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Allelopathy and its role in agriculture

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Abstract
Allelopathy as a tool, can be importantly used to combat the challenges of environmental pollution and herbicide resistance development. This review article provides a recent update regarding the practical application of allelopathy in agricultural systems. Several studies elaborate on the significance of allelopathy for weed management. Rye, sorghum, rice, sunflower, rape seed, and wheat have been documented as important allelopathic crops. These crops express their allelopathic potential by releasing allelochemicals which not only suppress weeds, but also promote underground microbial activities. Further, several types of allelopathic plants can be intercropped with other crops to smother weeds. The use of allelopathic cover crops and mulches can reduce weed pressure in field crops. Rotating a routine crop with an allelopathic crop for one season is another method of allelopathic weed control. Importantly, plant breeding can be explored to improve the allelopathic potential of crop cultivars.
The sustainability of agriculture relies on the development of strategies that lower the need for costly external inputs and minimize detrimental effects on the environment, which often involve either inappropriate or excessive use of agrochemical inputs. One strategy, integrating plant allelopathy into sustainable agriculture, is discussed in this paper. Agriculture integrated with allelopathy could reduce the heavy dependence on synthetic herbicides and other agrochemicals, and therefore ease problems such as environmental contamination, use of unsafe agricultural products and effects on human health.

Keywords: Allelopathy, sustainability, synthetic herbicides

Introduction
The definition of "Allelopathy" accepted by the International Allelopathy Society is 'any process involving secondary metabolites produced by plants, algae, bacteria and fungi that influence the growth and development of agricultural and biological systems.' Allelochemicals are defined as 'bio communicators', suggesting the possibility of active mixtures, because of the increasing number of findings in which single compounds are not active or are not as active as a mixture (Macias, 1998) [13]. Accordingly, he emphasizes that traditional agriculture practices based on ancient knowledge are useful as starting points for new allelopathic studies. The approach is based on the belief that these practices result from the close contact between nature and humans throughout history. Allelopathy will play an important role in future weed control and crop productivity. The allelopathic compounds can be used as natural herbicides and other pesticides; they are less disruptive of the global ecosystem than are synthetic agrochemicals. Many important crops, such as rice, sugarcane and mung beans (Vignaradiata) are affected by their own toxic exudates or by phytotoxins produced when their residues decompose in the soil (Einhellig, 1995) [6]. Eliminating or preventing the formation of the phytotoxins through field treatments can minimize autointoxication. These treatments may be a combination of crop rotation, water draining, water flooding and the polymerization of phytotoxic phenolics into a humic complex.

Integrated pest Management: Contemporary plant production systems rely heavily on inputs of chemicals to provide protection against insects, diseases and weeds. This extensive use of chemicals in plant protection has given rise to concerns about pesticide residues in the environment and to the development of pesticide resistance by many organisms. Alternative approaches to plant protection include the continued use of pesticides as components of integrated pest management programmes and more radical developments, such as enhancing and harnessing the array of defensive chemicals produced naturally by plants. An increasing body of evidence points to their ability to contribute to plant protection (Lovett, 1990) [12]. Allelopathic chemicals have already been used to defend crop plants against insects, nematodes and diseases however parallel approaches in control of weeds may be possible by finding compounds that inhibit seed germination, inhibit plant growth or prevent propagule production. There is a greater emphasis on the control of weeds in sustainable agricultural systems by reduced or non-chemical means that are compatible with reduced tillage and both traditional and recent weed management practices (Regnier and Janke, 1989) [15]. Allelopathic elements are involved in practically every aspects of plant growth; they can act from stimulants to suppressants. The intelligent exploitation of these processes can be a major breakthrough in the agriculture sector. Crop rotation, competitive varieties, allelopathic varieties, cover crops, tillage, relay cropping, dead and living mulches, flame weeding and ridge tillage together with classical biological control agents is being employed. Allelopathic interactions between plants and other organisms may become an alternative to herbicides and insecticides for weed, disease and insect control. The recognition of the role allelopathy may have in producing optimum crop yields is of fundamental importance (Waller, 1989) [20].

Natural phytotoxic compounds: Green plants produce hundreds of thousands of compounds that are not involved in the primary metabolism of the plants (secondary products); the compounds involved in interspecific chemical interactions (allelopathy) with higher plants are often phytotoxic or herbicidal to other species or even to the species producing them (Duke, 1986) [5]. Allelopathy is the direct influence of a chemical released from one living plant on the development and growth of another plant. Secondary compounds in plants may act as attractants or repellants, phagostimulants or antifeedants, nutrients or toxins to phytophagous insects. In initial efforts to develop botanical herbicides from allelochemicals, active principles of allelopathic chemicals have been isolated and identified in Asia and the U.S.A. (Kim, 1992) [10]. Four percent out of 10,000 rice germplasm lines possess various degrees of allelopathic activity against certain rice weeds (Smith, 1992) [17]. These lines differ in origin, grain type, plant height and maturity, which are desirable in developing commercially acceptable cultivars with allelopathic traits (Dilday, 1994). Mattice *et al*. (2000) [14] have developed an assay using the HPLC chromatograms to predict whether an accession of rice will inhibit growth of barnyard grass (Echinochloa crus-galli). These inhibitory rice accessions contain four to six compounds that inhibit the growth of this weed.

Allelochemicals production: To establish the cause and effect relationship of allelopathy one needs to demonstrate the production of allelochemicals (Table 1) by the host plant, their transport from the host plant to the affected plants in the surroundings, and exposure of affected plants to these chemicals in sufficient quantity for a sufficient time to cause the observed allelopathy (Einhellig, 1995) [6]. A key to the deciphering of the mechanisms of allelopathy could be through an understanding of such soil processes as retention and transformation, which affect the fate and transport of allelochemicals.

There are also questions regarding the chemical nature of the phytotoxic compounds, their specific effect on plants in the absence of other causal factors and their overall ecological significance. In research on the accumulation of allelochemicals as influenced by microflora, it was found that in particular zygogenic, macrotrophic bacteria and fungi were responsible for the formation of allelopathic inhibitors of rye and wheat.

Table 1: Allelochemicals produced by plants

Plant	Chemicals	Reference
Datura stramonium L.	Tropane alkaloids Scopolamine, Hyoscyamine	Lovett *et al.* (1981)
Secale cereale L. (Rye)	2,4-dihydroxy-1, 4(2H) benzoxazin-3-one (DIBOA) 2(3H)-benzoxazolinone (BOA)	Barnes & Putnam (1987)
Avena sativa L. *Sorghum bicolor* L. (Sorghum), *Triticum aestivum* L. (wheat)	Ferulic acid P-cumaric acids	Rice (1984)
Triticum aestivum L.	2,4-Dihydroxy-7-methoxy -1,4-benzoxazin-3-one (DIMBOA)	Perez (1990)
Melilotus alba Desr. (Sweet clover)	Coumarin	Winter (1961)
Avena sativa L. (Oats)	Scopoletin	Fay and Duke (1977)
Sorghum halepense L. Pers. (Johnson grass)	Dhurrin (a cyanogenic glycoside) and its epimer taxiphyllin	Rizvi and Rizvi (1992)
Sorghum bicolor	P-benzoquinone dimethoxy-substituted P-benzoquinone 2,6-dimethoxy-P-benzoquinone (most active primary haustorical inducer)	Chang and Lynn (1987) Chang *et al.* (1986)
Sorghum bicolor	Sargoleone	Nimbal *et al.* (1996)
Trianthema portulacastrum L. *(Horse purslane)*	Caffeic, cholorogenic P-hydroxy benzoic, P-coumaric and ferulic acids	Varadi (1987)
Pistia stratiotes L.	Linoleic acid, gamma-linolenic acid, alpha-asarone	Alliota (1991)
Barley	Hordenine	Liu and Lovett (1993)
Wheat	Hydroxamic acid	Corcuera *et al.* (1992)
Mungbean	glucosyl flavonoids (Vitexin and isovitexin)	Tang and Zhang (1986)
Catharanthus rosea L. (periwinkle)	Vinblastine, Vincristine	Vaughan and Vaughan (1988)
Medicago sativa L.	Saponins	Krol *et al.* (1995)
Chenopodium ambrosioides L.	Ascaridole, alpha-terpinene gamma-terpinene, Limonene	Jimenez-Osornio (1996)

Under aerobic conditions these compounds disappear rapidly and an ample supply of decomposable organic matter is available, volatile fatty acids and other organic acids accumulate while synthesis of microbial material is suppressed. Decomposition of the plant residue is important in toxin production.

Table 2: Allelopathic effect of crops on weeds

Crop	Weeds inhibited	Type of inhibition
Barley contains	Stellaria	Germination
the alkaloid	media	
gramine and	*Capsella bursa- pastoris*	Germination
hordenine	*Sinapis alba*	Germination
Sweet potato	*Cyperus*	Root growth
(*Ipomoea batatas*)	*esculentus*	Harrison & Paterson (1991)
Secale cereal	Several weeds	Growth reduction
(Rye)		
(*Triticum aestivum*)		Germination and
Wheat	Several weeds	Growth (Cheema *et al.*,1990)
Sunflower	Carthamus	reduction in seed
		germination
	Oxyacantha Bieb.	(Khalid and Shad ,1987)
	Asphodelus tenuifolius Cav.	
	Phalaris minor Retz.	
	Silybum marianum (L.) Gaertn.	
	Centaurea sp.	
	Achyranthes aspera L.	
Wheat	*Avena fatua*	Seed germination (Perez, 1990)
Sunflower	*Helianthus annuus*	reduction of seed
(*Helianthus annuus*)	*Erigeron canadensis*	germination
	Amaranthus retroflexus	
Wheat	*Convolvulus arvensis*	germination and growth
	Dactyloctenium aegyptium	
Rice (allelopathic	*Echinochloa crus-galli*	Seed bank reduction
Varieties)		(Hassan *et al.*, 1998)

Unless the residue is decomposed no phytotoxins can be produced; but recent evidence has also suggested potential of plants and their essential oils as safe natural herbicides, growth promoters and other agents in agriculture as well as their importance in the natural control of insects (Brud and Gora, 1990) [2].

Plant responses to allelochemicals: Roots become brown, stunted, and void of root hair, the leaf tip becomes yellow, plants stunted; one ppm of para. Hydroxy benzoic acid depressed root of wheat, soya bean, and corn significantly (Guenzi and Mc Calla, 1966) [8]. Some phenolic acids are associated with indoleacetic acid activity in plant respiration. One of the effects noted is a rapid inhibiting effect on respiration of root tips and of seedlings. Another striking feature is the extreme sensitivity of the roots to the phytotoxic extracts; roots appearing more sensitive to allelopathic effects than shoots (Qasem, 1993) [15]. Lawrence *et al*. (1991) [11] working with Ailanthus altissimafound that individuals of neighboring plant species has either incorporated active portions of inhibitory compounds or responded to Ailanthus by producing growth inhibiting substances. The cellular effects of plant-derived compounds are arrested pro-metaphases (Colchicine, dinitroanilines), multipolar divisions (Vinca alkaloids, carbamates) and production of binucleate cells (Caffeine, dichlobenil), (Vaughan and Vaughan, 1988) [20].

Crop rotations: In crop rotations, allelopathins produced by a preceding crop may favor or adversely affect the following crop (Hedge and Miller 1990) [9]. Thus avoiding inhibitory effects or exploiting favorable interactions could improve crop production. In agro forestry, the allelopathic effects of tree species on the crop/fodder plant must be investigated to avoid deleterious effects (Rizvi and Rizvi, 1992) [17].

Natural herbicides: There are several examples of allelochemicals as herbicides, these phytotoxic compounds from plants are used in the production of new herbicides. Phytotoxic compounds from plants and microorganisms represent a wide range of chemistries and mechanisms of action that have potential in the design and development of new herbicides (Anaya-Lang, 1989; Duke and Lydon, 1987) [1, 4]. Photosensitizes (light-activated compounds) are potentially useful in agriculture as herbicides (Towers and Arnason, 1988) [19]. Some of these compounds are naphtho and anthraquinones of fungi and higher plants, polyines of the Astraceae porphyrins, extended quinones and isoquinoline alkaloids. Macias (1995) has concluded that the most potential natural allelochemicals in terms of bioactivity are terpenoids, monoterpenes, sesquiterpenes, sesquiterpene lactones and triterpenes, and fatty acids with activity range of 0.25-10 5 ppb, rather than the traditionally considered phenolics, quinines or alkaloids. Terpenoids and fatty acids will receive a great attention in years to come in development of natural products as herbicides.

References

1. Anaya-Lang N. Role of allelochemcials in the management of natural resources. Boletin Sociedad Botanica Mexico. 1989; 49:85-98.
2. Brud WS, Gora J. Biological activity of essential oils and its possible applications. Proceedings of the 11th International Congress of Essential Oils, Fragrances and Flavours, New Delhi, India. 1989-1990; 2(12-16):13-23.
3. Chang M, Lynn DG. Plant-Plant Recognition Chemistry-Mediating Host Identification in the Scrophulariaceae Root Parasites. In: Allelochemicals Role in Agriculture and Forestry, Waller, G.R. (Ed.). American Chemical Society, Washington, DC., 1987, 551-561.
4. Duke SO, Lydon J. Herbicides from natural compounds. Weed Technol. 1987; 1:122-128.
5. Duke SO. Naturally occurring chemical compounds as herbicides. Rev. Weeds Sci. 1986; 2:15-44.
6. Einhellig FA. Characterization of the Mechanisms of Allelopathy Modeling and Experimental Approaches. In: Allelopathy Organisms, Processes and Applications, Cheng, H.H. and K.M.M. Indergit Dakshini (Eds.). American Chemical Society, Washington, 1995, 132-141.
7. Einhellig FA. Interactions involving allelopathy in

cropping systems. Agron. J. 1996; 88:886-893.
8. Guenzi WD, McCalla TM. Phenolic acids in oats, wheat, sorghum and corn residues and their Phyto toxicity. Agron. J. 1966; 58:303-304.
9. Hedge RS, Miller DA. Allelopathy and auto toxicity in alfalfa: Characterization and effects of preceding crops and residue incorporation. Crop Sci. 1990; 30:1255-1259.
10. Kim KU. Current status of biological control and integrated management of paddy weeds in Korea with emphasis on allelopathy of weeds. Proceedings of the International Symposium on Biological Control and Integrated Management of Paddy and Aquatic Weeds in Asia, (ISBCIMPAA'95), Tsukuba, Japan, 1995, 285-303.
11. Lawrence JG, Colwell A, Sexton OJ. The ecological impact of allelopathy in Ailanthus altissima (Simaroubaceae). Am. J Bot. 1991; 78:948-958.
12. Lovett JV. Chemicals in Plant Protection is there a Natural Alternatives. In: Alternatives to the Chemical Control of Weeds, Bassett, C., L.J. Whitehouse and J.A. Zabkiewicz (Eds.). Forest Research Institute, Rotorua, New Zealand, 1990, 57-67.
13. Macias FA, Oliva RM, Simonet AM, Galindo JCG. What are Allelochemicals. In: Allelopathy in Rice, Olofsdotter, M. (Ed.). IRRI, Philippines, 1998, 69-79.
14. Mattice JD, Skulman BW, Dilday RH, Moldenhauer KAK. Chemical aspects of rice allelopathy for weed control. Res. Ser. Arkansas Agric. Exp. Station. 2000; 476:102-108.
15. Qasem JR. Allelopathic effects of some arable land weeds on wheat. Pak. J Weed Sci. Res. 1993; 5:46-55.
16. Regnier EE, Janke RR. Evolving Strategies for Managing Weeds. In: Sustainable Agricultural Systems, Edwards, C.A., R. Lal, P. Miller, R.H. Miller and G. House (Eds.). Soil and Water Conservation Society, Ankeny, Iowa, USA., 1989, 174-202.
17. Rizvi SJH, Rizvi V. Exploitation of Allelochemicals in Improving Crop Productivity. In: Allelopathy Basic and Applied Aspects, Rizvi, S.J.H. and V. Rizvi (Eds.). Chapman and Hall, London, 1992, 480.
18. Smith Jr. RJ. Biological control as components of integrated weed management for rice in the US. Proceedings of the International Symposium on Biological Control and Integrated Management of Paddy and Aquatic Weeds in Asia, (ISBCIMPAWA'92), Tsukuba, Japan, 1992, 335-351.
19. Towers GHN, Arnason JT. Photodynamic herbicides. Weed Technol. 1988; 2:545-549.
20. Vaughan MA, Vaughn KC. Mitotic disrupter from higher plants and their potential uses as herbicides. Weed Technol. 1988; 2:533-539.
21. Waller GR. Biochemical frontiers of allelopathy. Biol. Plant. 1989; 31:418-447.