Herbicidal Potential of Catechol as an Allelochemical

Süleyman Topal[a,*], Ismail Kocaçalışkan[a], and Orhan Arslan[b]

[a] Section of Botany, Department of Biology, Faculty of Arts and Sciences, Dumlupinar University, Kütahya, Turkey. Fax: (+90)2742652056. E-mail: topal_tr@yahoo.com

[b] Department of Biology, Faculty of Education, Gazi University, Ankara, Turkey

* Author for correspondence and reprint requests

Z. Naturforsch. **61c**, 69–73 (2006); received June 8/July 21, 2005

Catechol is an allelochemical which belongs to phenolic compounds synthesized in plants. Its herbicidal effects on weed species; field poppy (*Papaver rhoeas*), creeping thistle (*Cirsium arvense*), henbit (*Lamium amplexicaule*) and wild mustard (*Sinapis arvensis*) were investigated using wheat (*Triticum vulgare*) and barley (*Hordeum vulgare*) species as control plants. In comparison to 2,4-D (a common synthetic herbicide), 13.64 mM of catechol have been found to have a strong herbicidal effect, as effective as 2,4-D on field poppy weed by killing it, and a suppressive herbicidal effect on the other weeds by inhibiting their growth significantly. Concerning all the weeds, in general, elongation of the shoot was affected more negatively than that of the root. Fresh weights of the weeds were decreased by catechol significantly only in field poppy but not in other weeds. The study reveals that catechol is a potent inhibitor of growth of the weeds and therefore it can be evaluated as a herbicide for future weed management strategies.

Key words: Allelochemical, Catechol, Herbicidal Effect

Introduction

Weed control research has been focused almost on synthetic herbicides so far. But researches on herbicidal activity of natural plant compounds especially allelochemicals have been emphasized recently, because wide spread use of synthetic herbicides has resulted in herbicide-resistant weeds, disturb the ecological balance of natural environment and is bad for human health (Hall *et al.*, 2000; Vyvyan, 2002). 2,4-Dichlorophenoxyacetic acid (2,4-D) which is a synthetic auxin and also a common synthetic herbicide has been found to show a genotoxic effect by mutagenic activity on cultivated plants, *Allium cepa* and *Oryza sativa* (Kumari and Vaidyanath, 1989). Many natural products are phytotoxic and some of these are allelochemicals. There are several reasons why there is interest in natural compounds as herbicides: Natural compounds have a short half-life since they are biodegradable, and therefore are considered environmentally and toxicologically more safe than synthetic compounds (Putnam and Duke, 1974; Duke and Lydon, 1987; Duke *et al.*, 2000, 2002; Vyvyan, 2002; Bhowmik and Inderjit, 2003).

Allelochemicals which have a special emphasis as natural herbicides are major agents of allelopathy in nature. The chemical interactions that occur among living organisms including plants, insects and microorganisms are called allelopathy, and the organic compounds involved in allelopathy are called allelochemicals. Sometimes an allelochemical produced by one organism is harmful to another and beneficial to a third organism; but they are, generally, toxic and cause stress and even death (Whittaker and Feeny, 1971; Rice, 1979; Hale and Orcutt, 1987; Rizvi and Rizvi, 1992; Inderjit and Keating, 1999).

Phenolic allelochemicals are believed to function as defensive agents against invading microbes and as signal molecules in plant interactions with pathogens and parasitic angiosperms (Inderjit *et al.*, 1999). For example, the allelochemical catechol belongs to phenolic compounds synthesized by the shikimate pathway via chlorogenic acid in plants. Catechol was shown to have antifungal effects on *Colletotrichum circinans* fungus (Farkas and Kiraly, 1962). Further, catechol has been found to have a significant antimicrobial effect on three bacteria (*Pseudomonas putida*, *Pseudomonas pyocyanea*, *Corynebacterium xerosis*) and two fungus species (*Fusarium oxysporum*, *Penicillium italicum*) which are pathogenic soil microbes (Kocaçalişkan and Talan, 1999). On the other hand, catechol has been isolated from leaf and needle litter of several deciduous (*e.g.*, beech, birch, oak, hazelnut, maple, willow, poplar) and coniferous

0939–5075/2006/0100–0069 $ 06.00

trees (*e.g.*, spruce-fir, Douglas-fir, larch). Catechol has been reported to form many naturally occuring aromatic substances during degradation (Snook and Fortson, 1979; Kuiters and Sarnik, 1986) and it has also been indicated to be synthesized abundantly in onion and released by its outer layer cells (Farkas and Kiraly, 1962).

Several allelochemicals have been studied for their herbicidal effects. For example, parthenin has been found to has an inhibitory effect on two weed species, *Avena fatua* and *Bidens pilosa* (Batish *et al.*, 2002). Cineoles also have been found to be toxic and injurious on bill goat weed (Singh *et al.*, 2002), and on *Echinochloa crusgalli* and *Cassia obtusifolia* (Romagni *et al.*, 2000). However, we have not encountered any information about the herbicidal effect of catechol on weeds. Therefore the objective of this work was to establish the herbicidal potential of catechol by comparing it to 2,4-D as a known common synthetic herbicide.

Materials and Methods

Seeds of wheat (*Triticum vulgare* cv. Gerek 79) and barley (*Hordeum vulgare* cv. Kışlık) were obtained from the Office of Agriculture in Kütahya. These seeds were sown in plastic pots filled with sterilized torf. Wheat and barley were used to compare the effect of catechol on weeds and to determine catechol doses that are not harmful to these cultural plants.

Four weed species, field poppy (*Papaver rhoeas*), creeping thistle (*Cirsium arvense*), henbit (*Lamium amplexicaule*), wild mustard (*Sinapis arvensis*), the most common in wheat and barley fields of Kütahya region, were found and used as test plants to observe the herbicidal effect of catechol. These weed species are also common in most countries of the world (Holm *et al.*, 1997). The seedlings of the weeds which have two or three leaves were taken from the field in May and brought to laboratory; then their roots were washed, and root and shoot lengths of the seedlings were measured by a ruler and fresh weights of the seedlings were taken. These values were recorded as initial growth values. The seedlings were planted into plastic pots filled with sterilized peat. All the plants were maintained in the laboratory on benches. The temperature and relative humidity were about 20 °C and 45%, respectively. In these conditions, all of the seedlings were left to grow for 10 d. Then the herbicides were applied on the leaves of the plants by spraying in the concentrations of 1 mM, 2 mM and 4 mM of 2,4-D and 6.82 mM and 13.64 mM of catechol. 2,4-D was used to compare the herbicidal effect of catechol. Maximum doses for catechol and 2,4-D were found to be 13.64 mM and 1 mM, respectively, in a proexperiment conducted to determine the doses not harmful to wheat and barley plants grown 10 d in the conditions mentioned above, as higher concentrations than these were found to be harmful to the plants. Application of the treatments was carried out using a hand sprayer until the solution dropped from the leaves. Tween-20 was mixed in the solutions with 0.01% content for wetting the leaves. Foliar spray application is the most convenient method, since the half-life of the natural herbicides is generally too short in soil. Especially, polymerization and transformation of catechol is rather rapid and therefore it is not stable in free form in soil (Inderjit *et al.*, 1999).

Distilled water was used as control for the treatments. Each treatment was replicated three times and at least five plants were used in each replicate. After 11 d of treatments, all the plants were taken out of the pots, and their roots were washed. Then root and shoot lengths and seedling weights of the plants were measured. These values were assumed as the last growth values. Change in growth was determined by abstracting initial growth values from the last growth values for both elongation and fresh weight.

The experiment was conducted using a completely randomized design with three replicates. The data were analyzed by ANOVA; then significant mean differences between the treatments of catechol and control were determined using Dunnet test (Little and Hills, 1978).

Results and Discussion

In this study, catechol was found to have herbicidal potential because it was injurious on weeds but not on wheat and barley (Table I). As seen in the Table I, there were negative effects of catechol on the weeds more or less depending on concentrations and weed species. It was more injurious on field poppy weed than on others. 13.64 mM of catechol was more effective on the weeds than 6.82 mM; even 13.64 mM of catechol completely killed field poppy weed seedlings. In general,

Table I. Effect of catechol on growth of wheat, barley and weed species.

	Control (dist. water)	Catechol (6.82 mM)	Catechol (13.64 mM)
Wheat			
Root elongation [cm/seedling]	22.56	23.06	21.81
Shoot elongation [cm/seedling]	28.81	27.87	26.44
Fresh weight [mg/seedling]	0.22	0.22	0.22
Barley			
Root elongation [cm/seedling]	27.44	26.75	25.94
Shoot elongation [cm/seedling]	27.31	27.06	26.75
Fresh weight [mg/seedling]	0.36	0.33*	0.33*
Field poppy			
Root elongation [cm/seedling]	4.10	1.04**	0.00**
Shoot elongation [cm/seedling]	11.20	2.44**	0.00**
Fresh weight [mg/seedling]	0.42	0.04**	0.00**
Creeping thistle			
Root elongation [cm/seedling]	16.00	15.50	12.37
Shoot elongation [cm/seedling]	11.37	10.00	7.62*
Fresh weight [mg/seedling]	1.31	1.22	1.34
Henbit			
Root elongation [cm/seedling]	2.44	2.20	2.02
Shoot elongation [cm/seedling)	6.74	6.30	5.30**
Fresh weight [mg/seedling)	0.22	0.25	0.17
Wild mustard			
Root elongation [cm/seedling]	7.22	6.14	5.08**
Shoot elongation [cm/seedling]	41.46	40.44	33.80**
Fresh weight [mg/seedling]	1.86	1.61	1.50

* Dunnet ($P < 0.05$); ** ($P < 0.01$). Mean values differ significantly from the control.

6.82 mM of catechol has shown only a suppressive effect on the weed growth.

Other weeds than field poppy were affected only by 13.64 mM of catechol significantly; this concentration decreased the growth of the weeds significantly. Shoot elongation was more affected than root elongation in creeping thistle and henbit weeds, whereas in the case of wild mustard both root and shoot elongation were decreased significantly by catechol. Fresh weights of the weeds were decreased only in the field poppy weed but in the other weeds they weren't affected significantly. As can be seen in Table I and Fig. 1, fresh weight of the creeping thistle was affected less than elongation.

Some natural compounds such as 1,3,7-T, tentoxin, sorgoleone, artemisinin, hydantocidin, chaparrinone and pelargonic acid have been indicated to inhibit weed growth (Rizvi *et al.*, 1987; Duke *et al.*, 2001). Recently, parthenin (Batish *et al.*, 2002) and cineoles (Singh *et al.*, 2002) have been found to have inhibitory effect on *Avena fatua* and *Ageratum conyzoides* weed species with 75% and 78% root inhibition, respectively. Effects of allelochemicals on weeds were found to be only suppressive so far. Although no literature data has been found about the allelochemical effect on the

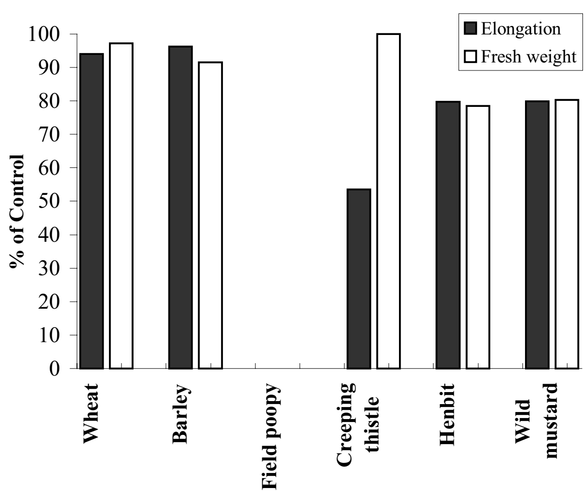

Fig. 1. Effect of 13.64 mM catechol on seedling elongation and fresh weight of the weed species.

Table II. Inhibitory effects of 2,4-D and catechol on seedling elongation. Each value in the table is the difference between initial and last measurements of the seedling lengths. (% Inhibition = percentage of treatment/control.)

Plant species	Control (dist. water)	2,4-D (1 mM)	% Inhibition	Catechol (13.64 mM)	% Inhibition
Wheat (*T. vulgare*)	51.37	51.31	1	48.25	6
Barley (*H. vulgare*)	54.75	53.18	3	52.69	4
Field poppy (*P. rhoeas*)	15.30	0.00	100	0.00	100
Creeping thistle (*C. arvense*)	27.37	0.00	100	19.99	27
Henbit (*L. amplexicaule*)	9.18	5.60	59	7.32	20
Wild mustard (*S. arvensis*)	48.58	0.00	100	38.88	20

weeds we studied, catechol has been shown to kill field poppy weed in the present study.

In most of the previous studies, several natural compounds have been defined to have herbicidal effects on weeds but their harmful effects on cultivated plants are not known. This is an important point to establish whether natural herbicides are harmful on cultivated plants, regarding their use in weed management (Duke *et al.*, 2001). The present study shows that catechol has no significant harmful effects on wheat and barley growth.

Inhibitory effects of 2,4-D and catechol on seedling elongation of both cultural and weed plants are compared in Table II. The effects of 2,4-D and catechol on weed growth were found very strong, indicated by the inhibition of seedling elongation, whereas growth inhibition of wheat and barley was slight. 2,4-D was more effective than catechol, in general, but the effect of 2,4-D and catechol on the field poppy weed was identical with 100% growth inhibition. Catechol has been found to have at least 20% inhibition effect on the other weeds, even 27% in creeping thistle weed.

In conclusion, this study indicates that catechol is a potent inhibitor of the weeds studied at 13.64 mM without affecting wheat and barley growth significantly. This result is promising regarding the use of catechol in future weed management at least for field poppy weed. Further, the studied weeds are common not only in Turkey but also in most countries of the world.

Acknowledgements

We thank Dr. A. Zafer Tel for his efforts in identification of the weed species. This research was supported by grant no 23 from the Research Fund of Dumlupinar University, Kütahya, Turkey.

Batish D. R., Singh H. P., Kohli R. K., Saxena D. B., and Kaur S. (2002), Allelopathic effects of parthenin against two weedy species, *Avena fatua* and *Bidens pilosa*. Environ. Exp. Bot. **47**, 149–155.

Bhowmik P. C. and Inderjit (2003), Challenges and opportunities in implementing allelopathy for natural weed management. Crop Protec. **22**, 661–671.

Duke S. O. and Lydon J. (1987), Herbicides from natural compounds. Weed Technol. **1**, 122–128.

Duke S. O., Dayan F. E., Romagni J. C., and Rimando A. M. (2000), Natural products as sources of herbicides: Current status and future trends. Weed Res. **40**, 99–111.

Duke S. O., Scheffler B. E., and Dayan F. E. (2001), Allelochemicals as herbicides. In: Physiological Aspects of Allelopathy (Bonjoch N. P. and Reigosa M. J., eds). First European OECD Allelopathy Symposium, Gamesal, SA, pp. 47–59.

Duke S. O., Dayan F. E., Rimando A. M., and Schrader K. K. (2002), Chemicals from nature for weed management. Weed Sci. **50**, 138–151.

Farkas G. L. and Kiraly Z. (1962), Role of phenolic compounds in the physiology of plant diseases and disease resistance. Phytopathology **44**, 105–150.

Hale M. G. and Orcutt D. M. (1987), The Physiology of Plants under Stress. John Wiley and Sons Inc., New York, USA.

Hall J. C., Van Eerd L. L., Miller S. D., Owen M. D. K., Prather T. S., Shaner D. L., Singh M., Vaughn K. C., and Weller S. C. (2000), Future research directions for weed science. Weed Technol. **14**, 647–658.

Holm L., Doll J., Holm E., Pancho J., and Herberger J. (1997), World Weeds. John Wiley and Sons Inc., New York, USA.

Inderjit and Keating K. I. (1999), Allelopathy: Principles, procedures and promises for biological control. Adv. Agron. **67**, 141–231.

Inderjit, Dakshini K. M. M., and Foy C. L. (1999), Plant Ecology. CRC Press, New York, USA.

Kocaçalişkan I. and Talan I. (1999), The effect of catechol on some microorganisms. In: Proceedings of the First International Symposium on Protection of Natural Environment and Pyramidal Black Pine [*Pinus nigra* Arnold. ssp. *pallasiana* (Lamb.) Holmboe var. *pyramidata* (Acat.) Yaltırık], Kütahya, Turkey, pp. 407–412.

Kuiters A. T. and Sarink H. M. (1986), Leaching of phenolic compounds from leaf and needle litter of several deciduous and coniferous trees. Soil Biol. Biochem. **18**, 475–479.

Kumari T. S. and Vaidyanath K. (1989), Testing of genotoxic effects of 2,4-dichlorophenoxyacetic acid (2,4-D) using multiple genetic assay systems of plants. Mut. Res. **226**, 235–238.

Little T. M. and Hills F. J. (1978), Agricultural Experimentation – Design and Analysis. John Wiley and Sons Inc., New York, USA.

Putnam A. R. and Duke W. B. (1974), Biological suppression of weeds: Evidence for allelopathy in accessions of cucumber. Science **185**, 370–372.

Rice E. L. (1979), Allelopathy – an update. Bot. Rev. **45**, 15–109.

Rizvi S. J. H. and Rizvi V. (1992), Allelopathy. Chapman and Hall, London, UK.

Rizvi S. J. H., Rizvi V., Mukerji D., and Mathur S. N. (1987), 1,3,7-T, an allelochemical from seeds of *Coffea arabica*: Some aspects of its mode of action as a natural herbicide. Plant Soil **98**, 81–91.

Romagni J. G., Allen S. N., and Dayan F. E. (2000), Allelopathic effects of volatile cineoles on two weedy plant species. J. Chem. Ecol. **26**, 303–313.

Singh H. P., Batish D. R., and Kohli R. K. (2002), Allelopathic effect of two volatile monoterpenes against bill goat weed (*Ageratum conyzoides* L.). Crop Prot. **21**, 347–350.

Snook M. E. and Fortson P. J. (1979), Gel chromatographic isolation of catechol and hydroquinones. Anal. Chem. **51**, 1814–1817.

Vyvyan J. R. (2002), Allelochemicals as leads for new herbicides and agrochemicals. Tetrahedron **58**, 1631–1646.

Whittaker R. H. and Feeny P. P. (1971), Allelochemicals: Chemical interactions between species. Science **171**, 757–770.