light therefore less able to grow thus allelopathic defenses can be used to prevent other plants growing nearby thus help them to compete for sunlight.

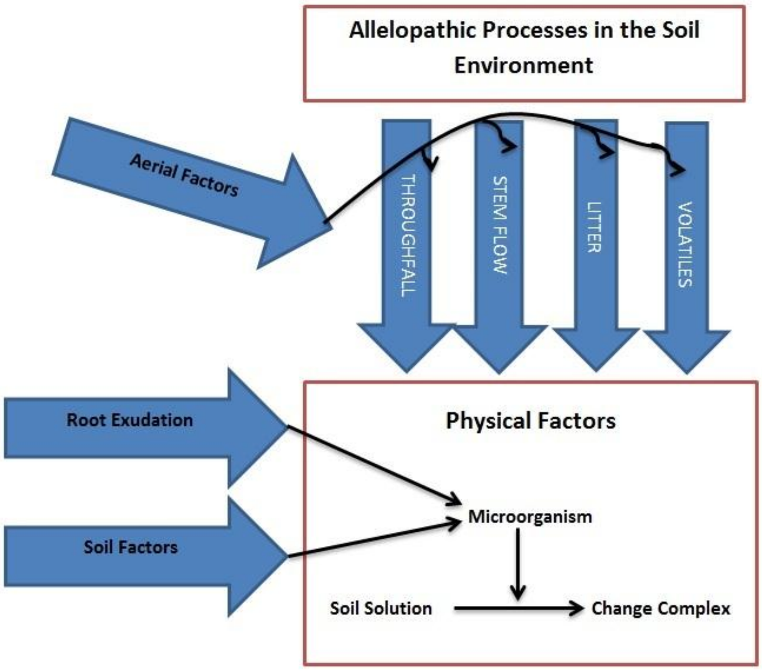

Figure 2: Allelopathic Processes in Soil and Aerial Environment.

Table 1: Examples of Allelopathy.

Allelopathic plant	**Impact**
Lantana, a perennial woody weed pest in Florida citrus	Lantana roots and shoots incorporated into soil reduced germination and growth of milkweed vine, another weed
Rows of black walnut interplanted with corn in an alley cropping system	Reduced corn yield attributed to production of juglone, an allelopathic compound from black walnut, found 4.25 m (~14 ft) from trees
Rows of Leucaena interplanted with crops in an alley cropping system	Reduced the yield of wheat and turmeric but increased the yield of maize and rice
Chaste tree or box elder	Leachates retarded the growth of pangolagrass, a pasture grass, but stimulated the growth of bluestem, another grass species
Sour orange, a widely used citrus rootstock in the past, now avoided because of susceptibility to citrus tristeza virus	Leaf extracts and volatile compounds inhibited seed germination and root growth of pigweed, bermudagrass, and lambsquarters
Red maple, swamp chestnut oak, sweet bay, and red cedar	Wood extracts inhibited lettuce seed as much as or more than black walnut extracts
Mango	Dried mango leaf powder completely inhibited sprouting of purple nutsedge tubers
Eucalyptus and neem trees	A spatial allelopathic relationship if wheat was grown within 5 m (~16.5 ft)
Tree of heaven	Ailanthone, isolated from the tree of heaven, has been reported to possess non-selective postemergence herbicidal activity similar to glyphosate and paraquat
Broccoli	Broccoli residue interferes with growth of other cruciferous crops that follow

Rye, fescue, and wheat	Allelopathic suppression of weeds when used as cover crops or when crop residues are retained as mulch
Jungle rice	Inhibition of rice crop
Forage radish	Cover crop residue suppression of weeds in the season following the cover crop
Jerusalem artichoke	Residual effects on weed species
Sunflower and buckwheat	Cover crop residues reduced weed pressure in fava bean crop
Garlic mustard	Inhibition of arbuscular mycorrhizal fungi colonizing on sugar maple
Barbados nut (*Jatropha curcas*)	Extracts of leaves and roots inhibited corn and tobacco
Tifton burclover	Growth inhibition in wheat and autotoxicity in burclover
Sunn hemp	Growth inhibition of smooth pigweed and lettuce and inhibition of vegetable seed germination
Desert horsepurslane (*Trianthema portulacastrum*)	Growth promotion of slender amaranth (*Amaranthus viridis*)
Rhazya stricta	Growth inhibition of corn
Rough cocklebur (*Xanthium strumarium*)	Growth inhibition of mungbean
Silver wattle (*Acacia dealbata*)	Inhibition of native understory species in northwest Spain
Sticky snakeroot (*Ageratina adenophora*)	Volatiles were inhibitory to plants in non-native ranges but not inhibitory to plants in the native range
Chicory	Inhibition of *Echinochloa crusgalli* and *Amaranthus retroflexus*
Swallow-worts	Invasive species in northeastern United States and southeastern Canada; inhibited several weed species
Vogel's tephrosia (*Tephrosia vogelii*)	Growth inhibition of corn and three narrow-leaf weed species
Green spurge	Inhibition of chickpea
Crabgrass	Inhibition of corn and sunflower but no inhibition of triticale when dry crabgrass residue was incorporated into soil
Teak wood	Leaf extracts inhibited jungle rice and sedge, but not cultivated rice
Rabbit foot grass	Leaf extracts and mulch inhibited wheat
Santa Maria feverfew (*Parthenium hysterophorus*)	Aqueous extracts had inhibitory effects on cereal crops

Proofs of Allelopathy

A number of investigations have provided clear evidence for allelopathy (similar to Koch's postulates for proof of disease) to demonstrate the proof of allelopathy in plants (Fuerst and Putnam, 1983). A specific protocol of allelopathy involves the following sequence of events.

i) Demonstrate the allelopathic effect using suitable controls, describe the symptoms, and quantify the growth reduction caused.
ii) Isolate, characterize and assay the allelochemicals involved. Identification of chemicals that are not artifacts is essential.
iii) Obtain toxicity with similar symptoms by adding the allelochemicals identified to the system.
iv) Monitor the release of chemicals from the allelopathic plant and detect them in the environment (soil, air, water etc.) around the affected plant, and ideally in the recipient plant itself.

Allelochemicals

There are many different types of chemical allelopathy. In one, the plant species releases allelochemicals are growth inhibitors from its roots into soil to protect its immediate surroundings.

New plants growing near the allelopathic plant absorbs allelochemicals from the soil retard growth and later on die. Interactions between soil microbes and plants can also be allelopathic in nature as bacteria and fungi also produce and release growth inhibitors or promoters however some soil bacteria enhance plant growth through nitrogen fixation while others make phosphorus available to plants.

Allelochemicals interactions are common in terrestrial plants. In aquatic plants allelochemicals released are much diluted thus have insignificant inhibitory effect but allelochemicals in aquatic conditions are used primarily to prevent the aquatic plant from being eaten by herbivorous, rather than to compete with surrounding plants.

Organism interacts in many interesting ways. Chemicals produced by one organism that affect another organism are called allelochemicals (Barbour et al., 1980; Krebs, 1978; Recklefs, 1979; Whittaker, 1975). Sometime a single chemical produce by one organism is harmful to another organism but it may be beneficial to a third organism. Plants of the mustard family secrete mustard oil that irritate many animals and prevent them from feeding on the mustard plants although the same oil attract other animals that feed upon mustard plant, one of the oils of mustard family stimulates the germination of fungal spores that is parasitic on mustard roots it was also observed fungi and mycelilelo secrete allelochemicals that are lethal to other bacteria, further-more it is common for one plant to harm another plant growing nearby by allelopathy. Many experiments as listed (Figure 1) have been performed. In this experiment one set of apple seedling was watered with tap water, another set with water that had percolated through soil with grass growing in it and a third set with water that had percolated through soil with nothing growing in it. It was observed the growth of apple seedling was inhibited by something produced by the grass plants, since seedlings in the other two experiments grew much better but in earlier case the allelochemicals have been isolated and identified played toxic role in nature similarly allelochemicals juglone (5-hydroxy-naphthoquinone) secreted from the roots of black wall nut (Juglens nigera) is allelopathic in nature which can kill tomato and alfafa plants. It is worth noting that many plant produced allelochemicals that are used to inhibit the neighboring wheat (Table 1).

Allelochemicals are generally secondary metabolites produced by plants and are by products of primary metabolic processes (Levein, 1976), they have allelopathic effects on the growth and development of neighboring plants.

Allelochemicals include

i) Plant bio-chemicals that exerts their toxicological actions on other plants
ii) Plant bio-chemicals metabolically active in plants, play an important role in the ecology and physiology at different stages of growth (Waller and Nowacki, 1987; Waller and Dermer, 1981).

Classes of Allelochemicals

Putnam, 1986 listed six classes of Allelochemicals from over 30 families of terrestrial and aquatic plant, these classes are: Alkaloids, Benzoxazinones, Cinnamic acid derivatives, Cyanigenic compounds, Ethylene and Flavonoids.

These allelochemicals produced in either above or below ground parts of plants or in both (Rice, 1974).

Roots

In general, they contain fewer, and less potent or smaller amounts of allelochemicals than leaves, although the reverse may be true (Kamal, 2011; Kamal, 2015; Kamal and Bano, 2009; Kamal and Bano, 2008a; Kamal and Bano, 2008b).

Stems

These contain allelochemicals and are sometimes the principal sources of toxicity (Kamal, 2011a; Kamal, 2011b; Kamal, 2010, Kamal and Bano, 2009; Kamal and Bano, 2008; Kamal and Bano, 2008; Kamal and Bano, 2008c).

Leaves

These are the most important sources of allelochemicals. Specific inhibitors in leaves have been demonstrated by many workers (Kamal, 2011; Kamal and Bano, 2009; Kamal and Bano, 2008a; Kamal and Bano, 2008b).

Flowers/inflorescences and pollen

Although studies on flowers or inflorescences are limited, there is growing evidence that the pollen of corn and sunflower have allelopathic properties.

Fruits

Many fruits are known to contain toxins found to inhibit microbial growth and seed germination.

Seeds

The seeds of many plant families or species have been found to inhibit seed germination and microbial growth.

Modes of Release of Allelochemicals

For successful allelopathy, the allelochemicals can be effectively release from the donor plant and transferred to recipient plants and the mode of release of transfer plays an important role in effectiveness of allelochemicals into the surrounding soil and environment, these processes are given below.

i) Volatilization: Allelochemicals may volatilize from plant into atmosphere and absorb directly from the atmosphere by another plants in the form of vapors, the genera which release volatile are *Artemisia, Salvia, Parthenium, Eucalyptus* and other members of family Brassiceae. The volatile inhibitors are camphene, camphor, cineole, dipentene etc. (White et al., 1989; Oleszek, 1987).

ii) Leaching: It is the removal of substances from plants by action of water in the form of rain, dew, mist, fog and snow many allelechemicals are reached like phenolic acid, terpenoids and alkaloids.

iii) Roots Exudate: Many higher plants are exuded from roots in rhizosphere or in soil environment.

Decomposition of Plant Residues

Decomposition of plants residues is responsible for most of the allelochemicals added to soil (Kamal, 2015).

Mode of Action of Allelochemicals

These chemicals influence plant growth (Rice, 1984) and act upon the following physiological processes: i) cell division and cell elongation; ii) phytohormone induced growth; iii) membrane permeability; iv) mineral uptake; v) availability of soil phosphorus and potash; vi) stomatal opening and photosynthesis; vii) respiration; viii) protein synthesis; ix) changes in lipid and organic acid metabolism; x) inhibition of porphyrin synthesis; xi) inhibition or stimulation of specific enzymes; xii) corking and clogging of xylem elements; xiii) stem conductance of water; xiv) internal water relations; and xv) other miscellaneous mechanisms.

Allelochemicals and Toxicity

Allelopathy is important in sustainable agriculture, it is interesting to note that the similarities between allelopathy and the herbal system of medicine with particularly with request to pests control and the treatment of human diseases. Both system used plants are plant extracts to control the plant pests or human diseases, the organism under attack do not develop tolerance / resistance either to allelochemicals or ayurvedic medicine unlike pesticides or conventional alleopathic system however, many developed countries the reporting environmental hazards associated with modern allelopathic medicinal systems and pesticides, therefore are turning to use of herbal medicine for human disease control and allelochemicals for crop paste management.

Allelopathy has been recognized as important ecological mechanism influencing plant dominance, succession finally development of climax community and crop productivity (Smith and Secoy, 1977, Rice, 1984). It has been related to the problems in wheat crop interference (Bell and Koeppe, 1972), in phytotoxicity in stubble mulch fanning (Mc Calla and Haskins, 1964). Most the allelopathic research on crops has been conducted in developed countries where mono-cropping is practiced because winters less research in irrigated areas in tropics and sub-tropics where climate allowed year round cropping it was observed that wheat exists together with crops despite the fact that allelopathy placed a greater role under these conditions. The role of allelopathy in sustainable agriculture may therefore make it an important strategy increasing agricultural production.

Fate of Allelochemicals

With the exception of the volatile allelochemicals, which are absorbed by plants directly from the air or as leachates (after dissolution in rain, dew, mist or snow), all other allelopathic responses occur through the soil. Potential allelochemicals must remain active in the soil to have an allelopathic effect. The biological activity, persistence, movement and fate of natural products in the soil depend upon their interaction with the soil adsorption complex, soil microbial population and soil chemical environment. Adsorbed allelochemicals may remain biologically active or be rendered inactive, depending on the nature of the adsorbing surface, but adsorbed molecules are less available to soil microbes. Some natural products/allelochemicals may become irreversibly bound in soil humic substances. Allelopathic effects in the soil therefore depend on the relative rates of addition to, and fixation of, allelochemicals in the soil.

Effect of Allelochemicals

The phytotoxins from crop residues have generally negative effects on crop plants such as: a) delayed or complete inhibition of germination; b) reduced population numbers; c) stunted and deformed roots and shoots; d) reduced nutrient absorption; e) lack of seedling vigor; f) reduced tillering; g) chlorosis; h) wilting; i) predisposition to root rot; and j) seedling death (Norman, 1959; Patrick, 1971; Guenzi et al., 1967; Norstadt and McCalla, 1963; Toussoun et al., 1968; Horricks, 1969; Kimber, 1973a,b; Cochran et al., 1977; Lynch, 1980; Kuo et al., 1981; Walker and Jenkins, 1986; Waller et al., 1987; Oleszek and Jurzysta, 1987; Hicks et al., 1988; Khaliq et al., (2004). However, the major effects of phytotoxins on crop plants are: i) inhibition of nitrification and biological nitrogen fixation; ii) predisposal to disease; and iii) inhibition or stimulation of germination, growth and yield.

Importance of Allelopathy

The science of allelopathy is a relatively new field of study, and there is convincing evidence that allelopathic interactions between plants play a crucial role in both natural and manipulated ecosystems.

1. These interactions undoubtedly an important factor in species distribution and abundance within some plant communities,
2. Allelopathic interactions are also thought to be an important factor in the successful spread of many invasive plants, for example spotted knapweed and nutsedge
3. The brightest hope for allelochemicals is that they will act as natural weed killers or pesticides, substituting for chemicals, and promote sustainable agriculture.
4. Plants that will suppress tree growth may, in future, reduce the cost of pruning or herbicide applications in conflicts between trees and power lines.
5. Use of allelopathic cover crops for weed suppression can decrease reliance upon herbicides.
6. An understanding of plant/chemical relationships could reveal practical benefits of, companion planting, a practical endorsed by organic gardeners, which is currently valued less than if it were based on science-based research.

CONCLUSIONS

Allelopathy includes both inhibitory and stimulatory effects of plants on each other including micrrorganisms. It is a very wonderful natural phenomenon; its importance can be summarized as follows: it is the cheaper way of weeds control without polluting our environment.

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