Role of Allelopathy in Plant Disease Management

Abstract:

Allelopathy is a natural and eco-friendly process causes agricultural plants to generate phytotoxins called "allelochemicals" that hinder or promote growth. The chemical substances generated through allelopathy can be potential tool to control agricultural important pests. Allelopathy can replace agrochemicals for crop disease and pest management. Agrochemical used in agriculture pollute the environment, lowers food quality, and increases disease-resistant biotypes. An agronomist can collaborate with a molecular scientist or plant breeder to selectively boost disease suppression by understanding allelopathy's physiological foundation. Allelochemicals are natural pesticides that fight disease, weeds, and insects, according to experts. Disease management strategies have been redesigned recently. Frequently, structural modifications or the synthesis of chemical analogs increase their bioactivity. Even though the progress in this regard is sluggish, some encouraging results are emerging, and many more are anticipated in the near future. This review attempts to discuss these characteristics of allelopathy for the rational management of diseases.

Keywords: Allelopathy, Allelochemical, Crop rotation, Disease management, Intercropping.

Introduction:

Allelopathy derives from the Greek terms allelon, which means "of each other," and pathos, which means "to suffer." This primordial idea was revived for classical scholars during the Greek and Roman eras [72]. The term 'allelopathy' was coined by an Austrian plant physiologist. According to Molsch, this is due to the chemical interaction between plants and other microorganisms. According to (Inderjit and Callaway, 2003) [34], allelopathy is the adverse effect of one plant on another plant caused by the release of numerous secondary metabolites into the soil and soil texture. Allelopathy is a powerful tool against alien plant species that are invasive. The mutualistic, antagonistic, and pathogenic impacts on the plant's native flora are mediated by chemicals secreted by the roots and other plant components [53]. Allelopathy consisted of the production of plant bioactive compounds known as allelochemicals, which are capable of acting as natural insecticides, herbicides, and fungicides to solve problems such as resistance development in pest biotypes, soil health issues, and environmental pollution caused by the improper and insufficient use of synthetic agro pesticides. Allelopathic crops such as cover crops mulch strip crop, alley crop and smother crops, intercrops or chief manures or fully grown in motility sequences will combine organic phenomenon stresses such as weed infestation, insect pests, and unknown pathogens and also build up fertility and organic matter standing of soil, thereby reducing wear and improving yields of field crops [13]. The purpose of allelopathy is to maximize the utility of locally available natural sources in agriculture and forestry, thereby reducing the use of agrochemical pesticides while maintaining economic productivity without harming the environment or atmosphere, thereby contributing to sustainable agricultural practices. Strategies of the allelopathy research for promoting the low chemical fertilizer input agriculture include: (A) Pests management (weeds, plant pathogens and insects and pests) by biological means and (B) utilization of available natural things (e.g. bio fertilizers such as vermin-compost, etc.) to enhance soil fertility. Despite the use of pesticides and other integrated pest management practices, vegetation and plant diseases continue to reduce crop yields, and sustainable agriculture places a high priority on pest management. Allelopathy is the influence of one plant on the growth of another plant, including microorganisms and secondary metabolites, through the discharge of chemical compounds into the environment [58, 59]. Typically, these organic chemicals are secondary metabolites or byproducts of the primary metabolic pathways in plants [59, 56, 17]. They are nonnutritive and can be synthesized from plant parts such as leaves, stems, roots, bark, seeds, etc. Under favorable environmental conditions, allelochemicals are released into the environment via volatilization processes such as root exudation, decomposition, and leaching, thereby influencing the growth of adjacent plants and plant parts [3]. Not all Allelochemicals are carcinogenic implicated in crucial physiological and biochemical processes within plant tissues [35]. Thus, allelopathy can be exploited in numerous profitable ways. Allelopathy is any process involving secondary metabolites that has both positive and negative effects on the growth and development of agricultural and biological systems (but not animals) [24,7]. These microorganisms, such as fungi, bacteria, viruses, and nematodes, are essential components of our agroecosystem [24]. Few of them are detrimental plant pathogens, while others have neutral or beneficial effects on the growth system of plants. In every crop production system, preventing disease-causing microorganisms is an essential component. The goal of allelopathy for disease management is essential for increasing crop production and crop yield. [17]. This is a crucial method for controlling diseases and parasites in various types of crops [7]. It depends primarily on the chemical composition of allelochemicals in the roots and other plant parts. Donor species are plants or other organisms that release these types of compounds, while target or recipient species are those that are influenced in their growth and development [3]. Allelopathy encompasses the plant, plant bacterium, plant virus, and plant-soil-plant chemical interactions [1]. Although allelopathy has contributed to the solution of some naturally occurring pest and disease problems in agriculture, it is still a relatively new concept [25]. The purpose of this review is to highlight the role of allelopathy in plant disease management.

- **Mechanism of Allelopathy and its Characters:**

  Allelopathy has two main parts: first, the contact is between plants, then between plants and animals. They don't talk about how plants and organisms connect with each other. Second, the relationship is between plants' secondary metabolites and the environment, and the secondary metabolites have never changed within the plants. Third, allelochemicals are used to change how a plant grows and develops or how it grows and develops with other plants. If a plant uses it to send a chemical message (like a warning) or to pollute the environment (like when volatile materials in the air and NO, CO2, NOX, O3, CFC from some agro plants and trees make smog), we won't consider that allelopathy. The most important part of allelopathy study is finding out how allelochemicals are released, or why and how plants release substances like allelochemicals.

- **Allelochemicals and its Types :**

  Allelochemicals are substances that plants secrete that can affect the growth, behavior, and population biology of living things.

  These substances include secondary metabolites from plants as well as substances from animals and other plants. Since the beginning of the 21st century, there has been a lot of research and development in science and technology, especially in the areas of chemistry and biology. This has led to the study of allelochemicals, which is important for healthy agriculture. Allopathic study is currently focused on how higher plants interact with each other, how higher plants interact with microorganisms like bacteria, viruses, and nematodes, how these microorganisms interact with higher plants, and how microorganisms interact with each other. Allelopathy can be used in many ways, such as to increase food production, take care of forests, control diseases and pests or use biological control, etc. Allelochemicals include water-soluble organic acids, straight-chain alcohols and fatty acids, aliphatic and aromatic series, aldehydes, ketones, and simple unsaturated lactones, long-chain fatty acids, multi-alkyne, naphtha-quinone, anthra-quinone acid, quinone compound, simple phenols, benzoic acid and all of its derivatives, cinnamic acid and all of its The most common types of allelochemicals are phenolic acids and terpenoid molecules.

- **Allelopathy for the Management of Phytopathogens:**

Pathogens like fungi, bacteria, viruses, phytoplasma, and worms can cause damage to crop plants. These different kinds of bugs cause plants to grow and produce less than they should. [12] For a lot of things, there is a growing movement toward natural and environmentally friendly alternatives to these kinds of chemicals. One of the most popular ways to deal with phytopathogens [23, 22] is to use the plants' allelopathic system. Allelochemicals are compounds that are biologically active and can be made and released by a wide range of plant types. [74] found that these chemical compounds can be released into the environment in a number of ways, including through root exudation activity from the plant's leaves, flammable material, and the breakdown of material. Allelopathy is the study of how secondary metabolites made by plants, viruses, bacteria, nematodes, and fungi affect the growth and development of agricultural, forestry, and biological processes. This is according to the International Allelopathy Society. The bad effect of allelopathy can be used to protect plants from pests and diseases [45, 23]. [22] say that scientists and farmers around the world are now paying more attention to how important allelopathy is.

- **Allelopathy for the Management of Fungal Pathogens:**

Fungi are responsible for about seventy-five percent of plant diseases. On the basis of appearance and biology, there are a number of important plant pathogens, such as *Macrophomina phaseolina, Sclerotium rolfsii, Fusarium solani, F. oxysporum*, and many diseases that affect a wide range of host plants. *M. phaseolina* is a soil-borne virus that causes charcoal rot disease in more than 500 different monocotyledonous and dicotyledonous plant species, including important crops like sorghum, soybean, alfalfa, maize, pearl-millet, oats, and barley [73]. So there is no antifungal medicine on the market that can treat the charcoal rot disease. In the same way, Sclerotium spp is a soil-borne plant disease that causes big economic losses and low yields on a wide range of science host plants, including 500 plant species in more than 100 plant families in Asia, Australia, Africa, America, and Europe. Plant diseases like leaf spots, root and crown rot, rust, smut, blight, wilt, dieback, mildew, mildew, etc. are caused by fungi pathogens. Triazole derivatives like diniconazole, triadimefon, tebuconazole, and hexaconazole are some of the most important types of fungicides. They are useful against a wide range of crop diseases [51].

- **Allelopathy for the Management of Bacterial Pathogens:**

Plant pathogenic microorganisms like bacteria, fungi, viruses, and nematodes cause many dangerous diseases in plants all over the world [67, 14]. However, microorganism diseases are fewer than fungi or viruses and that they cause comparatively less injury and economic loss caused by bacteria [14]. There are at least two hundred bacteria species that cause serious economic damage to at least 150 plant genera and their species, which belong to at least fifty plant families. Most of the microorganisms that live on plants are rods. Diseases caused by these microorganisms, like bacteria, show up on plants as spots, mosaic patterns, or pustules on leaves and fruits, or as serious tuber rots that kill young and old plants [14, 64]. There are many ways that plants can be used to control microorganisms, such as all plant pathogens and diseases, by using their allelopathic properties. Intercropping garlic (*A. tuberosum*) with tomato (*Pseudomonas solanacearum* Smith) slowed down the spread of the disease microorganism wilt of tomato by a lot, but it didn't hurt the tomato plant at all. Spread from different parts of the dicot genus mukorossi, tree nilotica, *Phyllanthus emblica*, and *Terminalia chebula* was very restrictive against the genus of bacteria *Campestrispv citri* and decreased the number of lesions on detached leaves and fruits of the same plant. Volatile nature of plant oil like thyme camphor (2-isopropyl-5-methylphenol) application significantly reduced *Ralstonia solanacearum* wilt disease incidence and increased the yield of tomato plant under the field conditions.

- **Allelopathy for the Management of Plant Nematodes:**

Nematodes are very small, worm-like, single-celled microorganisms that usually live in the dirt. [11] Many nematode species feed on plant roots, which is bad for plants in warm and semi-tropical parts of the world. Parasitic nematodes hurt the production and general health of plants by giving them all kinds of nutrients, both small and big. There are about 1,200 types of nematodes that live on plants and cause economic damage to their hosts [14]. Plant parasitic nematodes harm a lot of vegetable and agricultural crops, fruit, nut, and forest trees, and lawn grasses. Root signs include knots or galls, lesions on the roots, a lot of root branching, lacy root tips, and lower root systems. Root-knot nematodes (*Meloidogyne* spp.), which cause the most damage, range from host to host [15, 11].

From different parts of the world, it was estimated that *Meloidogyne* sp. (Root knot) worms cost the world economy $100 billion every year [11]. For getting rid of plant parasitic nematodes, soil fumigants like bromide, methyl radical halide, propargyl bromide, or 1,3-dichloropropylene are suggested. However, several of these chemicals can harm soil agro-ecosystems [11]. Different physical methods, like steam treatment, soil exposure, and plight injection, have also been used to get rid of plant parasite nematodes, with varying degrees of success. These methods are used instead of coating the soil with man-made organic chemicals. But the effectiveness of physical treatments will depend on things like the type of soil, the weather, and the amount of water in the soil [69, 11].

- **Role of Allelopathy in Disease management:**

Plant disease can be a big problem. It can hurt crops like cereals, oilseeds, etc., and veggies are usually hit the hardest by the microorganisms that cause it. A different kind of disease that spreads through the soil reduces food yield by making the plants sick and lowering the quality of the crop. Intercropping gives each plant its own environment, which [24] say can make sickness less severe. [14] found that the wood of a plant called Japanese cedar (*Cryptomeria japonica* L.) can stop many diseases, such as those that cause root infections in tomatoes (*Lycopersicon esculentum* L.). Wilt (*Pseudomonas solanacearum* Smith) could not grow as fast when garlic plant (*Allium tuberosum* L.) root juices were added. Sunflower (*Tagetes erecta* L.) leaves and stems release volatile allelochemicals. Intercropping tomato crops with cowpea has been very effective at stopping the disease *P. solanacearum*, which causes tomato plants to wilt. Brassica spp. release volatile sulfur compounds (glucosinolates) into the soil, which can be turned back into isothiocyanates through bio-fumigation to kill bacteria in the soil. Plant pathogens like bacteria, fungi, viruses, and worms will be less likely to grow in soils with these chemicals [22].

- **Allelopathy vis-a- vis Disease Management:**

- **Over view:**

Plant diseases damage many crops, especially vegetable crops, but they also affect agronomic crops like grains, pulses, oilseeds, etc. There are a lot of diseases in the soil that can affect crop yield by making plants fall over and lowering the quality of the food. Even though people have been using methods like burning infected crop debris and using resistant plant types for a long time, diseases still cause a lot of crop loss. The plant mechanism of allelopathy can be used as a part of integrated disease control. Chemical treatments for most diseases are either not available or don't work well for crop care. Allelopathic crops with different kinds of gaseous compounds can stop plant pathogens from spreading. [29,24]. Different cropping patterns, like intercropping, are a promising allelopathic way to biological disease control for managing different types of soil-borne diseases. Root exudation sends different types of secondary metabolites into the rhizosphere, where they affect how plants and bacteria in the area interact with each other [6, 10, 68, 69]. [54] found that a Canola (*Brassica napus*) plant with high amounts of the glucosinolate 2-phenylethyl (2-PE) is very toxic to a wide range of cereal pathogens, including plant parasitic nematodes. Intercropping and other important cropping systems create a microclimate on the nearby plant, which helps a lot when it comes to reducing the number of diseases in the crops. The bark of Sugi (*Cryptomeriaja ponica*) (L.f.) can stop diseases from getting into the roots of tomato plants (*Lycopersicon esculentum* L.). Root juices from the Chinese chive (*Allium tuberosum* L.) stop *Pseudomonas solanacearum* Smith from making more bacteria that cause bacterial wilt disease. When planted next to tomato, Chinese chive stopped the spread of bacterial wilt without hurting the tomato plant. Marigold plants (*Tagetes erecta* L.) send out different volatile allelochemicals from their leaves. When planted next to tomatoes, marigolds stopped more than 90% of the *Altemaria solani* disease that causes early blight. By planting tomato and cowpea together, bacterial wilt of tomato plant (P. solanacearum) has been very well managed. Some plants, like sunhemp (*Crotalaria juncea* L.), yellow sweet clover (*Melilotus officinalis* (L.), sorghum, oats, barley cowpea, alfalfa (*Medicago sativa* L.), velvet bean, red clover, and also ryegrass (*Loliwn perenne* L.) [31, 32]. The allelopathic impact of different cropping systems, like cover crops, can break disease cycles and reduce populations of different types of pathogens [20] and plant parasitic nematodes [54,66].

Scientists have found that mustards and other plants in the brasicaceace family can reduce the number of fungal diseases by releasing naturally toxic substances when glucosinolade chemicals in plant cell tissues break down [48]. Crop rotation is important for keeping many economically important crops from getting sick from fungi that spread through the soil. It is planting different crops in a field one after the other over a certain amount of time. In crop rotation, allelopathic crops use allelochemicals released by their roots and other substances released by the decomposition of crop leftovers from the previous crop to stop disease-causing pathogens from spreading. Crop rotation that is done right can improve yield by about 20%. Crop rotation is better than a single crop method in a lot of ways. When making a crop cycle plan, special attention should be paid to how diseases will be handled. Different root systems and plant structures, different sowing and harvesting times, allelopathy, different soil and crop management methods, and different practices like cultural mayhem all play a role be in charge of keeping diseases at bay and giving other benefits in a crop rotation.

- Allelochemicals are released by plants through root exudation and the breakdown of plant litter in cropping systems that use a rotational process. These chemicals stop diseases and plant-parasitic nematodes. Crop rotation is also very important for reducing the toxic effects of Allelochemicals in plant tissue systems [71, 29, 68]. Secondary metabolites or allelochemicals that are water-soluble and found in plant cells are taken out with water and used to keep diseases at bay. Allelochemical action can be shown through water extracts to stop the growth of other microorganisms like fungi, bacteria, and fungi. Several experts have suggested that allelochemicals extracted from water could be used to fight diseases both in the lab and in the field. [31] observed the potential effect of wheat, barley, oat, rye, canola, sweet clover and lentil plant (*Lens culinaris* L.) water extracts (1, 2 or 4% w/v) in suppressing the pathogen of the lesion development of *Sclerotinia sclerotiorum* (Lib .), the germination of different spore like ascospores and the carpogenic germination of sclerotia on detached bean leaves. When compared to water control, applying 1% canola extract, 2% barley, canola, oat, and lentil extracts, and 4% extracts of all seven crops greatly lowered sclerotsia germination. But 1, 2, and 4% extracts of barley and 1 and 4% extracts of oat stopped ascospores from growing, while the same amounts of extracts from plants like sweet clover, wheat, canola, lentils, and rye made ascospores grow. Inoculation of detached bean leaves with ascospores of *S. sclerotiorum* mixed with 4% barley extracts, oat or sweet clover have very effectively lowered the lesion severity of disease index compared to leaves inoculated with water and *S. sclerotiorum*.

The severity disease score went up a lot after being inoculated with 4% wheat extract. It compared the antibacterial, fungicidal, antioxidant, and herbicidal effects of momilactone A and B in a test tube. Momilactone B was more effective at killing fungi, bacteria, and plants than momilactone A, but it was less effective as an antioxidant than momilactone A. Most antifungal allelochemicals, on the other hand, are glycosides, such as cyanogenic and phenolic glycosides, etc. Allelochemicals have been shown to have many different kinds of antifungal activity. Most of the saponins, a few unsaturated lactones, and different types of mustard oils have been recorded. *Pythium ultimum* Trow, is important soil borne disease of sugarbeet (*Beta vulgaris* L.), field pea (*Pisum satiuum* L.), safflower (*Carthamus tinctorius*

L.) and canola (*Brassica napus* L. and *B. rapa* L.) in southern Alberta region [32] whereas *P. ultimum* and *P. irregulare* are the very important species for damping-off of field pea in northern Alberta [33]. [59, 56, 7] say that using allelopathy in different cropping systems may be a good, cheap, and natural way to deal with diseases and pests, and a good alternative to using too much pesticide, herbicide, and fungicide. Allelochemicals work differently than synthetic organic chemicals like fungicides and herbicides because their half-lives are shorter, they have fewer halogen substituents, and they don't have any unnatural ring structures [58, 7, 56, 30].

❖ **Limitation of Using Allelopathic Effects:**

There are some problems with using allelopathic potential as a way to get away of pests and diseases. The different rules are set by the plant itself, how it makes allelochemicals, and its state. Several non-living and living things in the soil affect the amounts of phototoxic alleleochemicals. Many nonliving and living compounds, such as plant age, temperature, light, soil conditions, microflora, nutritional status, and the actions of herbicides, affect the meeting and release of allelochemicals through allelopathy, which is thought to be caused by genes [55]. Allelochemicals in the soil could behave differently depending on the physical, chemical, and physicochemical qualities of the soil and other things in the soil's environment. The allelopathic potential of the rice plant depends on the amount of nutrients that are available to the plant and how well the plant can use those nutrients. According to [74, 41] a lack of nutrients in the soil makes it easier for secondary metabolites to form. [62] say that there should be some color force between cyanogenic chemicals and surroundings.

❖ **Future Thrust:**

Allelopathy in plants has some problems, and some of them can't be fixed. Natural chemicals are limited because they are selective and have very few possible uses. It may also be harmful to the organism it is aimed at. It is said that there aren't many reasons why allelopathy study in the crop field falls short when it comes to natural ways to deal with diseases like bacteria, viruses, fungi, and plant-parasitic nematodes. Different allelochemicals are very important and very expensive to make. Some allelochemicals have very short half-lives, and only a small number are poisonous or cause cancer in mammals, including birds and animals [32, 16]. So, the fact that allelochemicals are important is a very important part of understanding how allelopathy works and how it works. Different parts of allelopathy have already been found, even though a lot of study hasn't been done yet [5, 36, 42]. There is a lot to learn about both the giver plant and the recipient plant. Approaches like phenotypic characters, bioengineering, physiology, and anatomy, among others. Plant source-sink connection, nutrient availability, deficiency, ecology, environmental factors, soil physical and chemical charters, and chemical analysis of the released Allelochemicals can be used to study and describe different chemicals made from natural materials. Many plants and microorganisms, like rice, sunflower, sorghum, wheat, etc., have great allelopathic potential, which can be used to keep diseases under control. So, extra care needs to be taken in this area to keep the allelopathic effect from hurting different types of cropping methods. In this case, earth setting is the most important thing to think about. So, this place needs extra care for allelopathic potentiality to be successful. Weeds can become resistant to pesticides when they are used in large amounts. Also, using the same chemical over and over will change the community of weeds, and the unique properties of allelochemicals are important for using them effectively. A lot of allelochemicals should have something to do with allelopathic processes. So, it's important to find the genes in different plants that code for allelopathy. So, we can say that the qualities of allelochemicals in many plants are a better way to keep diseases under control. It doesn't affect the fertility and productivity of our land, which is good for our sustainable farming.

❖ Summary and Conclusion:

Allelochemicals are very effective as natural pesticides and should solve problems like pest biotypes becoming resistant to pesticides, soil and health problems, and pollution caused by the careless use of artificial agrochemicals like pesticides, herbicides, and fungicides. When used as cover crops, mulch crops, intercrops, or green manures, or when growing in a certain order, allelopathic crops will combine the effects of natural stresses like weed infestation, insect pests, and disease pathogens, or else they will build up nutrients and organic matter in the soil help keep it from washing away and make farm goods better. The effect of allelopathy on some higher plants could also be used to get rid of many plant diseases, mostly caused by fungi, bacteria, and worms. Pathogens and microorganisms can also be reduced in the soil by adding manure made from allelopathic plants. Pesticides made from natural products can be much less dangerous to the environment than pesticides made from agrochemicals. Allelochemicals are also recyclable. They work in different ways, so weeds don't just get used to them and stop responding to them. More and more people are paying attention to the role and possible effects of allelopathy as a way to protect crops from diseases and bugs. By adding allelopathy to natural and organic management practices, the use of different types of agrochemicals could be greatly reduced, which would protect the environment and soil and lower the risk of auto toxicity. There is a high demand for chemicals that are toxic to only certain parts of a plant and can be quickly broken down by either the plant or microorganisms in the soil. Also, all plant species, microorganisms, other soil organisms, and insects will become allelochemicals that offer new ways to keep and improve agricultural production and output in the years to come.

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Table 1. Effect of allelopathic plants and residues on plant pathogens

Allelopathic plants	**Target plant pathogens**	**Response of weeds/pathogens**	**References**
O. sativa	*Fusarium oxysporum*	Inhibition of spores and sporulation	[27]
Azadirachta indica	*Macrophomina phaseolina*	Reduced mycelia growth	[39]
Peanut root exudates	*F. oxysporum* and *Fusarium solani*	Spore germination, mycelia growth, and sporulation suppression	[49]
Watermelon	*F. oxysporum*	Suppression of conidia	[50]
Datura metel	*Trichoderma harzianum* and *Trichoderma viride*	Radial growth inhibition	[61]
Coronopus didymus	*Sclerotium rolfsii*	Antifungal properties	[38]
Azadirachta indica, *Datura alba*, and *Eucalyptus* sp. and *Melia azedarach*	*Alternaria alternata*	Up to 29% fungal suppression	[2]
Syzygium aromaticum, and *Vatica diospyroides*	*Aspergillus flavus*	Reduced conidial germination and disease infection	[9]
15 wild plant species	*F. solani*, *Botrytis cinerea*, *A. alternata*, and *Stemphylium Botryosum*	Suppression of mycelium	[19]
Melilotus indicus, *Melilotus alba*, *Medicago parviflora*, and *Solanum nigrum*	Various soil borne pathogens	Reduced activity of the pathogens	[44]
Cuminum cyminum L., *Mentha longifolia* L., and *Allium sativum*	*Fusarium oxysporum*	Suppressed growth of mycelium	[65]
Lycium spp.	*Verticillium dahliae*, *Sclerotinia sclerotiorum*, and *Harpophora Maydis*	Reduced mycelial growth	[63]
Pheum palmatum	*Pyricularia oryzae*, *Colletotrichum coccodes*, *Rhizoctonia solani*, *Phytophthora capsici*	Growth suppression	[37]
Reynoutria japonica	*Septoria glycines*	Reduced fungal viability	[8]
Artemisia herba, *Pistacia atlantica*, and *Juniperus Phoenicea*	*Erwinia carotovora*	Growth inhibition	[26]
Solanum lycopersicum	*Ralstonia solanacearum*	Inhibition of bacterial activity	[28]
Baccharis glutinosa	*Aspergillus ochraceus* and *Fusarium Moniliforme*	Maximum zone inhibition of fungal colonies	[46]

Table 2: Allelopathic suppression of pathogens, nematodes, and diseases

Allelopathic source	Application mode/rate	Pathogen/disease suppression	Reference
Barley + potato	Grown in rotation	55.1 % reduction in inoculum intensity of *Rhizoctonia solani* (JG Kuhn)	[47]
Turnip + Potato	Grown in rotation	56.2% reduction in inoculum intensity of *Rhizoctonia solani* (JG Kuhn)	[47]
Indian Mustard + Potato	Grown in rotation	45.5% reduction in inoculum intensity of *Rhizoctonia solani* (JG Kuhn)	[47]
Rice	Root exudates (1.5 mL)	37% reduction in germination of *Fusarium oxysporum* f. sp. *Niveum* Spores	[57]
Rice	Root exudates (20 mL)	71.88% reduction in spore reproduction of *Fusarium oxysporum* f. sp. *Niveum* Spores	[57]
Neem	Leaf water extract (20% w/v)	53.22% *Fusarium solani* f. sp. Melongenae	[43]
Eucalyptus	Leaf water extract (20% w/v)	46.76% *Fusarium solani* f. sp. Melongenae	[43]
Neem	cake 3% (w/w)	63.7% in root-knot nematode egg masses per root	[40]