

Conventional and Unconventional Research on Allelopathy in Australia (1988~1993)

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호주 알레로파시 연구의 두 방향(1988~1993)

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ABSTRACT

Although the number of active workers in Australia is small the range of species associated with allelopathic activity is at least as large as that reported elsewhere in the world.

In this paper, work on native and introduced plants is discussed under the general heading of "conventional allelopathy", that is, interactions between plants which are chemically mediated. Work in which compounds associated with allelopathy, in the conventional sense, are biologically active in different contexts is included under "unconventional allelopathy". Examples which involve microorganisms, corals and other marine species, and mammals are discussed.

Key words: Conventional allelopathy, Unconventional allelopathy, *Eucalyptus*, Allelochemicals, Allelopathy Research in Australia.

INTRODUCTION

Australia in the 1990s has been described in the media as a "megabiodiverse" continent. Certainly, in terms of its flora, Australia enjoys not only a rich array of native plants but also the crop, pasture and weed species familiar throughout the Westernised World.

While Australia's native forests continue to provide the basis of a sometimes controversial industry, the remainder of the native flora has been under-exploited. Given the unique and highly variable cli-

mate and ancient, impoverished soils of Australia, this is a matter of regret to many plant scientists. Adaptation to these difficult conditions by the native flora, it is argued, should afford advantages which may outweigh the apparent superiority of introduced species of crop and pasture plants in terms of yield potential.

What is beyond dispute is that the Australian flora is rich in secondary metabolites. Some, like the oils of *Eucalyptus* spp. or the alkaloids of *Duboisia* form the basis of small industries. The oil of the tea tree, *Melaleuca* spp. has pharmaceutical properties which have only recently been thoroughly explored. Since

the compounds found in these species belong to families which have long been associated with allelopathy it is understandable that Australian native plants have attracted the attention of scientists interested in this discipline. Introduced plants, especially weeds but also some crops, notably, barley (*Hordeum sativum*), have also received attention, as have their residues as sources of phytotoxins. Aquatic environments, too, have provided examples of allelopathy in recent times.

This paper provides an up-date to studies of allelopathy in Australia during the period 1988~1993 with some reference made to earlier work where this is necessary in providing a context.

CONVENTIONAL ALLELOPATHY

Eucalyptus

Several researchers such as Igboanugo(1986, 1987), Vicherkova and Polova(1986), Bowman and Kirkpatrick(1986a, b, c), Andrew(1986) and Lovett(1989) have contributed to studies of allelopathy in *Eucalyptus* species.

An Australian researcher, May(1989), pointed out that various *Eucalyptus* species can yield allelopathic chemicals which may be effective in suppressing understory vegetation. Furthermore, May and Ash (1990) employed techniques for resembling more natural ecological processes, i.e, extraction mimicked natural rainfall rates, root leachates, stemflow, soil leachates and volatiles from leaves. The results of these experiments demonstrated that fresh intact leaves caused little growth suppression, in contrast to coarsely chopped leaves and extracted leaf essential oils, which were both highly suppressive. Whole leaf litter, shed bark and, especially, stemflow yielded suppressive leachates. Evaporative concentration of leachates in soil showed an increase in their inhibitory effect. Decay was shown to reduce the allelopathic effects of leaf and bark litter leaches but some inhibitory chemicals remained after 5 months. Therefore, allelopathy must be considered in relation

to rainfall and the soil water balance and is likely to be a cause of understorey suppression by *Eucalyptus* species, especially in drier climates. Essential oils from *Eucalyptus globulus* and *E. citriodora* were extracted by stem distillation and the rich components, cineole and limonene were fractionated. Two experiments were carried out : (1) effect of eucalypt oil vapours and their pure components absorbed on the soil alone or in combination with a vapour column on germination behaviour of *Phaseolus aurens*, (2) effect of eucalypt oil vapours on growth of young *P. aurens* plants. Both experiments showed lower germination percentage compared with the controls.

According to Lisanewok and Michelsen(1993), aqueous leaf extracts of *Eucalyptus globulus*, *E. camaldulensis* and *E. saligna* significantly reduced both germination and radicle growth of tested crops such as chickpea, maize, pea and teff (*Eragrostis tef*) mostly starting from a concentration of 1 or 2.5%.

Weeds

Some 30,000 species have been classified as weeds world wide (Chalndler 1985). The Australian weed flora includes many species introduced from foreign countries. For grasses, alone, more than 250 members of the Poaceae are regarded as weeds in standard Australian weed texts and lists (Wilding *et al.* 1986, Auld and Medd 1987). Of these, 170 species, including most of the important weeds, are of exotic origin. Combella(1987) has estimated the total cost of all weeds to Australia as between \$2.50 and \$2.75 billion per annum, that is, about the gross value of the Australian wheat crop in recent years (Australian Bureau of Statistics 1987).

Allelopathy has been documented in both exotic and indigenous Australian weed (Lovett 1986, 1989).

Work undertaken by Purvis and Jessop(1985) and Purvis(1990) with *Avena sterilis* ssp. *ludoviciana* (Durieu) Nyman has shown that wild oat germination and growth are regulated by the biochemical characteristics of soil cropped to wheat, rendering the weed a 'specialist' in this crop. Experimental evidence

indicated that the presence of germinating wheat seeds can stimulate wild oats to emerge at the same time as the crop, whereas emergence into an already established crop is somewhat inhibited.

The majority of pasture in south eastern Australia contains either subterranean clover (*Trifolium subterraneum*) or white clover (*Trifolium repens*) and the most commonly sown grass is perennial ryegrass (*Lolium perenne*). Radicle elongation in *Trifolium* species was significantly reduced when grown in the presence of senescent, endophyte colonised, ryegrass vegetation, relative to endophyte-essential vegetation. And phytotoxicity of the vegetation remained despite weathering of the vegetation in the field for several months (McFarlane *et al.* 1992).

New research focusing on the use of allelopathic plants and their allelochemicals as natural herbicides for the biological control of leafy spurge (*Euphorbia esula*) has been progressed. The challenge was to target the perennating organs of leafy spurge as the site of action for phytotoxic compounds (Leather and Lovett 1992).

Residues

Phytotoxic substances from plant residues are leached out by rainfall or irrigation, or may be released into the rhizosphere. Phytotoxins contribute to the complex interactions between residues, the environment and microorganisms. Allelopathy sometimes results and is one of many stress factors which operate in the crop environment. At times, allelopathy may be dominant, or minor significance (Lovett and Hurney 1992).

In previous reviews (Lovett 1986, 1989), allelopathy has been associated with the residues of a diverse range of Australian crop species.

Purvis and Jones (1990) from results of glasshouse experiments showed that wheat seedlings emerging in sunflower stubble treatments exhibited a threefold increase in stubble quantity, from 0.5 to 1.5% w/w soil.

Allelochemicals

There are many thousands of secondary metabolites, but only a limited number of them have been identified as being involved in allelopathy (Rice, 1984). Whittaker and Feeny (1971) stated that, with few exceptions, the secondary compounds could be classified into five major categories: phenylpropanes, acetogenins, terpenoids, steroids and alkaloids. However, it is described, in this paper, several compounds mainly studied by Australian researchers or closely related paper with them.

1. Phenolic compounds

Phenolic compounds have been identified as allelopathic agents more commonly than any other substances (Stowe and Kil 1983). In Australia they have been identified as allelochemicals in both native and introduced plants.

Thus in central New South Wales, Australia, phenolic content among evergreen canopy trees was investigated. Polyphenols increased as leaves aged and corresponding insect grazing decreased (Lowman and Box 1983). Phenolic compounds secreted from the roots of white clover plants either had stimulatory or inhibitory effect upon the induction of the *nod* gene expression in *Rhizobium trifolii* (Djordjevic *et al.* 1987). Vanillin and isovanillin were identified from extracts of wheat seedlings and shown to have interactions with the nodulation (*nod*) gene *nodD1* from *Rhizobium* strain to induce the expression of other genes (Le Strange *et al.* 1990.)

Lovelock *et al.* (1992) investigated phenolic compounds in mangroves. Phenolic compounds were present as a band in the epidermal layers of the upper surface of the sun leaf. Sun leaves had greater contents of phenolic compounds than shade leaves. Over all tested species and sites, it was found that soluble phenolics were accumulated as a constant proportion of dry weight per leaf area.

Phenolic compounds seem to have several different functions in plants, in addition to their possible

Table 1. Effects of p-hydroxybenzoic acid(HBA) and pH adjustment on coleoptile and radicle elongation (mm) of barley seeds

Treatment	Concentration(mM)			
	Control	1.81	3.62	7.24
Coleoptile				
HBA(pH adj. to 5.5)	33.7 ^a	33.6 ^a	30.9 ^{abc}	29.0 ^{bc}
HBA(pH according to HBA concentration)	32.3 ^a	31.3 ^{ab}	28.0 ^{bc}	14.8 ^d
Radicle				
HBA(pH adj. to 5.5)	57.3 ^a	46.0 ^b	39.0 ^c	32.9 ^d
HBA(pH according to HBA concentration)	57.9 ^a	48.6 ^b	30.9 ^d	8.5 ^c

Values followed by the same letter within the same feature are not significantly different at $p < 0.05$ level.

allelopathic activity. Christen and Lovett(1993) found that 1.81 mM p-hydroxybenzoic acid significantly reduced the radicle length of barley, whereas coleoptile elongation was less sensitive(Table 1). The higher tiller categories in general showed a greater sensitivity towards an application of p-hydroxybenzoic acid and, therefore, could not compensate for the yield decrease in the main tiller.

2. Terpenoids

Terpenes and their relatives are not as widespread in the plant kingdom as phenolic compounds but they have a high potential as allelopathic agents because they volatilize readily from intact leaves and they can be phytotoxic at concentrations as low as $1 \sim 3 \times 10^{-6}$ M(Asplund 1968). The basic types of terpenoids are the monoterpenoids(C_{10}), sesquiterpenoids(C_{15}), diterpenoids(C_{20}), triterpenoids(C_{30}), and tetraterpenoids(C_{40})(Rice 1984).

Terpene(syn. terpenoids, isoprenoids) are hydrocarbons derived from isoprene via the mevalonic acid pathway. About 46 volatile terpenes have been identified in grape(Hardie and O'Brien 1988). These compounds are characteristic of *Eucalyptus* spp. (Wang and Fujimoto 1993) but occur also in other Australian plants. For example, a significant weed, *Prostanthera rotundifolia*, in northwestern New South Wales and southeastern Queensland, bears trichomes

on its leaves from which terpenoid chemicals are liberated. These chemicals can toxify seedlings of crop plants(Lovett 1985).

3. Flavonoids

There is a huge variety of flavonoids and they are very widespread in seed plants(Harborne and Simmonds 1964). In spite of the large number and wide distribution, only a few have been implicated in allelopathy. This may be due, in part, to the difficulties involved in identifying many of the flavonoids and their numerous glycosides(Rice 1984).

Allelochemicals may influence gene expression(see 1. phenolic compounds). In Australian work, Redmond *et al.*(1986) reported that flavones such as authentic 7,4-dihydroxyflavone found in washings of undamaged clover roots induced *nod* gene expression. Rolfe (1988) reviewed flavones and isoflavones as inducing substances of legume nodulation. In interactions between plants and bacteria, rhizobia have adapted to the use flavonoid compounds, released by the plant root, as part of a regulatory system to initiate the transcription of their infection(nodulation, *nod*) genes. Stimulatory compounds have been isolated from clovers, 7,4-dihydroxyflavone; from alfalfa, luteolin; from peas, apigenin; and soybeans, the isoflavones daidzein and genistein. These plant-derived compounds are responsible for the activation of the *nod* genes. These hydroxylated flavonoid compounds are derived from the phenylpropanoid biosynthetic pathways.

Curir *et al.*(1990) found that flavonoid(identified as quercetin glycosides) accumulation is correlated with adventitious roots forming in *Eucalyptus gunnii* Hook micropropagated through axillary bud stimulation.

4. Tannins

There are few reports of the involvement of condensed tannins in allelopathy in Australia. Duarsa *et al.*(1993) investigated soil moisture and temperature effects on condensed tannin concentration in *Lotus*

corniculatus and *L. pedunculatus*. The potential for elevated condensed tannin levels in *L. pedunculatus* appeared to be enhanced when growth rates were reduced by moisture stress and temperatures were high. Condensed tannin concentrations were elevated, primarily, in proportion to the size of the reduction in growth rate.

In terms of the distribution and content of tannins in *Lotus* from two experiments, it can be concluded that young plant parts as well as young plants contained higher tannins than old ones, and that leaves accumulated higher tannins than stems (Duarsa *et al.* 1992).

5. Alkaloids

The alkaloids are a structurally diverse group of secondary chemical compounds which are widely distributed in plants.

Alkaloids are distinguished generally from most other plant components by being basic. They usually occur in plants as the salts of various organic acids (Robinson 1983).

Alkaloids of barley (*Hordeum sativum*), gramine and hordenine, affect radicle elongation of test species in the typical fashion of biologically active compounds (Liu and Lovett 1987). Effects on white mustard by gramine and hordenine included reduction of radicle length and an apparent reduction in health and vigour of radicle tips (Liu and Lovett 1990). The ability to produce one of the barley metabolites, gramine, may be a heritable characteristics (Lovett and Hoult 1992). Hordenine was released from the roots of barley in a hydroponic system for up to 60 days. The amount reached a maximum, 2 $\mu\text{g}/\text{plant}/\text{day}$, at 36 days, then declined. Transmission electron microscopic examination of white mustard radicle tips exposed to hordenine and gramine showed damage to cell walls, increase in both size and number of vacuole, autophagy, and disorganization of organelles. These biologically active secondary metabolites of barley may play a significant role in self-defence by the crop (Liu and Lovett 1993). Hoult and Lovett (1993)

reported on the isolation and quantification of gramine and hordenine from barley material using Sep-Pak C₁₈ cartridges to prepare the samples, followed by reversed-phase liquid chromatography. The method was faster and easier to use than methods hitherto reported.

Pyrrrolizidine alkaloids were analysed from a weed, *Heliotropium europaeum*. The alkaloids varied significantly between sites and sampling dates but no marked seasonal trend was detected. These were three major pyrrrolizidine alkaloids: europine, lasiocarpine and heliotrine (O'Dowd and Edgar 1989).

Duboisia species, Australian native plants, have long been harvested for their alkaloid content. Gritsanapan and Griffin (1992) detected alkaloids from a *Duboisia* hybrid, that is, scopolamine, 6-hydroxy-hyoscyamine and hyoscyamine as major alkaloids, and butropine, valtropine, norvalerodine, valeroidine, tropine, acetyltropine, norscopolamine, hygrine, nor-nicotine, tetramethylputrescine, anabasine and aposcopolamine as minor alkaloids. In addition, protoanemonin has been isolated from the Australian 'Headache Vine' *Clematis glycinoides* by Southwell and Tucker (1993).

The tropane alkaloids, scopolamine and hyoscyamine, are also liberated from seeds of thornapple (*Datura stramonium* L.), an important weed, and interfere with the growth of seedling roots of some crop plants, including sunflower. TEM of damaged sunflower root tip cells exposed to thornapple allelochemicals at 0.5 and 0.05% concentrations showed cell division apparently disrupted at metaphase and anaphase. There was evidence also of damage to mitochondria, increasing with concentration of allelochemicals (Lovett and Ryuntyu 1988).

UNCONVENTIONAL ALLELOPATHY

Microorganisms

Interrelationships between allelopathy and microorganisms in Australia have been reported by several researchers (Lovett 1987, Djordjevic *et al.* 1987, Ga-

briel *et al.* 1988).

Bacteria play an important but often ill-defined role as ameliorants in allelopathy. The genera so far identified are frequently cosmopolitan and capable of activity in both the phyllosphere and rhizosphere. It seems likely that allelopathy occurs when environmental conditions retard the sequence of breakdown and permit accumulation of concentrations of phytotoxic compounds to occur (Lovett 1987).

In the clover-*Rhizobia* symbiosis, a distinct cocktail of phenolic compounds (flavonoids) has been recognised. Flavonoids of the correct structure induce the expression of several bacterial nodulation (*nod*) and other genes required for plant infection. Flavonoids of the incorrect, but related, structure can antagonise *nod* gene induction (Djordjevic and Weinman 1991).

McGee *et al.* (1991) showed that two isolates of *Acremonium strictum* significantly inhibited, *in vitro*, the rate of growth of five fungi commonly associated with grasses. Extracts from cultures of the isolates also inhibited the rate of hyphal elongation.

Coral and other marine species

Conventionally, studies of allelopathy have focussed on terrestrial environments. However, there is a sig-

nificant Australian literature on marine coral algae. Earlier work is reviewed in Lovett (1989).

Coll and Sammarco (1988) have pointed out that the chemistry of soft corals reveals the presence of a variety of terpenoid metabolites, often in unexpectedly high quantities. These rich terpenes in soft corals relate to roles in their defence, for example, concerning toxicity, feeding deterrence, physical defence and allelopathic interactions between soft corals and hard corals.

The specialized predator *Chaetodon melannotus*, which feeds on highly toxic and sometimes allelopathic octocorals, initially locates its prey using visual rather than chemical cues (Alino *et al.* 1992).

Extraction of the soft coral, *Sinularia flexibilis* (Coelenterata, Octocorallia) and quantitative chemical analysis for the three major diterpene components, flexibilide, dihydroflexibilide and sinulariolide, afforded average ratios of 4:3:1, respectively. Possible biosynthetic pathways were presented (Maida *et al.* 1993).

Shallow and deep marine sponges were classified into 6 toxicity groups, falling into 3 broad categories: 100% lethal to a test fish, *Gambusia affinis*. Over 73% of the sponges were at least harmful to toxic, deep sponges being generally more lethal (La Barre *et*

Table 2. Inhibition of bacterial growth by extracts from four bryozoans

	2A	2B	4A	6A	6B	8A	8B	10A	10B
Am DCM	++	++	++	++	-	++	++	++	++
Am MeOH	+++	-	+	+	-	+	+	++	-
Ortho DCM	+++	++++	+	++++	+++	++++	++++	++++	-
Ortho MeOH	++++	+	++++	+++	++++	+	+	++++	-
Cel DCM	-	-	-	-	-	+	-	+	-
Cel MeOH	-	-	-	-	-	-	-	-	-
Bug DCM	+	+	-	+	-	-	-	+	-
Bug MeOH	-	-	-	-	-	-	-	-	-
Gram stain	-	+	-	-	-	-	-	+	-
Morphology	rod	rod	curved rod	rod	rod	curved rod	rod	rod	rod
Size	var	var	var	var	small	var	var	small	v small
Motility nm	m	m	nm	m	m	m	m	nm	nm

Size of inhibition zone : + 0~2mm; ++ 2~4mm; +++ 4~6mm; ++++ 6~8mm.

Am=*A. wilsoni*; Ortho=*O. ventricosa*; Cel=*C. pilosa*; Bug=*B. dissimilis*; DCM=dichloromethane; MeOH=methanol.

2A~10B indicates plates incubated in seawater 2 and 10 days.

A and B indicates two different bacterial strains tested at each interval (at the 4 day interval strain B failed to grow).

Var=variable size; small=5~10 μ m; v small=less than 5 μ m; m= motile; nm=non-motile.

al. 1988).

Secondary compounds, particularly terpenes, in alcyonacean soft corals (Coelenterata, Octocorallia) may play a role in predator defense, competitor defense, anti-fouling/anti-biosis (Sammarco 1988).

Whilst two bis-prenylated phenols have been isolated from brown alga, *Encyothalia cliftonii*. The major metabolite, 2,4-bis(3-methylbut-2-enyl) phenol showed significant feeding deterrence toward the herbivorous sea urchin (Roussis *et al.* 1993).

Extracts from four species of bryozoans, found in Tasmanian coastal waters, have been demonstrated to exhibit selective antibacterial activity (Walls *et al.* 1993) (Table 2).

Mammals

The presence of at least 125 ng ml⁻¹ of corynetoxin inhibits the growth of *Corynebacterium rathayi*. Corynetoxins are responsible for the primarily neurological disease known as "annual ryegrass toxicity" which has caused high mortalities of grazing livestock in South Australian and Western Australia (Stynes and Vogel 1983). The production of corynetoxin appears to be related to physiological aging of the plant (Stynes and Bird 1983).

Corynetoxin complex is the family of tunicamycin-like antibiotics isolated from annual ryegrass (*Lolium rigidum*) seedheads infected with a plant pathogenic *Corynebacterium* and identified as the causative toxins for annual ryegrass toxicity in Australia (Payne and Cockrum 1988).

Most stock losses caused by annual ryegrass toxicity occur because stockowners unknowingly allow their stock to graze annual ryegrass (*Lolium rigidum*) infected with the bacterium *Clavibacter toxicus* (Mckay and Riley 1993).

A report describes poisoning in cattle after they are discarded seeds of choumoellier (*Brassica oleracea* convar. *acephala*) that were 10 years old. Within 24 h 2 cows were dead and one was acutely ill (Mason and Lucas 1983).

Reichmann *et al.* (1987) reported that both the seeds and leaf of *Castanospermum australe* tree contain a potent inhibitor of bovine α -glucosidase assayed *in vitro*. That this inhibition is also expressed *in vivo* was confirmed by feeding cattle.

According to Reichmann *et al.* (1987) *C. australe* seeds contained the indolizidine alkaloid, castanospermine, and this chemical caused reduction in the activity of alpha-glucosidase. Reichmann *et al.* (1989) demonstrated that Pompe's disease is characterised by

Table 3. Tissue levels of alpha-glucosidase and glycogen in 2 animals at necropsy after daily doses of *Castanospermum australe* seeds for 13 months

Component	Animal	Skeletal muscle	Cardiac muscle	Liver	Kidney	Brain
Alpha-glucosidase ([IU/g protein] × 100)	4A*	3.1	3.6	9.3	4.1	3.6
	4B*	3.6	4.2	9.8	3.7	4.1
	Controls ⁺	23.3	37.2	116.6	84.5	48.2
		(18.0~31.2)	(33.7~41.1)	(100.4~135.1)	(79.5~88.2)	(39.2~54.9)
Affected ⁺⁺		2.4	1.9	3.1	1.5	1.0
		(2.0~3.0)	(1.8~2.7)	(2.2~4.2)	(1.3~1.8)	(0.8~1.3)
Glycogen (% wet weight)	4A	1.47	0.56	2.60	0.03	0.04
	4B	1.65	0.69	1.89	0.02	0.02
	Controls	1.81	0.63	1.90	0.02	0.04
		(1.11~2.18)	(0.55~0.69)	(0.40~3.40)	(0.01~0.05)	(0.01~0.05)
Affected		3.89	4.33	5.60	0.92	1.05
		(2.55~5.32)	(3.28~5.35)	(2.61~7.09)	(0.08~1.02)	(0.78~1.20)

* Animals dosed with 1.2 g/kg body weight of *C. australe* seeds daily.

⁺ Mean(range) of 3 control animals.

⁺⁺ Mean(range) of Pompe's disease-affected animals.

an absence of lysosomal alpha-glucosidase. This enzyme is also inhibited by *Castanospermum australe* seeds (Table 3).

Cowling *et al.* (1988) tested mature, dry stems of *Lupinus angustifolius* to determine if resistance to phomopsis stem blight reduced the lupinosis toxicity of stems in sheep.

About 500~600 plants in Queensland are either known or suspected to be poisonous to livestock under appropriate conditions. Only a limited number of these are significant risks to livestock production, consistently causing death or disease (McKenzie 1991). Bourke and Carrigan (1992) found phalaris "sudden death" syndrome could have as many as 4 different underlying mechanisms and that these might reflect the presence in the plant of a cardio-respiratory toxin, a thiaminase and amine co-substrate, cyanogenic compounds, and nitrate compounds.

It was proposed that harmane and norharmane, alkaloids identified from *Tribulus terrestris*, accumulate in tryptamine-associated neurones of the central nervous system in sheep, during months of tribulus ingestion, and gradually interact irreversibly with a specific neuronal gene DNA sequence (Bourke *et al.* 1992).

Pyrrolizidine alkaloids become toxic to yaks when, after absorption from the alimentary tract, they are converted to pyrroles by microsomal oxidative metabolism in the liver cells (Winter *et al.* 1993). *Echium plantagineum* is an annual weed which forms dense stands over large regions of Southern Australia. *Echium* feeding induced a high rate of destruction of pyrrolizidine alkaloids in the sheep rumen (Culvenor *et al.* 1984). But lupin seed with levels of *Phomopsis leptostromiformis*-infection of up 10% could be safely fed to sheep and pigs under commercial conditions (Allen *et al.* 1984). Food pellets containing *Echium plantagineum* were provided, young rats fed on 40% level of *Echium* for only the first 14 days, and having consumed no more than 0.7 g total alkaloid per kg liveweight, developed extensive chronic liver damage, leading to death from the 35th day after the start of feeding (Peterson and Jago 1984). There is a

report described an outbreak of pyrrolizidine alkaloid poisoning in calves associated with the eating of straw bedding containing *Heliotropium europeum* (Harper *et al.* 1985). Harper *et al.* (1993) studied vetch toxicosis in cattle grazing *Vicia villosa* ssp. *dasycarpa* and *V. benghalensis*.

Break crops

According to Kirkegaard *et al.* (1993), alternative crops to wheat such as winter oilseeds and grain legumes are being increasingly grown in the cropping phase of farms in the traditional wheat/sheep zone of south-eastern Australia (Mead 1992). This trend reflects the need for producers to diversity in the face of uncertain commodity prices, and the growing awareness of the benefits to wheat yield arising from sound crop rotations. These break crops can increase the yield of subsequent wheat crops by depriving soil borne wheat pathogens of a host and reducing infection of the subsequent crop (Kollmorgen *et al.* 1983).

Kirkegaard *et al.* (1993) demonstrated the effect of the *Brassica* crops, canola and Indian mustard, on the growth and yield of subsequent wheat crops at four sites in southern New South Wales. The effect of break crops on grain yield was influenced by water availability after anthesis. At one site, where significant rainfall occurred after anthesis, the early improvements in growth persisted to maturity and yield was significantly improved following the break crops. At the other three sites, dry conditions occurred after anthesis and the greater biomass of wheat following break crops resulted in more rapid depletion of soil water.

CONCLUSION

Mukerji and Garg (1988) stated that "Almost any process, occurring naturally or done artificially, which affects the relationship between organisms in such a way that the natural biological balance is restored, can be regarded as biocontrol". Allelopathy is encompassed by this definition and deployment of all-

elopathy in agriculture, aquaculture, horticulture or silviculture may best be regarded in this context.

Studies of allelopathy in Australia include all of these milieux. However, reports of allelopathic potential in Australia outnumber instances of the application of allelopathy and allelochemicals as components of management systems for weeds or other pest organisms. In this respect the Australian experience mirrors that elsewhere in the World.

Direct use of allelopathy, on a field scale, by plant to plant activity has been documented -in India- by Joshi and Mahadevappa(1986). These workers found that the leguminous plant, *Cassia sericea*, could exert effective control of *Parthenium hysterophorus* in the field through allelopathic activity.

Parthenium weed is becoming widespread in Australia, where others species of *Cassia* occur, suggesting a potential to emulate the Indian work. But the significance of the work of Johi and Mahadevappa(1986) lies not only in the application of allelopathy to solving a weed problem but also in the fact that Joshi(1990) attempted a benefit: cost analysis in respect of his findings.

At the beginning of the 1990s decade, Australia's Commonwealth Scientific and Industrial Research Organisation(CSIRO) compared an investment of \$2,330,000 in biocontrol programs with estimated benefits of \$261,200,000, an average return of \$112 per \$1 invested(Lovett et al. 1990). Returns of such magnitude to allelopathy programs would finally confirm the place of the discipline as a positive contributor to food and fibre production systems.

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적 요

호주에서 여러 학자들이 알레로파시 연구에 활용한

식물은 비록 적은 수이지만, 실은 전 세계 도처에서 알려진 범위 만큼이나 된다.

이 논문에서는 호주내 자생식물과 외부로부터 도입된 식물을 총망라하여 이들 식물-식물 상호작용에서 화학물질이 관계하는 이른 바 "전통적 의미로 본 알레로파시" 연구를 모아서 논의하였다. 또한 이것과는 달리 "비전통적인 알레로파시"라는 논제하에 생물학적 활성 문제를 논했다. 예컨대, 미생물, 산호, 기타 해산생물과 포유류의 화학물질에 의한 연구결과 등을 모두 포함시켰다.

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