Geraniol, an allelochemical of possible use in integrated pest management

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Summary

Various allelochemicals were screened for their weed- and fungi-controlling properties in the hope of identifying a multipurpose pesticide for use in integrated pest management. *Amaranthus spinosus* and *Alterneria solani* were the test weed and fungus respectively. Among the allelochemicals tested, geraniol proved to be the most potent against both test organisms. It completely blocked seed germination in *A. spinosus* at a concentration of 3 mM and mycelial growth of *A. solani* at 2.8 mM. Probit analysis revealed a LD_{90} of 1.65 and 2.23 mM for *A. solani* and *A. spinosus* respectively. Since the utility of geraniol would depend upon how it affects the crop plant, its effect on germination and early seedling growth was studied in tomato, in which both the test organisms present problems. Geraniol exerted no adverse effect on any of the parameters considered. The possibility of using geraniol in integrated pest management is discussed and its structure–activity relationship described.

Introduction

An integrated pest management system (IPMS) depends upon integrating various approaches to pest control in such a way that the benefits of the different possible combinations are maximized while the disadvantages are minimized. Despite many attempts to develop IPMS, control by synthetic chemicals is still the dominant technique. Increasing global concern about the indiscriminate use, over-dependence and hazards of synthetic pesticides has prompted exploration of natural plant products since these could be expected to be comparatively safe (Fawcett and Spencer 1970; Mathur *et al.* 1982; Rizvi and Rizvi 1987; Rizvi *et al.* 1987). However, any IPMS requires simultaneous use of different chemicals. Moreover, there are indications that though some of the synthetic pesticides may be harmless when used singly, may become poisonous after interacting with other pesticides (Samersov and Prishchepa 1978; Ramakrishna and Ramachandran 1978; Verma *et al.* 1984). The cost of applying many pesticides in any IPMS is also of concern to plant protectionists. Accordingly, we propose that the number of chemicals used in any IPMS should be reduced to minimize the chances of synergistic toxicity as well as to cut costs. Surprisingly, while much emphasis has been given to the integration of various strategies of pest control, little effort appears to have been made to develop multipurpose pesticides capable of controlling more than one agricultural pest.

The fact that plants can affect the vegetation and microflora of their habitat by producing allelochemicals (Rice 1984), prompted us to explore the possibility of using allelochemicals as multipurpose pesticides. This paper reports that geraniol can suppress more than one pest and its possible use in integrated pest management is discussed along with that of allochemicals in general.

Materials and methods

Various allelochemicals were tested for their herbicidal and fungicidal activities in terms of the inhibition of germination and growth of the test weed (*Amaranthus spinosus*) and inhibition of mycelial growth of the test fungus (*Alternaria solani*) respectively. The non-target toxicity of the selected allelochemicals was established on the basis of its effect on tomato plants. (Both the weed and the fungus are common pests of tomato.)

Preparation of test solutions

Owing to their water-insoluble nature, the allelochemicals used in the study were first dissolved in 2.0 ml acetone and then the desired concentrations were prepared by adding the required quantities of Teepol (BDH) at 5.0 ppm in distilled water. A solution of same strength of acetone in 5.0 ppm Teepol was used for the control sets.

Test of herbicidal activity

This study was done as described by Rizvi *et al.* (1981) using seed germination bioassay. In this procedure the seeds of the test weed were germinated on two layers of Whatman filter paper No.1 in Petri dishes (80 mm) in 4-ml test solutions. The treated and the control sets were allowed to germinate in an incubator maintained at 30 ± 1°C and the percentage germination was recorded over a period of 120 h when the control set showed maximum germination. Radicle and plumule lengths were also recorded for each set. A similar procedure was used to test for any possible toxicity with respect to the test crop.

Test of fungicidal activity

Fungitoxicity was determined by the poison food technique as described by Rizvi *et al.* (1980). The test fungus was grown in Petri dishes on Czapeck's agar medium with the following constituents: $NaNO_3$ (3.0 g), K_2HPO_4 (1.0 g), $MgSO_4$ $7H_2O$ (0.50 g), KCl (0.50 g), $FeSO_4$ (0.01 g), sucrose (30.0 g), agar (15.0 g) and distilled water (1000 ml). The medium was sterilized at 20 lbs pressure per square inch for 30 min. The solutions of allelochemicals were prepared in acetone and then concentrations of 1.6, 2.0, 2.4, 2.8 and 3.2 mM were maintained in the medium. Five millilitres of the medium containing the allelochemical was poured into pre-sterilized Petri dishes (50 mm diam.) and incubated for 24 h. For the control, the medium without allelochemical was poured. A mycelial disc (5 mm diam.) cut from the periphery of a 7-day-old culture of the test fungus, was placed asceptically upside down in the centre of each assay plate in the treated and control sets. The plates were incubated at 28°C for 6 days and observations were recorded on day 7. The diameter of the colony of the test organism in the treated and control sets was measured in perpendicular directions and percentage mycelial inhibition was calculated as follows:

$$\% \text{ Mycelial inhibition} = (DC - DT)/(DC) \times 100$$

where DC is the diameter of the control colony and DT that of the treated colony. LD_{90} was calculated for both the test weed and fungus by means of probit analysis.

All the experiments were performed in triplicate and repeated thrice. The results were statistically analyzed and the standard deviations calculated.

Results

Among the allelochemicals tested, citral, citronellol and geraniol showed considerable herbicidal activity. However, geraniol was the most effective. It completely inhib-

Table 1 Inhibition (%) of seed germination by allelochemicals in *A. spinosus*

Allelo-chemical	Concentration (mM)			
	1.0	2.0	3.0	4.0
Citral	4.51 ± 1.52	28.68 ± 2.0	43.44 ± 2.64	85.24 ± 2.0
Citronellol	19.26 ± 2.78	38.11 ± 3.25	65.16 ± 3.04	83.20 ± 2.21
Geraniol	2.86 ± 0.64	75.40 ± 2.1	100.0 ± 1.03	100.00 ± 0.12

Table 2 Effect of allelochemicals on seedling growth in *A. spinosus*

Allelo-chemical	Concentration (mM) 1.0	2.0	3.0	4.0	1.0	2.0	3.0	4.0
	Plumule length (cm)				Radicle length (cm)			
Citral	3.52±0.35	2.72±0.50	2.42±0.22	1.52±0.31	2.48±0.34	1.60±0.30	1.50±0.14	1.46±0.11
Citronellol	2.54±0.40	1.70±0.10	1.62±0.20	1.42±0.12	1.10±0.30	0.24±0.05	0.13±0.02	0.12±0.04
Geraniol	2.80±0.32	0.84±0.50	0.0	0.0	4.36±0.23	0.0	0.0	0.0

Table 3 Inhibition (%) of mycelial growth by allelochemicals in *A. solani*

Allelo-chemical	Concentration (mM) 1.6	2.0	2.4	2.8	4.2
Citral	46.6±1.23	68.1±1.68	80.3±2.01	92.0±1.89	100±0.12
Citronellol	47.3±2.02	56.4±1.98	75.4±2.09	90.2±1.80	100±1.01
Geraniol	83.5±1.80	92.8±2.10	98.4±1.68	100.0±1.11	100±0.03

Table 4 LD_{90} of allelochemicals for *A. spinosus* and *A. solani*

Allelo-chemical	LD_{90} (mM) *A. spinosus*	*A. solani*
Citral	5.01±0.12	2.34±0.00
Citronellol	5.01±0.16	2.63±0.08
Geraniol	2.23±0.08	1.65±0.09

ited germination, radicle and plumule growth of *Amaranthus spinosus* at a concentration of 3 mM (Tables 1 and 2).

At 2.8 mM (Table 3) it also completely inhibited mycelium growth in *A. solani.*

The probit analysis revealed a LD_{90} of 1.65 and 2.23 mM for *A. solani* and *A. spinosus* respectively (Table 4). Thus geraniol proved to be the most potent of the allelochemicals tested.

The possible utility of geraniol in plant protection, however, depends on how it affects the host crop. Hence, its effects on seed germination and growth of tomato were studied. None of the parameters considered were adversely influenced; hence geraniol has the necessary selectivity (Table 5).

Discussion

The terpenes are well known for their allelopathic properties (Muller and del Moral 1966). However, little or no attempt has been made to exploit their allelopathic potential in plant protection. Total inhibition of seed germination of *A. spinosus* and that of mycelial growth of *A. solani* by geraniol at very low concentration, together with its non-toxicity for the crop plant is very promising. The non-toxicity of geraniol for the crop plant in this instance concurs with earlier reports on plant products that have been stated to be safer owing to their readily biodegradable nature (Beye 1978). By contrast, synthetic pesticides have been found to be harmful for crops, their consumers and the environment because of their persistence (Beniwal and Chaubey 1976), phytotoxic (Raza and Bano 1980), teratogenic (Paul and Vadlamudi 1976; Javorska 1978), carcinogenic (Epstein *et al.* 1967), pollutive (Matsunaka and Kwatsuka 1975), mutagenic (Wild 1975) and residual effects (Smith and Stratton 1986). The selective toxicity of geraniol between a crop weed and a fungus may be of great value in reducing the number of chemicals in integrated pest management systems and hence the chance of synergistic toxicity. From an economic viewpoint, the cost of producing allelochemical-based pesticides would be less than that of specific action pesticides.

Citral, citronellol and geraniol are structurally very closely related. However, they significantly differ in their pest-controlling properties. A comparison of the molecular structures revealed that geraniol differs from citral only in having an alcoholic group instead of an aldehyde and from citronellol in possessing an extra double bond at the second carbon position. This leads to the conclusion that the strong pesticidal activity of geraniol may be attributed to both the presence of an alcoholic group and an extra double bond at the second carbon position.

Table 5 Effect of geraniol on seed germination, seedling growth and total biomass production of *Lycopersicon esculentus*

Treatment (mM)	Germination (%)	Radicle length (cm)	Plumule length (cm)	Biomass production (mg)
0.0	73.66±2.65	3.08±0.83	2.93±0.03	9.2±0.012
2.5	74.33±1.98	3.05±0.53	3.08±0.18	10.2±1.110

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