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Review on the role of Allelopathy in pest management and crop production

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Abstract

Allelopathy is a naturally occurring ecological phenomenon of interference among organisms that may be employed for managing weeds, insect pests and diseases in field crops. In field crops, allelopathy can be used following rotation, using cover crops, mulching, crop smothering and plant extracts for natural pest management. Plant pathogens including fungi, bacteria, viruses and nematodes are responsible for huge yield losses in many economically important crops. Use of synthetic agrochemicals as soil fumigation, foliar spray or seed dressing is the most popular strategy for the management of plant diseases in the recent days. However, due to adverse effects of these chemicals on health and environment, consumers are currently demanding produce, which is free of these chemicals. Natural compounds derived from plants are more environmentally safe than synthetic chemicals. Many recent studies have shown that allelochemicals can effectively be used for the management of plant pathogens. Allelopathy thus offers an attractive environmentally friendly alternative to pesticides in agricultural pest management. Their bio-efficiency can be enhanced by structural changes or the synthesis of chemical analogues based on them. Although the progress in this regard is slow, nevertheless some promising results are coming and more are expected in future. This review attempts to discuss all these aspects of allelopathy for the sustainable management of pests.

Keywords: Allelopathy; Pest; Crop rotation; smothering crops; agro-chemicals

1. Introduction

Allelopathy is a relatively newer and potential area of research. Allelopathy is a phenomenon where by secondary metabolites synthesized by fungi, viruses, microorganisms and plants influence biological and agricultural systems, which may be either stimulatory or inhibitory (Torres *et., al* 1996). The word allelopathy is derived from two Greek words: 'allelon', meaning 'of each other', and 'pathos', meaning 'to suffer'. This ancient concept was known to classical researchers in the Greek and Roman era Blum (2007). The term 'allelopathy' was first used by Austrian plant physiologist Molísch, who defined it as the chemical interaction among plants and microorganisms (Duke, 2003).

However, according to Rice (1984) allelopathy is the influence of one plant on the growth of another one, including microorganisms, by the release of chemical compounds into the environment. These chemicals are usually secondary plant metabolites or byproducts of the principal metabolic pathways in plants. They are non-nutritional and can be synthesized in any plant part, i.e. leave, stems, roots, bark, seeds, etc. Under favorable environmental conditions, allelochemicals are released into the environment through the processes of volatilization, root exudation, decomposition and/or leaching, thereby affecting the growth of adjacent plants. Nonetheless, not all allelochemicals are involved in vital physiological events within the plant system (Rice, 1984).

Allelopathy involves the synthesis of plant bioactive compounds, known as allelochemicals, capable of acting as natural pesticides and can resolve problems such as resistance development in pest biotypes, health defects and soil and environmental pollution caused by the indiscriminate use of synthetic agrochemicals Allelopathic crops, when used as cover crops, mulch, smother crops, intercrops or green manures, or grown in rotational sequences, can combat biotic stresses such as weed infestation, insect pests and disease pathogens and additionally build up fertility and organic matter status of soil, thereby reducing soil erosion, and improve farm yields (Wato T, 2020).

Sustainable agriculture aims at long-term maintenance of natural resources and agricultural productivity with minimal adverse impact on the environment. It emphasizes optimal crop production with minimal external inputs, reducing dependence on commercial inputs (fertilizer and pesticides) and substituting them with internal resources and relying on sustainable practices, which could maintain the productivity over long periods. Research has shown that allelopathic practices may meet all these requirements; hence in future, allelopathy may provide a basis to sustainable agriculture (organic, alternative, regenerative, biodynamic, low input, or resource conserving agriculture). To achieve the goals of sustainable agriculture, current research involves, plant breeding, soil fertility, tillage, crop protection, and cropping systems. Allelopathy, being an important phenomenon in agriculture, is also important in sustainable agriculture. Thus for sustainability, future weed control practices must minimize the use of herbicides and use allelopathic strategies and other practices for weed management (Farooq *et al*., 2011)

Indiscriminate use of herbicides for weed control during the last 50 years has resulted in serious ecological and environmental problems as under: (A) Increasing incidence of resistance in weeds to important herbicides (Duke *et al*., 2001), such as S-triazines and dinitroanilines and in contrast to pest-resistant crops, the introduction of herbicide-resistant crops will make farming increasingly dependent on herbicides and thus enhance herbicide use in agriculture, (B) Shifts in weed population (i) to species that are more closely related to the crops infested e.g., wild oat (Avena fatua) in oat (A. sativa) and sorghum (Sorghum bicolor M),wild okra (Abelmoschus esculentus Moench) in cotton (Gossypium hirsutum), and red rice (Oryza fatua) in rice (O. sativa) and (ii) minor weeds have become dominant. (C) Greater environmental pollution (FAO, 1990) and health hazards (i) particularly from surface and groundwater contamination, which is used for human and livestock consumption, for example in USA, the groundwater contains sizeable quantity alachlor and atrazine widely used herbicides (Ahrens, 1989) and (ii) from their inhalation during handling and application. (D) Toxic residues of herbicides pollute the environment and may prove hazardous to even future generations. (E) Some agricultural commodities may contain minute quantities of herbicide residues, with long-term adverse effects on human and livestock health. Because of these reasons, serious ecological questions about the reliance on herbicides for weed control have been raised. FAO Expert Consultation Group on ‘Weed Ecology and Management ‘has expressed great concern about the problems associated with the use of herbicides for weed control and has recommended minimizing or eliminating use of herbicides with alternative strategies viz., Allelopathy (FAO, 1997) to maintain weeds at economic threshold level and use of clean crop seed.

Crops have been grown since ancient times without damaging the environment but the use of herbicides during the short span of last 64 years has raised serious doubts about their continued use. Prior to invention of herbicides, weeds were controlled through mechanical and cultural practices. Allelopathy may help in weed control through inhibition of weed seed germination and seedling growth. Present understanding of the plant biochemistry, physiology, morphology, inter and intra-plant specific interactions and chemistry of natural products have shown that smothering crops, trap crops, and allelochemicals may be used in weed control, overcoming the problems associated with herbicides. Reinhardt *et al*. (1993) has suggested three allelopathic strategies for weed control (a) selection of weed smothering crops and breeding their varieties to control major weeds in a given area, (b) inclusion of allelopathic crops in rotation and/or use their residues as mulches (Liebman and Dyck, 1993), and (c) selecting allelochemicals from plants or microbes with herbicidal activity.

Wise exploitation of allelopathy in cropping systems may be an effective, economical and natural method of pest management, and a substitute for heavy use of pesticides. Pesticide use may be reduced by exploiting allelopathy as an alternate pest management tool in sustainable intensive crop production. Several researchers have described allelochemicals as natural pesticides. Allelochemicals usually have a mode of action different from synthetic herbicides, being more easily and rapidly degradable owing to a shorter half-life, with comparatively fewer halogen substituent and no unnatural ring structures (Dayan *et al.*, 2001).
Phytochemicals have low or no toxicity to animals and beneficial insects, possess an array of activity with varying and diverse site of action and have a comparatively high degradation rate (Regnault *et al.*, 2004). Allelochemicals may influence vital physiological processes such as respiration, photosynthesis, cell division and elongation, membrane fluidity, protein biosynthesis and activity of many enzymes, and may also affect tissue water status (Cloyd, R.A. and Chiasson, H, 2014).

Allelochemicals are usually more effective in mixtures than singly to influence targets. Previous reviews on allelopathy include research on allelopathic potential of plants genetic differences among cultivars to suppress crops and weeds, identification of allelochemicals, significance of allelopathy in ecosystems and possibilities of using allelopathic crops for weed management in field crops. In the present review, the possible use of allelopathy as an alternative to pesticides for managing weeds, insect pests and diseases, especially in small-farm intensive agricultural systems (Weston LA and Duke, 2003). The objective of the paper was to review the role of allelopathy in pest management and crop production

2. Role of Allelopathy in Weed Management for Sustainable Agriculture

The word weed means any wild plant that grows at an unwanted place for example in fields and interferes with the growth of cultivated plants are known to reduce crop yield Weeds have substantially adapted characteristics (e.g. produce an abundance of seed, rapid seedling growth, quick maturation, dual modes of reproduction, environmental plasticity) that enable them to grow, flourish, invade and dominate an important part of natural and agricultural ecosystems In agro-ecosystems, weeds compete with crop plants for resources, interfere in crop handling, reduce crop yield and deteriorate their quality, and thus result in huge financial losses (Kholi *et al*., 2004).

Several techniques (e.g. mechanical and chemicals) are used for weed control. Nowadays, chemical method provides an effective strategy for weed control. Nevertheless, the indiscriminate use of herbicides has provoked an increasing incidence of resistance in weeds to some herbicides, changes in weed population to species more related to the crop, environmental pollution, and potential health hazards (Macías *et al*., 2006). Overuse of synthetic chemicals for weed control worsens the quality of soil, water, other life support systems, human health and food. Because of all these problems, efforts are being made to find out alternative low-input strategies for weed management. In this regard, much attention has been focused on the use of allelopathic plants and their products for managing weeds in a sustainable manner. Natural products release from allelopathic plants may help to reduce the use of synthetic herbicides for weed management and therefore, causeless pollution, safer agricultural products as well as alleviate human health concerns. So, it is worth while to explore the potential of plants with strong allelopathic activity for the management of agricultural weeds (Sodaeizadeh *et al*., 2010).

The use of allelopathy for controlling weeds could be either through directly utilizing natural allelopathy interactions, particularly of crop plants, or by using allelochemicals as natural herbicides. In the former case, a number of crop plants with allelopathic potential can be used as cover, smother, and green manure crops for managing weeds by making desired manipulation since the cultural practices and cropping patterns. These can be suitably rotated or intercropped with main crops to manage the target weeds (including parasitic ones) selectively. Even the crop mulch/ residues can also give desirable benefits (Khanh *et al*., 2007).

Table 1: Allelopathy inhibition of weeds with various mulches, crop residues and cover crops

Allelopathic source	Application mode	Rate (tha^{-1})	Dominant weed species	Weed control (over control)	Increase in yield (over control)
Black mustard (*Brassica nigra* L.)	Mulch	Incorporated in soil 30 DAS	*Avena fatua* L.	68% reduction in DW	-
Billy goat weeds (*Ageratumconyzoides* L.)	Mixed in soil as powder	2	*Echinochloa crus-galli* L.	70% reduction in growth	-
Rye (*Secale cereale* L.)	Cover crop	-	*Amaranthus* spp.	80-90%	-

2.1 Allelopathy as Crop rotation

Crop rotation is the sequential sowing of various crops in a particular field over a definite time period. In crop rotation, allelopathic or smothering crops use allelochemicals exuded by roots and released by decomposition of preceding crop residues to suppress weeds, disease pathogens and insect pests (Voll *et al*., 2004). A properly designed crop rotation can increase yield by around 20%. Crop rotation leads to numerous benefits over monocultures. Special attention should be paid to pest management when designing the rotation. Factors such as different root systems and plant architecture, differences in sowing and harvesting times, allelopathy, varying soil and crop management techniques and diverse cultural practices may be responsible for pest suppression and other benefits in a rotation (Peters *et al*.,2003). Plant-released allelochemicals through root exudation and litter decomposition in rotational sequence suppress weeds. Crop rotation is also helpful in neutralizing potential auto toxic effects associated with allelochemicals. Crops following sorghum (*Sorghum bicolor* L.) face less weed competition owing to suppression of weeds by allelochemicals added to soil by the sorghum crop (Einhellig and Rasmussen, 1989).

Rice-wheat is a major cropping system in many Asian countries. Heavily infested with weeds, this system largely relies on herbicide inputs for weed control. Integration of smothering allelopathic crops such as pearl millet (*Pennisetum glaucum* L.), maize and sorghum in the rice–wheat cropping system, grown after harvesting wheat (*Triticum aestivum* L.) and before rice transplantation, offers effective weed control for the upcoming rice crop for at least 45 days. Fodder crops such as oats (*Avena sativa* L.) or Egyptian clover (*Trifolium alexandrinum* L.) can be grown in wheat fields heavily infested with weeds for natural weed control for at least one season (Peters *et al*., 2003). *Orobanche minor* (JE Smith), a parasitic weed infesting many crops, can be avoided in red clover (*Trifolium pratense* L.) if sown in wheat-vacated fields. Wheat has the potential for integration as a trap crop as it stimulates parasitic seed germination without attachment, so working as a false host. This can therefore be used to suppress the parasitic weed infestation (Lins *et al.*, 2006).

Nevertheless, damaging consequences of an allelopathic crop in rotation have also been observed. For instance, in a sorghum–wheat rotation, allelochemicals exuded from sorghum affected the development of the subsequent wheat crop. Investigation of rotational sequences with allelopathic effects to control weeds and screening and development of crop varieties with allelopathic effects against pests are currently needed (Roth *et al*., 2000).

2.2 Allelopathy as Cover Crops

Cover crops are grown to control weeds, conserve soil, suppress insects, nematodes and other disease pathogens, enhance nutrient recycling and supply fodder. Important cover crops include sun hemp (*Crotalaria juncea* L.), yellow sweet clover (*Melilotus officinalis* L.), sorghum, cowpea, alfalfa (*Medicago sativa* L.), velvet bean, red clover and ryegrass (*Lolium perenne* L.).Legume crops such as velvet bean, jumbie bean (*Leucaena leucocephala*), wild tamarind (*Lysiloma latisili-quum* (L.) and jack bean *Canavalia ensiformis*.), used as cover crops in maize, substantially reduced the barnyard grass *Echinochloa crus-galli* (L.) population; however, velvet bean was the best cover crop for weed control Likewise, barley (*Hordeum vulgare* L.) grown as a cover crop for weed control in soybean suppressed weeds such as crabgrass [*Digitaria ciliaris*) and barnyard grass.

The smothering effects of velvet bean, jack bean and hyacinth bean (*Lablab purpureus* L.) effectively controlled mission grass (*Pennisetum polystachion*.), a troublesome weed in rubber plantations (Kobayashi *et al.*, 2003). Cover crops incorporated into soil as green manure can delay planting and emergence owing to excess soil moisture, have phytotoxic effects on major crops and increase nitrogen immobilization. This can, however, is avoided through the adoption of good management practices and by optimizing and integrating cover crops in a cropping system (Caporali, 2010*).*

2.3 Allelopathy as Mulching

Mulch is spread over the soil surface to suppress weeds, among other strategies. Mulches obstruct seed germination of weeds and inhibit weed seedling growth through the release of allelochemicals Established weeds, however, are difficult to control with mulches. In addition to weed suppression, use of allelopathic crop residues as surface mulch benefits agricultural sustainability by adding organic matter to soil, conserving soil moisture, improving water infiltration into soil, decreasing the impact of raindrops on soil, modifying/regulating soil temperature, enhancing biological activities in soil and controlling soil erosion (Teasdale and Mohler, 2000).
Allelopathic plant mulches applied to rice fields at suppressed noxious paddy weeds such as barnyard grass, purple nuts edge (*Cyperus rotundus* L.), and Wheat residues as soil cover reduced weed density and dry weight while conserving soil moisture. Teasdale and Mohler, (2000) reported quantitative relationships between emergence and mulch properties with mulches such as maize stalks, rye (*Secale cereale* L.), crimson clover (*T. incarnatum* L.), hairy vetch (*Vicia villosa* Roth), *Quercus* leaves and landscape fabric strips. Another study by Gruber *et al. (*2008). determined the effect of wood chips [0 (control), 80 and 160 m^3 ha^{-1} annually] derived from hedgerow and tree mulch on weeds of organically grown wheat. Wood chip mulch effectively suppressed weeds in the field, while their allelopathic potential in the laboratory reduced germination rates in oilseed rape (*Brassica napus* L.), blackgrass (*Alopecurus myosuroides* Huds) and field poppy (*Papaver rhoeas* L.). Wood chips also improved organic matter, nutrient levels and water storage capabilities of the soil.

2.4 Allelochemicals as Herbicides

There is increasing evidence that allelochemicals or natural plant products derived from higher plants/microbes can be ideal agrochemicals. Initially, the reason why plants devote resources to the production of these compounds was not understood as they were regarded as functionless waste products. It is now increasingly accepted, however, that these compounds function as defensive agents against pathogens, insects and neighboring plants (Mattner *et al*., 2006).

Many such natural compounds have the potential to induce a wide array of biological effects and can provide great benefits to agriculture and weed management (Macías *et al*, 2006). Evidence showed that higher plants release a diversity of allelochemicals into the environment. Despite so much chemical diversity, allelochemicals can be broadly characterized into phenolics and terpenoids. They are released by volatilization, root exudation, death and decay of plants, and leachation from living or decaying residues After release, allelochemicals are involved in a variety of metabolic processes Several factors determine their toxicity such as concentration, flux rate, age and metabolic state of plant, and prevailing climatic and environmental conditions (Singh *et al*., 1999).Their amount and production varies in quality and quantity with age, cultivar, plant organ, and time of the year. Einhellig, (1996) mentioned that both a biotic (temperature, nutrient amount, and moisture deficit) and biotic (disease and insect damage and interaction of plans with herb ivory) factors enhance the amount and biosynthesis of allelochemicals in plants. Allelochemicals offer excellent potential as herbicides (Dayan, F.E. and Duke, S.O, 2009). First, they could be used directly as herbicides because these are free from all the problems associated with present herbicides. Second, their chemistry may be used to develop new herbicides. As traditional methods of discovering and developing new herbicides have become more difficult and expensive, the interest in natural products as sources of herbicide chemistry has increased. Besides, public awareness and demand for environmentally safer herbicides with less persistence, more specific targets and less potential for contaminating groundwater makes searches for new weed control strategies, using natural products more attractive. Plants and microorganisms produce hundreds of secondary compounds; many of these are phytotoxic and have potential as herbicides or as templates for new herbicide classes. It has been estimated that only about 3 % of possible 400,000 secondary metabolites from plant and microorganisms have been so far identified. Only a fraction of those identified have been evaluated for herbicidal or bio regulator activity.

2.5. Allelopathy for the Management of Phytopathogens

Crop plants are attacked by a large number of pathogens namely fungi, bacteria, viruses, phytoplasmas and nematodes. These pathogens are responsible for substantial plant growth and yield losses In the presence of a susceptible host and under favorable environmental conditions, total crop failure may occur after disease development. There are many reports where these plant diseases spread in an epidemic form and caused very high yield losses in economically important crops such as chilli, wheat, rice, potato and tomato on large cultivated areas (Wang *et al*., 2009).

A number of methods are available for the management of plant diseases. These include cultural practices such as crop rotation, host eradication and sanitation; cultivation of resistant varieties use of biological agents such as Trichoderma spp.and use of synthetic agrochemicals (Paulo and Gouveia, 2009); Growers are generally attracted by utilization of synthetic agrochemicals to combat diseases, since this option is rapid and easy to practice, resulting in maximum profitable yield. Fungicides, bactericides and nematocides are being used to control fungal, bacterial and nematode diseases. These agrochemicals are generally used as seed dressing, soil fumigant or foliar spray Although these synthetic agrochemicals are very effective in controlling crop diseases; however, their use is becoming more limiting due to environmental pollution, residual toxicity problems, carcinogenic effects and occurrence of microbial resistance For more sustainable systems, there is an increasing trend towards search for natural and environmental friendly alternatives of these chemicals (Cuthbertson and Murchie, 2005).

Exploiting allelopathy potential of plants is one of the most popular alternative strategies to manage the phytopathogens (Farooq *et al*., 2011).Several plant species are capable of producing and releasing biologically active compounds called allelochemicals include phenolics, coumarins, alkaloids, terpenoids, steroids, tannins and quinines. These compounds are released into the environment by various mechanisms including root exudation, leaching from aerial parts especially leaves, volatile emissions and decomposition of plant material (Xuan *et al*., 2005). Allelopathy is beneficial or detrimental effect from a donor plant to the recipient by chemical pathway (Rice, 1984). According to IAS, allelopathy concerns the study of any process involving secondary metabolites produced by plants, algae, bacteria and fungi that influence the growth and development of agricultural and biological systems (IAS, 1996). The harmful impact of allelopathy can be exploited for the management of pests and diseases (Kohli *et al*., 1998). Ample research work has recognized the potential of allelopathic plants in suppressing the growth of plant pathogens Plant products are biodegradable, exhibit structural diversity and complexity and rarely contain halogenated atoms. These can act directly as pesticides or may provide structural lead for pesticide discovery (Duke *et al*., 2000). The phenomenon of allelopathy has recently received greater attention from researchers and farmers worldwide (Farooq *et al*., 2011).

2.5.1 Management of Fungal Pathogens

About75 % of plant diseases are caused by fungi. On the basis of morphology and biology, plant pathogenic fungi are categorized into five major groups, Plasmodiophoromycetes, Zygomycetes, Oomycetes, Ascomycetes and Basidiomycetes. There are many notorious fungal pathogens such as Macrophomina phaseolina, Sclerotium rolfsii, Fusarium solani, F. oxysporum and many other that cause diseases on a large number of host plants. M.phaseolina is a soil-borne fungal plant pathogen that causes charcoal rot disease in more than 500 different monocotyledonous and dicotyledonous plant species including such important crops as sorghum, soybean, alfalfa, maize etc (Wyllie, 1993). So far, there is no registered fungicide against the charcoal rot pathogen. Similarly, S. rolfsii is also a soil-borne plant pathogen responsible for significant economic losses on a wide range of agronomic host plants including 500 plant species, in over 100 plant families, in countries of Asia, Australia, Africa, America and Europe Plant diseases caused by fungi include leaf spots, root and crown rot, rust, smut, blight, wilt, dieback, powdery mildew, downy mildew etc. Triazole derivatives such as diniconazole, triadimefon, tebuconazole, andhexaconazole represent the most important category of fungicides to date, effective against a wide spectrum of crop diseases (Lu *et al*., 2011).

2.5.2 Management of Bacterial Pathogens

Bacteria are single-celled microscopic organisms, ranging in size from 1–2 lm. Plant pathogenic bacteria cause many serious diseases of plants throughout the world. However, the bacterial diseases are fewer than fungi or viruses and they cause relatively less damage and economic loss (Kennedy and Alcorn, 1980). There are about 200 bacterial species causing severe economically damaging diseases worldwide on 150 plant genera belonging to more than 50 families of higher plants. The majority of plant-associated bacteria are rods, however, by biochemical, genetic and molecular biological analyses, it has been shown that these bacteria are quite heterogeneous Symptoms of bacterial diseases on plants ranging from spots, mosaic patterns or pustules on leaves and fruits, or smelly tuber rots to plant death (Thiele *et al*., 2012). Some bacteria namely Agro bacterium tumefaciens and A.vitis cause hormone-based distortion of leaves and shoots called fasciations or crown gall. Amongst the pathogenic bacteria about one half of the species belong to genus Pseudomonas.

There are many examples of exploiting allelopathic potential of the plants for the management of bacterial plant pathogens and diseases. Intercropping of Chinese chive (A. tuberosum) with tomato significantly delayed and suppressed the occurrence of bacterial wilt of tomato caused by Pseudomonas solanacearum, Smith without having any negative effect on the tomato. Diffuseness from various parts of Sapindus mukorossi, Acacia nilotica, Phyllanthus emblica and Terminalia chebula were highly inhibitory against Xanthomonas campestrispv. citri and reduced the number of lesions on detached leaves and fruits .Volatile plant essential oil thymol (2-isopropyl-5-methylphenol) application significantly reduced Ralstonia solanacearum wilt incidence and increased the yield of tomato under filed conditions Aqueous extracts of fresh leaves of Datura stramonium, A. Sativum and Nerium oleander exhibited antibacterial activity against bacterial wilt pathogen Ralstonia solanacearumin vitro and in vivo (Abo-Elyousr and Asran, 2009).

The aqueous extracts of leaves of Camellia sinensis was found highly effective against X. campestris pv.campestris, the cause of black rot of cabbage and cauliflower. The hexane leaf extract of A. nilagirica was found to be effective against X.campestris, P. syringae and Clavibacter michiganense with MIC of 32 lg mL-1Momilactone A and B, the two potent allelochemicals of rice, are known to exhibit antibacterial activity (Fukuta *et al*., 2007).

2.5.3 Management of Plant Nematodes

Nematodes are small wormlike multi cellular organisms, and generally live freely in the soil. However, there are several nematode species that parasitize plant roots and are problematic in tropical and subtropical regions of the world. Plant-parasitic nematodes reduce productivity and general fitness of the plants by feeding plant nutrients. There are about 1,200 plant-parasitic nematode species responsible for drastic economic losses to a great range of hosts. Vegetable and agronomic crops, fruit, nut and forest trees, and turf grass are attacked by nematodes. Typical root symptoms include knots or galls, root-lesions, excessive root branching, injured root tips and stunted root systems. Symptoms on the aboveground plant parts are wilting even with ample soil moisture, foliage yellowing and fewer and smaller eaves. Stem nematodes cause stem swellings and shortened internodes. Bud and leaf nematodes distort and kill bud and leaf tissue. The most damaging are root knot nematodes (Meloidogyne spp.) that have quite a large host range (Douda *et al*., 2012).

Global economic losses caused by Meloidogyne sp. nematodes were evaluated at 100 billion USD per year. Others are cyst (Heterodera spp. and Globodera spp.), root lesion (Pratylenchus spp.), bud and leaf (Aphelenchoides spp.), needle (Longidorus spp.), reniform (Rotylenchulusreniformis), burrowing (Radopholus similis), spiral (Helicotylenchus spp.), bulb and stem (Ditylenchus dipsaci), dagger (Xiphinema spp.), and stubby root nematodes (Paratrichodorous spp.), all are able to cause radical changes in root cells to facilitate their lifestyle. Soil fumigants namely methyl bromide,methyl iodide, propargyl bromide or 1, 3-dichloropropene are suggested for nematode management however, many of these chemicals disturb soil ecosystems Various physical methods including steam disinfection, soil solarization and hot water injection have also been employed for the control of nematode with varying success as alternate to soil fumigation with synthetic chemicals. However, many factors including soil type, climatic conditions and water content of soil can affect the effectiveness of physical treatments(Wang *et al*., 2009),

2.5.4 Allelopathy for Insect-Pest Control

Extensive use of synthetic insecticides usually has negative effects on the environment and on human and animal health and, most critically, develops resistance among insects. Scientists are therefore turning towards natural insect suppressants. Neem (*Azadirachta indica* L.) seed oil exhibits antifeedant properties against nymphs and adults of strawberry aphids [*Chaetosiphon fragaefolii* (Cockerell)], Conifer plantations treated with neem oil deter feeding activity of large pine weevil (*Hylobius abietis* L.) for 3 months. Sitka spruce [*Picea sitchensis* (Bong.)] seedlings without neem oil treatment were killed by the feeding weevil, while those treated with neem oil (30 cm above the root collar) were not affected; azadirachtin, nimbin and salannin are the allelochemicals identified in neem oil (Dayan *et al.*, 2009).

Decomposing residues of cover crops improved soil nutrient status and released allelochemicals that deter plant pests, particularly soil-borne disease pathogens. Gallandt and Haramoto, (2004) Exposure to volatile oils from eucalyptus (*Eucalyptus globulus* L.) during larval periods of rice moth (*Corcyra cephalonica* St) severely affected post-embryonic development and adult emergence evaluated the effectiveness of allelopathic water extracts of sorghum, mustard and sunflower, along with combinations of sorghum and mulberry (*Morus alba* L.) and sorghum and sunflower, for controlling aphids and sucking insects of *Brassica* spp. Sorghum water extracts were most effective (62.5% aphid mortality) at a concentration of 8%, and sunflower water extracts (16% concentration) resulted in 52.5% aphid mortality. Combination water extracts (16%) of sorghum and mulberry resulted in 45.7% aphid mortality, and sorghum and sunflower had 57.5% mortality.

Table 2. Allelopathic suppression of insect pests

Allelopathic source	Application rate/mode	Insect suppression
California pepper tree (*Schinus molle* Rev L.	Ethanol extract (4.7% w/v)	91.77% mortality of elm leaf beetle (*Xanthogaleruca luteola* Müller)
Fig-leaf goosefoot (*Chenopodium ficifolium* Sm.)	Ethanol extract (5000 mg mL^{-1})	86% control of aphid (*Aphis gossypii* Glover)
Eucalyptus (*Eucalyptus camaldulensis* L.)	Oil volatile	Reduction in male (78%) and female (66.67%) adults of *Corcyra cephalonica*
Birbira (*Milletia ferruginea* Hochst.)	Seed crude extract	93-100% mortality of adult *Macrotermes* termites
Neem	Seed kernels water extract (2%)	Reduction in flower thrip (*Taeniothrips sjostedti* Trybom) (54%) and pod borer (*Heliothis armigera* Hb.) (32%) incidence

Source:

Ethanol extracts from leaves of California pepper tree (*Schinus molle* L.) imparted insecticidal effects on adults of the elm leaf beetle (*Xanthogaleruca luteola* Müller.) by killing more than 97% of the population at concentrations of 4.3 and 4.7% w/v, while their water extract exhibited complete inhibition of feeding activity of the insect pest (Kong, 2010).

2.5.5 Role of Allelopathy in Disease Management

Plant disease is a serious issue causing detrimental effects on many crops including cereals, oilseeds, etc., and especially vegetables. A number of soil-borne diseases cause substantial losses to crop production by disturbing the crop stand and lowering product quality. Although cultural practices such as burning infected plant debris and using resistant cultivars have long been used, diseases still cause abundant losses in crop yields. Chemical disease control for most diseases is either unavailable or ineffective. Plant pathogens can be suppressed using allelopathic crops in different ways.

Intercropping creates a microclimate, which is helpful for reducing disease intensity (Gómez *et al.*, 2003). Sugi (*Cryptomeria japonica* L) bark has inhibitory effects against diseases causing root infections in tomato (*Lycopersicon esculentum* L.). Root exudates from Chinese chive (*Allium tuberosum* L.) inhibit multiplication of bacterial wilt (*Pseudomonas solanacearum* Smith). When intercropped with tomato, Chinese chive suppressed bacterial wilt while having no negative effect on the tomato. Certain volatile allelochemicals are exuded from aerial parts of marigold (*Tagetes erecta* L.). When intercropped with tomato, marigold suppressed tomato early blight disease caused by *Alternaria solani* by more than 90%. Bacterial wilt of tomato (*Ps. solanacearum*) has been well controlled by intercropping tomato with cowpea. *Brassica* spp. produces volatile sulfur compounds (glucosinolates) in the soil microenvironment, which are converted to isothiocyanates through biofumigation to suppress soil organisms. These compounds can reduce fungal pathogens and nematodes in the soil (Cohen *et al.*, 2005).

Table 3: Allelopathic suppression of pathogens, nematodes and diseases

Allelopathic source	Application mode/rate	Pathogen/disease suppression
Barley (*Hordeum vulgare* L.) + potato	Grown in rotation	55.1% reduction in inoculum intensity of *Rhizoctonia solani* (JG Kühn)
Rice (*Oryza sativa* L.)	Root exudates (1.5 mL)	37% reduction in germination of *Fusarium oxysporum* f. sp. *Niveum* spores
Rice	Root exudates (20 mL)	71.88% reduction in spore reproduction of *Fusarium oxysporum* f. sp. *Niveum*
Neem (*Azadirachta indica* L.)	Leaf water extract (20% w/v)	53.22% reduction in the growth of *Fusarium solani* f. sp. Melongenae
Eucalyptus (*Eucalyptus globulus* Labill)	Leaf water extract (20% w/v)	46.76% reduction in the growth of *Fusarium solani* f. sp. Melongenae
Neem cake	3% (w/w)	63.7% reduction in root-knot nematode egg masses per root

2.5.6 Limitation of Using Allelopathic Effects

There are many limitations in using allelopathic potentiality as a weed management tool. The limitations are both because of plant itself, producing allelochemical and the environmental condition. Many a biotic and biotic soil factors have influences on phototoxic levels of allelochemicals (Huang *et al*., 1999). Various a biotic and biotic factors such as plant age, temperature, light and soil condition, micro flora, and nutritional status and herbicides treatments influences the production and release of the allelochemicals although allelopathy is considered as genetically influenced factor (Put nam, 1988).

While moving in the soil allelochemicals may undergo transformation as various factors regarding soil environment like physical, chemical, and physiochemical properties of soil may influences the activity of allelochemicals. So to study the allelopathic potentiality of plant the role of soil should not be ignored according to Inderjit and Dakshini (1996). Many studies on allelopathy, however don't involves an artificial soil substrate after entry in to soil allelochemicals may be toxified or detoxified by microbes (Inderjit, 1996).the amount of nutrient available to plant and the efficiency of the plant to utilize the nutrient influences the allelopathic potentiality of rice plant , sometimes the deficiency of the nutrient favors the production of secondary metabolites as mentioned by Xuan,*et al* .(2005).While studying the role of allelopathy in controlling weeds the auto toxicity of plants should not be ignored. There must be some strong inter action among auto toxic chemicals and environments. In some areas of the world the phytotoxic effects of decomposing rice residues in the soil cause problem on the next year's crop (Asaduzzaman *et al*., 2010).

3. Summary and conclusion

Allelochemicals are capable of acting as natural pesticides and can resolve problems such as resistance development in pest biotypes, health defects and soil and environmental pollution caused by the indiscriminate use of synthetic agrochemicals Allelopathic crops, when used as cover crops, mulch, smother crops, intercrops or green manures, or grown in rotational sequences, can combat biotic stresses such as weed infestation, insect pests and disease pathogens and additionally build up fertility and organic matter status of soil, thereby reducing soil erosion, and improve farm yields. So many investigation and research have been attempted to exploit allelopathy of plants against pest, and disease weed in agricultural field.. The need to reduce harmful environmental effects from the discriminate and\or over use of herbicides has encouraged the development of weed management system, witch are impacts on ecological manipulation compared to herbicide.

Allelopathic potential of higher plants can be exploited for the management of variety of phytopathogens especially fungi, bacteria and nematodes. Allelopathic plants of many angiosperm families especially Brassicaeae and Chenopodiaceous contain antifungal constituents. For the management of soil-borne plant pathogens especially fungi and nematodes, allelopathic plants should be planted in rotation with susceptible crops, or as cover crops before sowing of susceptible plant species. In addition, allelopathic crops can be incorporated into the soil as green manure to reduce the population of phytopathogens. Crude extracts of these crops may be used as foliar spray for the management of aerial pathogens. Finally, the structures of allelochemicals can be used as analogue for the synthesis of new pesticides. These natural product based pesticides will possibly be far less harmful for the environment as compared to synthetic agrochemicals. Allelochemicals are advantages as they are biodegradable; having different modes of action and weed may not easily develop resistance to them. But there are many limitations using allelopathic potentially as weed management tool. The limitations are both because of plant itself, producing allelochemicals and environmental conditions.

Increasing attention has been given to the role and potential of allelopathy as a management strategy for crop protection against weeds and other pests. Incorporating allelopathy into natural and agricultural management systems may reduce the use of herbicides, insecticides, and other pesticides, reducing environment/soil pollution and diminish auto toxicity hazards. There is a great demand for compounds with selective toxicity that can be readily degraded by either the plant or by the soil microorganisms. In addition, plant, microorganisms, other soil organisms and insects can produce allelochemicals which provide new strategies for maintaining and increasing agricultural production in the future.

4. Prospects

Crop allelopathy plays an important role in agricultural production. Issues such as environmental pollution, unsafe agricultural products, human health concerns, and decline in crop productivity, soil sickness and depletion of crop diversity may be dealt appropriately if crop allelopathy is appropriately utilized or manipulated. Allelopathic crops should be used as cover crops, smother crops, companion crops and for crop rotation. The selection of crop varieties with strong allelopathic potential to biologically reduce the intensity of pests, weeds, pathogens, diseases and nematodes is indispensable in the current and future agricultural production.

Several areas of allelopathy have already been studied and some studies are in progress although some areas are needed to be studied extensively to implicate the mechanism of allelopathy successfully. For optimal use of allelopathy under field conditions, the influence of environmental factors needs to be investigated. In this concern soil environment is the most important factor. From agronomic point of view the allelopathy must be studied. The intensity of competition between crops and weeds for space, light, moisture and nutrient will differ under various field conditions, which in turn will affect the allelopathic potentiality. So, this area needs special attention to make allelopathic potentiality successful.

Use of heavy doses of herbicides creates the problem of resistance development in weed. Another problem is continuous use of one herbicide can change the weed community. For successful utilization of allelopathic properties the identification of allelochemicals is necessary. It may happen that more than one allelochemicals are involved in allelopathic mechanism. Finally identification of genes encoding for allelopathy in different plants is required.

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