

REVIEW ARTICLE

Allelopathy and its Potential in Pulses

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ABSTRACT

Plant releases many bioactive chemicals from its various parts such as leaves, stem, root and sometimes decomposed body through different mechanism into its surrounding environment. These bioactive chemicals are often termed as allelochemicals because they interact with the surrounding environment. This interaction is either positive or negative. Effects of allelochemicals to the agricultural and biological ecosystem are well documented. In leguminosae family many species are involved in releasing of allelochemicals. Many researchers found that this allelochemicals have both positive and detrimental effects on the successive legume crops. Legume monoculture is common in many parts of the world where they cause a numbers of ecological and economic problems such as decline in crop yield due to soil sickness, regeneration failure and replant problem. These negative effects of allelochemicals open a great concern on allelopathy research. This chapter will give the adverse effects of allelochemicals, their extraction and isolation, mechanism inside the plant body. These all are done to find out the possible selection methods of succeeding crops to avoid the allelopathic effects in the next crop of a monoculture farm field. The main purpose of this article is to highlight the adverse allelopathic effects of legume crops to provide ways for sustainable development in agro-ecosystem.

KEYWORDS:

• Allelopathy • Allelo-Chemicals • Replant Injury • Succeeding Crops

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INTRODUCTION

The Leguminosae family represents the third family of 750-year-old large plants and more than 18,000 species with an unusual flower structure, leafy fruit, and the ability of 88% of the species tested to date to form rhizobia nodules de Faria *et al.*, 1989. In terms of human value, the second largest family after Graminae. Grain and fodder make up 27% of the world's major crop production, with only grain providing 33% of the nitrogen (N) protein requirements for Humans Vance *et al.*, 2000. Legume seeds contain 20-50% protein which creates a growing interest in the use of proteins from different vegetables. Commercial consumption of food is almost limited to protein from soy beans *Glycine max*, while other legume plants are less commonly used. Other large legumes of pea (*Pisum sativum*), broad beans (*Vicia faba*), lentils (*Lens culinaris*), common beans (*Phaseolus vulgaris*), *Lupinus* spp., and chickpea (*Cicer arietinum*) are commonly grown in combination with the seeds to improve crop yields., increase nitrogen utilization efficiency, and reduce weed growth and the emergence of plant diseases Hauggaard-Nielsen *et al.*, 2008.

Allelopathy is a phenomenon that involves direct or indirect effects and beneficial or adverse effects of a plant (including microorganisms) on another plant through the release of chemicals in the environment Bertin *et al.*, 2008. Among the legume plants are cultivated as a monoculture system that significantly reduces crop yields. Legume production decreases in transplant conditions due to autotoxicity, a type of intraspecific allelopathy that occurs when a plant species releases chemical substances that inhibit or slow down the growth and development of the same plant species Singh *et al.*, 1999. The phytochemicals of legume plants are well documented. Plants often produce complex mixtures of secondary metabolites that usually comprise members from different groups, such as polyphenols, terpenoids Wink, 2013. Among the secondary metabolites, some have alelopathic effects on other plants such as *P. sativum* Kato-Noguchi, 2003, velvet beans (*Mucuna pruriens*) Fujii *et al.*, 1991, *G. max* Yan and Yang, 2008, and *C. arietinum* Yasmin *et al.*, 1999. These alelopathic chemicals affect the growth and development of the legume plant and ultimately produce.

Baziramakenga *et al.*, 1994 studied the effects of benzoic acid and trans-cinnamic acid on growth of *G. max* (L.) planted in nutrient solution. Two chemicals alelochemicals reduce root and shoot dry biomass of soybeans. He found that medicinal plants with few side roots tend to grow horizontally compared to untreated plants. The lateral roots were fragile and slightly inflexible. Asao *et al.*, 2007 the sweet pea mentioned (*Lathyrus odoratus* L.) shoots new weight and dry weight significantly reduced by the release of autotoxic malonic acid, benzoic acid p-hydrobenzoic acid and vanillic acid from its roots to the rhizosphere. Assaduzzaman and Asao, 2012 investigated the autotoxicity of *P. sativum*, *P. vulgaris*, and *V. Faba* in hydroponics with or without activated charcoal (AC). Growth and yield of the three beans were significantly reduced when planted in a traditional solution without the addition of AC. In *P. sativum* plants, number of pods, pod fresh mass, number of seeds, and weight of new seeds were reduced when plants were planted in a culture solution that could be renewed without AC. Number of pods plants⁻¹ and new pods weight⁻¹ plant in *P. vulgaris*, and pod number in *V. faba*, significantly decreased to 49%-67% without the addition of AC. Chung and Miller, 1995 found that alfalfa (*Medicago sativa* L.) aqueous extracts inhibit seed germination and plant growth, and that auto-toxicity depends on concentration and due to toxic substances dissolving in water. Batish *et al.*, 2008 investigated that caffeic acid significantly suppresses the growth of mung bean roots (*Phaseolus aureus*). Salama *et al.*, 2014 investigated the inhibitory effects of *M. sativa* L. residues in seed germination, nutrient acquisition and *V. faba* L. growth planted in clay and sandy soils. In that study the release of *M. sativa* severely inhibited the index of seed germination and the length of the plumule and radicle. In field research, fossils and extracts of plants *P. sativum* suppresses growth and number of plant species Akemo *et al.*, 2000.

EXTRACTION AND SEPARATION OF ALLELOCHEMICALS

In order to successfully identify the chemicals in alelochemicals, proper absorption and separation method are essential. During autotoxicity plants release chemicals/ allochemicals into their rhizosphere Singh *et al.*, 1999 through a variety of methods.

These include root removal, plant decay, leakage, maturation of volatilization, and pollination of other plants Cruz-Ortega *et al.*, 1988. Therefore, the release of allelochemicals depends largely on the components of plants that are related to the release of allelochemicals or that contain allelochemicals such as soil or air. Many researchers have identified allelochemicals derived from legume plants using different methods and techniques using different plant components and release sites. Han *et al.*, 2000 identified allelochemicals of *G. max* from rhizosphere soil extracted by gas chromatography-mass spectrometry (GC-MS). Tomita-Yokotani *et al.*, 2003 identified the chemical allelochemicals derived from the variable chemicals of *M. pruriens* L. Chung *et al.*, 2000 detected the chemical composition of allelochemicals in *M. sativa* of its alfalfa leaves. In this study the chemical separation processes involve the release of methanol of new *M. sativa* leaves., activated charcoal treatment, microcrystalline cellulose thin-layer chromatography (MCTLC), and finally separation by column chromatography. The various components were continuously tested with high-performance liquid chromatography (HPLC). The first diagnosis by HPLC was confirmed by GC-MS. It was finally found to be suggested that chlorogenic acid is involved in *M. sativa* autotoxicity. Kato-Noguchi, 2003 identified the allelochemicals of *P. sativum* L. with methanol extracted from its shoots. The chemical composition of this compound is determined by high visibility data for MS, IR and ¹H NMR. Asaduzzaman and Asao (2012) identified the allele chemicals in *P. vulgaris*, and *V. faba* by GC-MS analysis of root exudates with methanol adsorbed with AC form a hydroponic nutrient solution.

ALLELOCHEMICALS

During plant allelopathy it releases chemicals into the environment called allelochemicals. Accumulated allelochemicals create harmful effects on plant growth for the next season.⁷ In the agro ecosystem legume plants emit large amounts of allelochemical chemicals. Assaduzzaman and Asao²⁵ identified benzoic, salicylic, and malonic acids in root extracts of *P. vulgaris* and lactic, benzoic, p-hydroxybenzoic, vanillic, adipic, succinic, malic, glycolic, and p-hydroxyphenylacetic

acids in *V. faba*. In another study, pisatin in the list of *P. sativum* identified by Kato-Noguchi.¹³

Asao *et al.*²⁴ found malonic acid, benzoic acids p-hydrobenzoic acids and vanillic acids in *L. oduratus* roots extracts. Kato-Noguchi, 2003 is a segregated cis, trans-xanthoxin and trans, trans-xanthoxin from the leaves of *Pueraria thunbergiana* through the release of aqueous methanol. Miller, 1983 reported that a variety of toxic compounds that may be involved in toxic behavior were found in the area of seeds, new leaves, stems, crowns, dry grass, old roots, and *M. sativa* soil residues. Abdul-Rahmanandand Habib, 1989 in their study found caffeic, chlorogenic, isochlorogenic, p-coumaric, p-hydroxybenzoic, and ferulic acids in *M. sativa* exudates root and residues. Chung *et al.*, 2000 also isolated and quantified the allelopathic compounds chlorogenic and salicylic acid in *M. sativa* fresh leaves and suggest that chlorogenic acid be involved in alfalfa autotoxicity. Han *et al.*, 2000 extract organic acid, alcohol, acetone, aldehyde, naphthalene phenyl and furan hydrocarbon in *G. max* rhizosphere many of which have been reported as alelochemicals. Fujii, 2003 is a separate amino acid, L-DOPA from hairy vetch (*Vicia villosa*) and cyanamide in *M. pruriens*.

ALLELOCHEMICAL MECHANISM

Often allelochemical plays many roles in the physiology of plant extracts. It can inhibit plant growth, alter mineral absorption, cause constipation and cause water stress, affect respiration, affect photosynthesis and protein synthesis by disrupting hormone balance and altering enzyme activity. Many researchers have developed a pattern of allelochemicals in legume plants Doblinski *et al.*, 2003. Cruz *et al.*, 1998 investigated the chemical effect of allelochemicals on the root of *P. vulgaris* when the nucleus point cells are released together and that cell association was disrupted by small cell division. Batish *et al.*, 2008 reported that the activity of proteases in the hypocotyl cutting of *P. aureus* decreases significantly when caffeic acid is treated as allelochemical. Baziramakenga *et al.*, 1994 studied the effects of benzoic acid and trans-cinnamic acid on growth, mineral composition, and chlorophyll content of soybean beans *G. max* grown in nutrient solution. These allelochemicals have shown adverse effects on *G. max* by altering ion absorption and transport, and reducing

chlorophyll content. In his research, he found that soybean plant reduces P, K, Mg, Mn, the content of shoots and roots. Patterson *et al.*, 1981 reported that caffeic, coumaric, ferulic, cinnamic, and vanillic acid significantly inhibit the growth of soybean *G. max* by reducing photosynthetic products and chlorophyll content. In another study Baziramakenga *et al.*, 1997 studied the allelochemical effect on *G. max* found that soybean growth is affected by the disruption of allelochemicals by nucleic acid and protein metabolism. He also found that phosphorus intake was reduced in *G. max* with benzoic, cinnamic, vanillic and ferulic acid. Mersie and Singh, 1993 also state that the chemical allelochemicals affect photosynthesis and protein synthesis in *M. pruriens*.

OPTIONS FOR SUCCESSFUL PLANTING IN REPLANTED SOIL

Soil diseases and damage to replanting are most common in successive cultures affecting growth and crop yields. Replanting problems in continuous cultivation occur when chemical interference from the previous crop or residues on the same crop or another crop of the next culture. Allelopathic effects from plant residues and root exudates have been widely studied in legume such as alfalfa Chung *et al.*, 2011, beans Asaduzzaman and Asao, 2012. Generally, legumes such as broad beans, garden peas and snap beans are grown extensively in the same farming area without maintaining crop rotation which disrupts bean production due to replanting conditions due to autotoxicity Singh *et al.*, 1999. In such a case the proper crop rotation can be effectively controlled. It can limit soil autotoxicity due to all allelopathy for maximum growth Batish *et al.*, 2001. Assaduzzaman *et al.*, 2013 investigated sixty-seven cultivars of 42 species of vegetable plants from 14 families using a seedling bioassay using transplant seeding soil *V. faba* L., *P. sativum* L. and *P. vulgaris* L. rep growing soil to suggest the possibility of successive plants. He suggested that most of the tested cultivars could be planted after three beans and a few affected. Among the bioassay methods he used a nutrient solution, direct seed sowing and planting seedlings in replanted soil. The bioassay of nutrient solution is more sensitive than replanting soil bioassay. However, in the case of a field the effects of the bioassay of the nutrient solution may not

be reproducible. Therefore, he proposed the method of planting seedlings as a simple and effective way of bioassay to promote effective garden plants with re-planting problems.

SOME SALIENT RESEARCH FINDINGS

The allelochemicals present in pea seed powder added to the soil acts as bioherbicides which suppress the growth of canarygrass associated with wheat plants. Analysis of the allelopathic pea seed powder at the applied rates revealed the presence of phenolic compounds and flavonoids. The mixing of pea seed powder with the soil surface at 80 g/pot 1 week before sowing was the most efficient treatment in controlling weeds and gave the highest wheat yield (Gad El Rokiek *et al.*, 2019. Soni *et al.*, 2017 studied the allelopathic effect of *Tridax procumbens* aqueous extract on the seed germination of three pulses (*Cicer arietinum*, *Cajanus cajan* and *Pisum sativum*). The results shows that if concentration of plant extract increases, the percentage of germination decreases and the maximum germination percentages were found in control followed by 5% to 100% aqueous extract.

Shankar *et al.*⁷ analyzed allelochemicals effect of *Gmelina arborea* on *Vigna mungo* and *Vigna radiata*. The presence of allelopathic compounds such as polyphenols and terpenoids was analysed by TLC and GC-MS. The extract inhibited the proteolytic enzyme important for seed germination. The extract inhibited the germination, seedling growth, and total protein content of both test crops. In another study conducted in pots by Shankar *et al.*, 2014, it was found that allelopathic compounds present in the leaf leachates of *Gmelina arborea* such as phenolics and 4hydroxy-3-benzoic acid inhibited crucial enzymes responsible for seed germination. The study revealed that allelochemicals released from *Gmelina arborea* affected the germination and growth of blackgram, greengram, redgram and chickpea.

Farooq *et al.* (2014) reported that when grown in rotation with tobacco (*Nicotiana tabacum* L.), the stand establishment and growth of maize (*Zea mays* L.) were improved compared to mung bean (*Vigna radiata* L.), whereas mungbean stand establishment and growth were suppressed. Therefore, the allelopathic nature of crops must be considered

in crop rotation, intercropping and stalk mulching (Xuan *et al.*, 2005; Cheng *et al.*, 2011; Cheng and Xu, 2013). Belel *et al.*, 2015 studied allelopathic effect of aqueous concentration of leaf and seed extract of nutgrass (*C. tuberosus*) on germination of cowpea. It was concluded that the leaf extract of *C. tuberosus* has more allelopathy than its seed extract. Bioassays also indicate that the inhibitory effect was proportional to the concentration of the extracts that is higher the concentration the stronger inhibitory effect, whereas the lower the concentration the lower stimulatory effect in some cases.

In another study, the Allelopathic effect of leaf ethanolic extract of *Solanum nigrum* was tested on test crops *Pisum sativum*, *Eleusine coracana* and *Trigonella foenumgraecum* and compared with control. *Pisum sativum* was the most sensitive crop to ethanolic extract of *Solanum nigrum*. Phytotoxic effect and inhibitory influence was observed in *Pisum sativum* followed by *Eleusine coracana*. In *Trigonella foenum graecum*, inhibitory influence was observed only in higher concentrations (80 & 100µg), whereas in lower concentrations no such influence was observed compared with that of control. The plant extract had higher inhibitory influence on the growth of *Pisum sativum* and was comparatively reduced in case of *Eleusine coracana*. Stimulatory influence on seedling growth was observed in lower concentrations (20 µg, 40 µg and 60 µg) with that of control in case of *Trigonella foenumgraecum*. The *Solanum nigrum* leaf extracted showed distinct allelopathic effect. Generally leaves are the most potent source of allelochemicals, however, the toxic metabolites are also distributed in all other plants in various concentration. From the results observed secondary metabolites produced by plants are by-products of primary metabolic process. They have allelopathic effect on the same plant or neighbouring plants. Their effects are selective (Girija and Gowri, 2008).

Ashti *et al.*, 2018 studied the allelopathic effect of two types of chickpea against three weeds of the chickpea crop by using ethanolic extracts. It was found that kabuli seed ethanolic extract showed the maximum degree of seed germination percentage inhibition of all plant species. The extracts acquired from the two types of chickpea caused significant reduction

in radical and shoot length of all plant species. In a study conducted by Lertmongkol, et al., 2011 the allelopathic effects of mungbean on the seed germination and plant growth of subsequent crops were evaluated in laboratory and pot experiments. In the laboratory experiment, the allelochemicals in mungbean inhibited the germination and root length of lettuce, whereas it had no negative effect on *Echinochloa crus-galli* seed germination. The pot experiment revealed that allelochemicals from decomposed mungbean in soil reduced the seed germination and plant height of subsequent crops especially in soybean (*Glycine max*) and lettuce (*Lactuca sativa*).

CONCLUSION

In the field of legume allelopathy extensive research has been done and a large number of allele antibodies against allelopathy have been identified. In order to achieve sustainable crop production in agriculture, the study of allelopathy is very important. Since allelopathy causes significant losses to legume plants in the monoculture system in such a situation, the study of allelopathy is inevitable. For effective research knowledge of allelopathy in plant physiology and ecology is required. This will help you to be able to integrate and release plant chemicals into the environment. Lack of knowledge in the above two aspects of plants, chemical analysis is futile. Nowadays the use of genetic engineering in allelopathy has begun to open up a new era in the re-examination of allelopathy. To understand the allelopathic approach to legume further studies on the production, role, and end of allelopath chemicals in the many legume species with the surrounding ecosystem are needed using all of the mentioned information and techniques. Progress is that this research will help create a crop rotation schedule to ensure sustainable crop growth and yield.

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