Mysore J. Agric. Sci., 56 (3) : 1-15 (2022)

Allelopathy in Weed Management - A Review

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Received : June 2022

Accepted : September 2022

Abstract

Allelopathy is the releasing of allelopathic compounds by one plant species that inhibit the growth and development of neighboring plants of another species. Weed management in crops is challenging. Besides, weeds remove moisture, nutrients and harbor insects and diseases. Adopting manual weed management is in practice, but it is laborious and expensive. Further, availability of labour at crucial time remains unanswerable. Though, herbicides being effective in increasing yield, indiscriminate use of herbicides have resulted in serious ecological implications such as development of herbicide resistant weeds and weed shift. Recently, research attention has been focused to find out alternative strategies for chemical weed control in several crops. Reduction in herbicide use is one of major goals of modern agriculture and there is much emphasis on search for alternative weed management strategies that are cheap, safe and sustainable. Allelopathy is considered as an effective, economical and environment friendly weed management approach. The release of allelochemicals from leaves, flowers, seeds, stems and roots of living and decomposing plant materials can influence weed density and growth. Keeping this in view, the literature on various allelopathy concepts in weed management is reviewed in this paper

Keywords : Allelopathy, Allelochemicals, Weed management, Herbicide

Ever rising human population has made the food security, a challenge for scientists and farming community to achieve targeted food security. Agriculture sector especially crop production is under immense pressure to meet the food demand of the growing population. Weeds, insect-pests, diseases, abiotic stresses and imbalanced crop nutrition are major threats to crop production (Semenov and Halford, 2009 and McDonald *et al.,* 2009).

Among the stress, weed is a menace in all crops as they compete for light, water and nutrients and harbor diseases and insects (Pathipati *et al*., 2011). High volume of herbicides usage induces numerous changes in plant growth *viz.,* inhibition of growth, foliar chlorosis, albinism and necrosis (Subba Rao and Madhulety, 2005), Presently weeds are managed by various conventional and modern approaches. Use of synthetic herbicides is very common due to their prompt response and availability (Santos, 2009 and Jamil, 2009). Use of synthetic herbicides persist in the environment and causes biomagnifications, Concern about the toxicity and development of resistance against synthetic herbicides have demanded looking for alternative weed management approaches, so there is every need to develop herbicides which are ecofriendly. Allelopathy has gained sufficient support and potential for sustainable weed management. Herbicides developed from the plants will be safer and they are biodegradable. In this contest, allelochemicals of plant derivatives are potential for selective biological weed management. The phenomenon of allelopathy refers to chemical interactions between all types of plants. In this process the chemical exudates or leachates released from plant parts *viz.,* leaf, stem, roots of a plant can inhibit the growth of a neighboring one (Scrivanti *et al*., 2011).

The phenomenon of allelopathy may be employed to tackle these problems.

The term allelopathy was coined by plant physiologist Molisch (1937), University of Vienna, Austria. consisting of two Greekwords, allelon meaning 'mutual' and pathos meaning 'to suffer', harmful effects on each other (Rizvi *et al.,* 1992 and Chon & Nelson, 2012) and could therefore be used both positive (Sympathetic) and negative (Pathetic) interactions. The concept of allelopathy received new attention in 1974, after the publication of the first book in English on allelopathy by Elroy L. Rice. He defined allelopathy as the effect(s) of one plant on other plants through the release of chemical compounds in the environment (Rice, 1984). This definition is largely accepted and includes both positive (growth promoting) and negative (growth inhibiting) effects.

Allelopathy is the direct or indirect chemical effect of one plant on the germination, growth or development of neighboring plants (Dhanpal *et al.,* 2019). It is a biological phenomenon by which an organism produces one or more biochemicals that influence the germination, growth, survival and reproduction of other organisms. These biochemicals are known as allelochemicals and can have beneficial (positive allelopathy) or detrimental (negative allelopathy) effects on the target organisms and the community.

Allelopathins (Dorota *et al*., 2013) are products of the secondary metabolism and are non-nutritional primary metabolites (Weir *et al*., 2004 and Iqbal & Fry, 2012).

These compounds belong to numerous chemical groups including: triketones,terpenes, benzoquinones, coumarins, flavonoids, terpenoids, strigolactones, phenolic acids, tannins lignin, fatty acids and nonprotein amino acids. A wide range of these biochemicals are synthesized during the shikimate pathway (Hussain and Reigosa 2011) or in the case of essential oils, from the soprenoid pathway. Allelochemicals can be classified into 10 categories (Li *et al*., 2010) according to their different structures and properties :

1. Water-soluble organic acids, straight-chain alcohols, aliphatic aldehydes and ketones
2. Simple lactones
3. Long-chain fatty acids and polyacetylenes
4. Quinines (benzoquinone, anthraquinone and complex quinines)
5. Phenolics
6. Cinnamic acid and its derivatives
7. Coumarins
8. Flavonoids
9. Tannins
10. Steroids and terpenoids (sesquiterpene lactones, diterpenes and triterpenoids).

Putnam and Duke, 1974, listed classes of allelochemicals namely alkaloids, benzoxazinones, cinnamic acid derivatives, cyanogenic compounds, ethylene and other seed germination stimulants and flavonoids which had been isolated from over 30 families of terrestrial and aquatic plants.

The readily visible effects of allelochemicals on the growth and development of plants includes inhibited or retarded germination rate, seeds darkened and swollen; reduced root or radicle and shoot or coleoptile extension; swelling or necrosis of root tips; curling of the root axis; discoloration, lack of root hairs; increased number of seminal roots; reduced dry weight accumulation and lowered reproductivity capacity in the receiver plants. These gross morphological effects may be secondary manifestations of primary events, caused by a variety of more specific effects acting at the cellular or molecular level in the receiver plants (Rice, 1974).

Allelopathy is often used narrowly to describe chemically-mediated competition between plants however, it is sometimes defined more broadly as chemically-mediated competition between any type of organisms. Allelochemicals are a subset of secondary metabolites (Stamp, 2003) which are not directly required for metabolism (*i.e.,* growth, development and reproduction) of the allelopathic organism. The study of allelopathy increased in the 1970s and has undergone rapid development since the mid-1990s, becoming a popular topic in Botany, Ecology, Agronomy soil science, Horticulture and other areas of inquiry in recent years. The allelopathic interaction can be one of the significant factors contributing to species distribution and abundance within plant communities and can be important in the success of invasive plants (Chou, 1999; Mallik, 2003; Field *et al.*, 2006; Inderjit *et al.*, 2006 and Zheng *et al.*, 2015), such as water hyacinth (*Eichhornia crassipes* Mart. Solms) (Jin *et al.,* 2003; Gao and Li, 2004) spotted knapweed (*Centaurea stoebe* L. sp. *micranthos*) (Broeckling and Vivanco, 2008) and garlic mustard (*Alliaria petiolata* M. Bieb) (Vaughn and Berhow, 1999). It plays a key role in both natural and managed ecosystems. In agroecosystems, several weeds, crops, agroforestry trees and fruit trees have been shown to exert allelopathic influence on the crops, thus, affecting their germination and growth adversely. Some of the agricultural and horticultural crops affect their own seedlings grown in succession.

Allelopathy is also thought to be one of the indirect causes of continuous cropping obstacles in agriculture. As a result of the in-depth study of allelopathy, strategies for the management of agricultural production and ecological restoration involving the application of allelopathy and allelochemicals are improving. One such thrust area is combination of weed, food production and allelopathy.

Yield Loss due to Weeds and Effect on Food Production

Weed causes harm to crops in many ways and this happens due to the unusual adaptation characteristics of the weeds and their regeneration ability. Therefore, weed management is the major and important part of crop production. Furthermore, prevention is the most essential aspect of weed management. Once a harmful weed infestation becomes established, any increase in size and density creates more expensive management efforts. But, despite the development and adoption of various weed management technologies, the problem of weeds is increasing day by day due to the way we manage our crop lands and other non-cropped situations. Further, in India increasing globalization and unchecked import of seed materials and food grains from other countries in the past have led to invasion of alien weeds in the country for instance parthenium weed. In view of this, yield loss caused due to weeds has become the major burning issue for discussion in the present scenario. In general, the yield loss due to weeds is almost caused by a group of different weed species and these species can differ considerably in competitive ability (Weaver and Ivany, 1998). Basically, it is very difficult to estimate the yield loss due to single weed species and therefore, it is estimated as the cumulative loss by all the weeds. It was proved that weeds are economically more important than insects, fungi or other pest organisms (Savary *et al.*, 1998). Globally, weeds caused the highest potential loss (34%), with animal pests and pathogens being less important (losses of 18 and 16%, respectively). It has been estimated that on an average, weeds caused five per cent loss in agricultural production in most developed countries, while loss is ten per cent in developing countries and 25 per cent in least developing countries (Oerke, 2006).

Weeds coincide spatially with crops. They deprive the crop plants from nutrients water and light. Hence the physiological activities and growth of crops are negatively affected in presence of weeds. Weeds can lower crop productivity by 34 per cent. The potential yield reduction by weeds in some important crops are wheat 23 per cent, Soybean 37 per cent, rice 37 per cent, Maize 40 per cent, Cotton 36 per cent and potatoes 30 per cent (Oerke, 2006).

Crop growth and development is affected by allelopathy from certain weeds. These allelochemicals from the allelopathic weeds can disturb the root and shoot growth of emerging crop seedlings, as well as cause several other damages. Studies indicated that allelochemicals excreted from *Chenopodium murale* L., root hairs were responsible for the cell cycle disturbance in wheat. Similarly, allelopathic water extracts from the weed species, including *Malva parviflora* L., C. murale showed inhibition on growth and photosynthetic activity in barley (Al-Johani *et al.,* 2012). The concept of allelopathy from certain weeds, causing damaging to certain crop family can be a breakthrough, if studied on the weed belonging to the same crop family.

Allelopathy and Weed Management

Weeds are the most aggressive crop competitors, producing significant output reductions through sharing light, air, water, nutrients, and space. Allelopathic water extracts have been used to successfully manage other weeds. Studies conducted by Kamala Bai *et al*., 2021, application of *Alternanthera Philoxeroides* leachates or extracts had significant inhibitory effect on the growth and development of water hyacinth.

Allelochemicals are produced by plants as end products, by-products and metabolites liberalized from the plants. These allelochemicals are diverse in nature and structure, thus they do not have the same mode of action.

Application of allelopathic water extracts at high concentrations significantly reduces weed density and biomass in cotton, sunflower and mungbean, weeds have all been successfully controlled using it and also enhanced crop output by 3-59 per cent depending on crop type, frequency of application and time of application. Water extracts have been tried as potential herbicides in terms of reduced dose of chemical herbicides (Cheema *et al.,* 2012). Allelopathy-based organic weed control offers a wide range of applications in the field since many of these methods are incorporated in a systematic manner for effective weed control.

The proportion of a certain practice that should be used to introduce allelopathy must be determined on a site-by-site basis. Crops should be genetically improved and biotechnologically modified to increase their allelopathic capacity. It will aid in the development of their potential and competitiveness (Farooq *et al.,* 2013).

Allelopathic control of certain weeds using botanicals for instance dry dodder powder has been found inhibit the growth of water hyacinth and eventually kill the weed. Likewise, carrot grass powder found to detrimental to other aquatic weeds. The presence of marigold (*Tagetes erecta*) plants exerted adverse allelopathic effect on parthenium spp. growth. The weed coffee sena (*Cassia* sp) show supressive effect on parthenium. The eucalyptus tree leaf leachates have been shown to suppress the growth of nut sedge and bermuda grass.

Potential Allelopathic Crops

Sorghum is important allelopathic crop, the allelopathic activity of the sorghum varies across cultivars, environmental conditions and plant growth stages. The important allelochemicals are hydrophobic p-benzoquinone (sorgoleone), phenolics and cyanogenic glycoside (dhurrin) (Weston *et al.*, 2013). Sorgoleone is the most potent allelochemical of sorghum exuded by its roots. Root hair cells are responsible for the production of sorgoleone in sorghum plants (Weston *et al.,* 2012). The allelopathic activity of sorghum can be manipulated for weed control by planting allelopathic cultivars, applying sorghum residues as mulch, using sorghum as cover crop and intercrop or including sorghum cultivars in a crop rotation.

The Brassicaceae family has a strong allelopathic potential against other crop and weed plants (Haramoto and Gallandt, 2004). Brassicas produce the allelopathic compound glucosinolate throughout their plant parts. However, the concentration of these allelochemicals varies in different parts of the plant. Glucosinolate is released into the environment through either volatilization or decomposition. After the release, glucosinolate is decomposed into several biologically active compounds such as isothiocyanate (Morra and Kierkegaard, 2002). Further, these allelochemicals isothiocyanate suppress the growth and development of plants/weeds which take them up (Petersen *et al.,* 2001). The allelopathic potential of brassica plants can be extracted as cover crops, intercrop of brassica crops with the main crop, or as sequence crop or use of brassica litter as mulch (Norsworthy, 2011).

Sunflower is considered the most important allelopathic crop. Sunflowers can be phytotoxic to the following crop in a cropping rotation. Several weed species have also been reported to be suppressed by sunflower allelopathy. Recently Alsaadawi *et al.*, 2012 evaluated the allelopathic potential in sunflower cultivars. Sunflower was grown along with mixture of weed or applied the residues (600 to 1400g m^{-2}) of sunflower cultivar to the wheat crop and its weeds.

In the study, the allelopathic activity suppressed total weed density (24-75 %) total weed biomass (12-67%) and increased wheat grain yield and yield components over the non-treated control. Further, 16 allelochemicals (phenolic acids) were found across potential of the sunflower varied and suppressed the total wed density (24-75%) and total weed biomass by 34-81% Sunflower residues also expressed through the exudation of a diversity of allelochemicals.

Allelopathy concept to control weeds and various ways for practical implementation of allelopathic weed control are as follows :

Allelopathic Cultivars

The allelopathy potential of crop plants contributes to the weed suppressing ability of cultivars. Table 2. Summarizes important studies narrating the allelopathic crop cultivars and weeds suppressed by them. Preferring weed-suppressive allelopathic cultivars over non-allelopathic cultivars can reduce weed infestation without incurring any extra cost and would help to improve the efficacy of inputs and the method of weed control.

A number of studies clearly elaborate the importance of sowing allopathic cultivars in reducing weed pressure. Mahajan and Chauhan (2013) highlighted the importance of cultivars have Molisch (1937) have allelopathic potential for managing weeds in aerobic rice. The rice cultivars which exhibited higher reductions in growth and germination of weeds were found to possess higher concentrations of allelochemicals including momilactone A and momilactone Sun *et al*. (2012) compared the rice. - *Eichhornia crusgalli* interactions in allelopathic (PI312777) and non-allelopathic (Liaojing-9) rice cultivars. Both types of cultivars reduced the biomass of *E. crusgalli* over the control; however, the reduction in biomass was 33 per cent higher by the allelopathic cultivars. The authors reported that the difference in the weed suppression activity of allelopathic and on-allelopathic cultivars was governed by the release pattern of the growth promoting allelochemicals allantoin. The allelopathic rice cultivars could sense the presence of *E. crusgalli* and hence released allantoin in lower concentration, which led to the poor growth of *E. crusgalli* plants adjacent to allelopathic rice cultivars (Sun *et al.,* 2012). In

TABLE 1

Allelochemicals of some important crops

Crops	Scientific name	Allelochemicals	References
Rice	*Oryza sativa L.*	Phenolic acids	Rimando *et al.,* 2001
Wheat	*Triticum aestivum*	Hydroxamic acids	Niemeyer, 1988
Black Mustard	*Brassica nigra L.*	Allyl isothiocyanate	Weston ,1996
Buck Wheat	*Fagopyrium esculentum L.*	Fatty acids	Weston ,1996
Clovers	*Trifolium*	Bioflavonoids Molisch, H. (1937)	Weston ,1996
Sweet clover	*Melilotus*	Phenolics	Weston ,1996
Oat	*Avena sativa L.*	Phenolic acids and Scopoletin	Weston ,1996
Cereals		Hydroxamic acids	Weston ,1996
Sudan grass		Phenolic acids and Dhurrin	Weston ,1996
Sorghum	Sorghum bicolor L.,	Sorgoleone	Netzley and Butler (1986)

TABLE 2

Allelopathic effects of some important weeds on different terrestrial field crops and weeds

Weed	Donor weed		Recipient crop /weed		Reference
	Weed extract/ weed referenceresidues	Phytotoxin	Crop/weed	Inhibitory effect	
Alternanthera Philoxeroides (Mart.) Griseb.	Water extract	ND	Algal	Algal and cyanobact eria growth inhibition	Zhang *et al.,* 2007 Zuo *et al.,* 2011
(Alligator weed)	Tissue extract	ND	Mustard, rice and ryegrass	Seedling growth inhibition	yang 1992
	Extract and residues of Different plant	ND	Rice	inhibition parts of germination n and seedling growth	Mehmood 2014
	Whole plant extract and residues	4-Hydroxy-3-methoxy benzoic acid, m-Coumaric acid and p-Coumaric acid	Wheat	Germination and seedling growth inhibition	Abbas 2014
	Extract of different plant parts	ND	Lettuce and barnyard grass		Liuqing *et al.,* 2007
Alternanthera sessilis L. (Joy weed)	Extract and residues of different plant parts	Chlorogenic acid, ferulic acid, gallic acid and vanillic acid	Rice	Inhibition of germination and seedling growth	Mehomood, 2014
	Extract of different different plant parts	ND	Lettuce and ferulic acid, gallic barnyard grass		Mehomood, 2014 Liuqing *et al.*
Cyperus rotundus L. (Purple nut sedge)	Water extract of tubers	ND	Bajra, cowpea, sorghum, maize, black gram, rice, sesame, sunnhemp and ground nut.	germination and seedling growth	Singh, 1968
	Plant extract	ND	Corn, rice, tomato, cucumber, sorghum and onion	Seedling growth	Meissner *et al.,* 1980

TABLE 2 (Contd.)

Weed	Donor weed		Recipient crop /weed		Reference
	Weed extract/ weed referenceresidues	Phytotoxin	Crop/weed	Inhibitory effect	
	Aqueous extract	ND	Maize	Inhibited the seed germination and plumule and radical growth	Hamayun *et al.,* 2005
	Aqueous extract	ND	Leachates of leaves and tubers	Rice seedling growth	Quayyum *et al.,* 2000
	Extract	ND	Banana	Growth Inhibition	Singh *et al.,* 2009
	Root exudated	ND	Tomoto and cucumber	Plants reduce root and shoot growth	Alsaadawi and Salih 2009
	Residues incorporated soil	ND	Sorghum, soyabean and cowpea	Inhibit seedling growth	
	Volatile compounds released from its shoot and tubers	ND	Mungbean	Reduce seedling r = growth	
	Extract and residues	Alkaloids, fla-vonoids, tannins, starch, glycosides and furochromones, and many novel sesquiterpenoids	Rice cultivers	Germination and seedling growth	Geethambigai and prabhakaran, 2014

ND = Not detect

contrast, Gealy *et al*. (2013) reported that the allelopathic rice cultivars had higher tillering and developed an extensive and strong root system than the non-allelopathic cultivars. The authors argued that this strong root system helps the allelopathic cultivars to distribute allelochemicals extensively, which ultimately suppressed weed growth. In another study, 73 cultivars of rice from Vietnam were evaluated for their allelopathic activity against *E. crusgalli* (Khanh *et al.*, 2009). Out of the tested cultivars, a few (Khau Van, Y-1 and NhiUu) were effective in suppressing *E. crusgalli* under greenhouse conditions while, the other one (PhucTien) was effective under field conditions.

Wheat is among the most important food crops of the world. Work is in progress to develop new allelopathic wheat cultivars with allelopathic potential from the already existing genepool through classical and modern breeding (Fragasso *et al.,* 2013). For example, Mahmood *et al.* (2013) investigated the allelopathic activity of 35 Pakistani wheat cultivars against *Avena fatua* L. The tested cultivars expressed a variable allelopathic activity against *A. fatua*. Out of these 35 cultivars 11 showed a high allelopathic activity, that is 42-83 per cent. Although allelopathy cultivars significantly influenced by environmental factors, the allelopathic potential of crop cultivars is a genetically controlled process. The allelopathic potential of crop cultivars against weeds can be increased through the breeding process. As a first step, the crop germplasm can be screened for its allelopathic potential, however a weed suppressive allelopathic cultivar should also be high yielding. After selecting cultivars with desired traits, the genomic approaches can be applied for characterizing the relevant genes. Various scientist around the world have conducted bioassays to find crop cultivars with allelopathic potential. For example, Pheng *et al.* (2009) conducted a bioassay, in which they about 395 rice lines tested found to suppress the weed in the bioassay. Hence, studies suggest that crop cultivars possessing allelopathic potential can be grown for controlling weed at inexpensive cost and found to be ecofriendly and safe.

Allelopathy Intercrop: Intercropping with Cultivars Possessing Allelopathic Potential

Makoi and Ndakidemi, 2012 reported that growing crops in mixtures not only improves natural resources efficiency, in addition it can be used to suppress weeds under ecofriendly and economic way.

Intercropping of two allelopathic crops (sorghum and sunflower) for weed management in cotton was studied by Kandhro *et al. (*2014). They evaluated that both intercrops suppressed weeds in cotton by 60 to 62 percent, which resulted in a 17 to 22 per cent increase in seed cotton yield. Sorghum and sunflower grains were also harvested, leading to increased crop yields, land productivity and economic benefits. Crops having allelopathic potential helps to lower weed intensity and thereby increase agricultural output when intercropped with other crop plants. As an example, maize intercropped with cowpea on alternate ridges helped to reduce weed *Echinochloa colona* (L.) Link., *Portulaca oleracea* L., *Chorchorus olitorius* L. and *Dactyloctenium aegyptium* (L.) Willd. intensity by ~50 per cent and also improved land use efficiency (Saudy, 2015).

Allelopathic Cover Crops

Cover crops are produced with the goal of ensuring a different agricultural ecosystem's viability. Cover crops are grown for a variety of reasons, including enhancing soil fertility and quality, as well as reducing weeds and plant diseases. Weeds can be suppressed by cover crops having allelopathic potential. Canola, rape seed, cereal rye, crimson clover, wheat, red clover, brown mustard, oats, cowpea, fodder radish, annual ryegrass, mustards, buckwheat, hairy vetch and black mustard are some of the most significant cover crops. For weed control, some cropping methods (*e.g.,* organic cropping) extensively on cover crops. (Mirsky *et al.,* 2013).

Cover crops can also be used to effectively reduce weeds in conservation tillage systems. Researchers have examined the performance of a rye cover crop to suppress weeds for planting soybean in a no-till system and found that soybean could be successfully grown in a no-till soil with a standing rye cover crop. The cover crops reduced the biomass of weeds such as *Eleusine indica* (L.) *Gaertn.*, *Amaranthus palmeri S. Wats* and *Ipomoea lacunose* L., allowing for season-long weed management. In conservation till systems, cover crops can also help to minimize the weed seed bank. Some cover crops like Hairy vetch and oat effectively reduced seed banks (30-70 per cent) of weeds in the upper soil layer, such as *Datura stramonium* L., *Digitaria sanguinalis* (L.) *Scop.*, *Amaranthus retroflexus* L. and *E. indica* (Dube *et al.,* 2012). Ultimately, a diversity of allelopathic cover crops can contribute in the reduction of weed infestation in field crops.

Allelopathic Plant Residues

Allelopathic plant residues that have been left in the field accidently or deliberately express their weed-suppressing function. Similarly, maize residues were found to lower weed biomass in the next crop (broccoli) by 22-47 per cent in an organically farmed maize-broccoli rotation (Bajgai *et al.,* 2013). In terms of density and biomass, the mulches were more successful than the control treatment in suppressing weeds (35-80 per cent), with oat being one of the most efficient of the mulches in suppressing weeds. Oat, on the other hand, had a detrimental impact on tomato yield.

Hairy vetch, on the other hand, produced significant increase in yield over the control. In a comparable study, oat and hairy vetch residue mulch effectively reduced weed density in black pepper (*A. retroflexus*, *Polygonum aviculare* L., *Polygonum oleracea* and *C. album*) (Campiglia *et al.,* 2012).

Potentials for Development of Allelopathic Cultivars for Weed Management

Biological screening of allelopathic crop cultivars for weed suppression : The identification of cultivars with strong allelopathic activity and the transfer of this trait into modern cultivars may be able to recover a property that has been lost inadvertently during the breeding process for increased growth rate and yield. There are significant differences in allelopathic activity across accessions of cucumber, rice, and wheat, according to research, and some accessions strongly impede the growth of particular weed species.

In the fields at the International Rice Research Institute, Olofsdotter and Navarez (1996) examined 111 rice cultivars for allelopathic activity against *Echinochloa crus-galli* (L.) *Beauv*. The results showed that 11 cultivars inhibited weed growth (dry matter) by more than 50 per cent in a dry season while 21 cultivars decreased weed growth (dry matter) by more than 50 per cent in a wet season. The results of the field screening were confirmed in laboratory testing. An extract bioassay was used to test 38 wheat cultivars (*T. aestivum*) and one durum wheat (*T. durum Desf.*) for their differential allelopathic capability against *Lolium rigidum* Gaud (Wu *et al.,* 1998).

Chemical screening of genotypes with high allelochemical contents : The inherent driver of the allelopathic impact is the plant's production of allelochemicals. Crop accessions with higher levels of allelochemicals are more likely to be allelopathically effective. Direct allelochemical screening among accessions will aid in explaining biological screening results and will reveal the likely genetic regulation of differential allelochemical output amongst crop cultivars. Nicol *et al.* (1992) enlarged the screening to a global collection of 47 *Triticum* cultivars (mostly *T. aestivum*) and discovered that DIMBOA levels ranged from 0.99 to 8.07 mmol kg^1 fresh weight. The differential generation of allelochemicals (cyclic hydroxamic acids) in *Triticum* spp. has also been the focus of many studies. 2,4-dihydroxy-7-methoxy-1,4-benzoxazin-3-one is the most prevalent of these acids in wheat (*T. aestivum*) (DIMBOA)Copaja *et al.* (1991) found that cultivars differed in the generation of DIMBOA, ranging from 1.4 to 10.9 mmol kg^1 fresh weight, in a screening of 52 Chilean *T. aestivum* and *T. durum* cultivars.

Allelopathic effects of weeds on crop plants : In Korea, water extracts of shoot and root of *Cirsium arvense* significantly inhibited the germination, germination rate, vigour, seedling length and weight in lucerne. The shoot extracts exhibited greater allelopathic effects than root. (Chung and Miller, 1995). The allelopathic effect of *Parthenium* sp. On the germination and shoot growth of maize and barely found that the root concentrations of *parthenium* sp. increased so the germination shoot length, and root length decreased. (Haroon *et al.,* 2008) Parthenium dry biomass incorporate in the soil significantly reduced the seedling growth and germination of maize seed and population density also effect on dry biomass production and plant height. Khan *et al*. (2011) reported significant reductions in germinations and seedling growths of soybean, mung bean and maize by aqueous leaf extracts of parthenium with 25 g L^{-1} and 50 g L^{-1} concentrations. Biswas *et al*. (2010) conducted an experiment to determine the effect of parthenium debris in the soil and found that, allelochemicals release from parthenium had inhibitory effect on rice.

Allelopathic effect of weed on another weed : Tripathi *et al,* 1981 reported that *Eupatorium adenophorum Spren* which is a common rudcral weed of Meghalaya is highly allelopathic to such herbs as *Trifolium repens* Linn., *Ruinexnepalensis Meism*., *E. riparlum Kegels* and *Paspalum dilatum Poir*. The inhibitory effect was co-related with the cone of the extract. The aqueous extract also caused a significant reduction in leaf number and dry matter production of *T. repens*. Datta and Chakrabarti (1982) studied the allelopathic potential of *Clerodendrum viscosum Vent*, in relation to germination and seedling growth of weeds. The activity of decaying plant parts of viscosum Vent and field soils collected beneath *Clerodendrum* plants were studied on the seed germination and root and hypocotyl growth of 5 types of weed seeds, *i.e., Abutilon indicum sweet*, *Amaranthus spinosa* L., *Cassia sophera* L., *C. tora* L. and *Tephrosia hamiltonii. Drumm*., Germination was strongly inhibited in *A. spinosus*, *Abutilon indicum Sweet* and *T. hamiltonii* by the underground soil. Decaying roots are most inhibitory.

Allelopathy effect of crop on weed : Neustruyeva and Dobretsova (1972) reported that wheat, oats and peas and buck-wheat suppressed growth, accumulation of above-ground bio-mass and leaf surface of *Chenopodium album* Linn. Markova (1972) found that oats suppressed the growth of *Erysinum cheiranthoides* L. owing at least in part to an allelopathic mechanism. *Prutenskaya* (1974) reported that wheat (*Triticum durum des* f.), rye and barley strongly inhibited the weedy *Sinapis arvensis* L. whereas, *Panicum milliaceum blanco* stimulates *S.arvensis*.

Stimulatory effect : Zwanenburg and co-workers worked on the development of synthetic germination stimulants to induce suicidal germination under field conditions (Wigchert and Zwanenburg, 1999). Ejeta and co-workers selected sorghum lines with reduced induction of germination (Mohamed *et al*., 2001). Also, the wide use of trap crops, used in monoculture or in intercropping, and catch crops is a control measure partly based on the (suicidal) induction of germination (Chittapur *et al.,* 2001).

Limitation of Using Allelopathy Effect

There are many limitations in using allelopathy potentiality as a weed management tool. The limitations are both because of plant itself producing allelochemicals and the environmental conditions. Many abiotic and biotic soil factors have influence on phytotoxic levels of allelochemicals, such as plant age, temperature, light and soil conditions, microflora, nutritional status and herbicide treatments influence the production and release of allelochemicals, although allelopathy is considered as a genetically influenced factor. While moving in the soil, allelochemicals may undergo transformation due to various factors regarding soil environment (Physical, chemical and biological) after the entry into soil, allelochemicals may be toxified or detoxified by microbes.

Many allelochemicals are very expensive to synthesize inspite of having excellent herbicidal properties as for example tentoxin (Duke *et al*., 2000). Some allelochemicals are toxic to humans' beings and are carcinogenic. Sorgoleone, for example is reported to cause dermatitis. Some allelopathic agents are active under hot and dry climates they work in vapour phase such as monoterpenes.

The amount of nutrient availability to the plant and the efficiency of the plant to utilize the nutrient strongly influences the allelopathic potentiality. Some allelochemicals affect the growth of the plant itself *i.e.,* autotoxic effect for example derivatives of benzoic and cinnamic acids from the root exudates of cucumber. Therefore, while studying the role of allelopathy in controlling weeds the autotoxicity of plants should not be ignored.

Future Line of Work

Identification of allelochemicals and its movement in the soil, transportation, absorption, mode of action, its interaction with other chemicals, half lives in soil, biodegradability etc., should be taken under consideration. The identification of allelochemicals activities have been isolated that numerous allelochemicals are undiscovered. The identification of allelochemicals is of prime importance for the development of bioactive pesticides. Despite the fact, the direct use of allelochemicals as natural pesticides/ herbicides is difficult in the field because of their easy degradation in nature and high cost of delivery, the synthesis of compounds derived from various allelochemicals may help resolve these problems.

Allelopathy has been known and used in agriculture since ancient times; however, its recognition and use in modern agriculture are very limited. Allelopathy plays an important role in investigations of appropriate farming systems as well as in the control of weeds, diseases and insects, alleviation of continuous cropping obstacles, and allelopathic cultivar breeding. Furthermore, allelochemicals can act as environmentally friendly herbicides, fungicides, insecticides and plant growth regulators and can have great value in sustainable agriculture. Although allelochemicals used as environmentally friendly herbicides for decades, there are very few natural herbicides in the market that are derived from an allelochemical. However, there are a few research investigations testing natural-product herbicides. With increasing emphasis on organic agriculture and environmental protection, increasing attention has been paid to allelopathy research, and the physiological and ecological mechanisms of allelopathy are gradually being elucidated. It is obvious that allelopathy requires further research for widespread application in agricultural production worldwide.

So, it is clear from the above discussion, that there is immense prospect of allelopathic mechanism as a weed management tool. Allelochemical from several plants have been identified and their activities have also been established. Inspite of that at some points need to be considered before implications of allele chemicals as natural herbicide. Firstly, along with laboratory experiments, field experiments are exclusively needed to study its interaction with soil properties. Secondly, the movement of allele chemicals, mode of action, selectivity etc., should be broadly studied. Finally, the impact of use of allele chemicals from agronomic and environmental point of view needs special attention. The dose, frequency and method of application determine the extent of toxicity of a chemical.

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