J Plant Growth Regul (1991) 10:221–223

Journal of
Plant
Growth
Regulation

Promotive Effect of Chrysanthemic Acids on Adventitious Root Formation in Some Plants

Z. R. Zhao, G. R. Li, and G. Q. Huang

Research Institute of Elemento-Organic Chemistry, Nankai University, Tianjin 300071, China

Received April 4, 1991; accepted July 16, 1991

Abstract. Adventitious root formation in excised cucumber (*Cucumis sativus* L.) cotyledons was significantly promoted by (±)-*cis*-chrysanthemic acid at 0.006–1.8 mM. The effect of (±)-*cis*-chrysanthemic acid on indole-3-acetic acid (IAA)-induced rooting was additive. Rooting in excised cucumber cotyledons was significantly promoted by several isomers of chrysanthemic acid and sodium (±)-*cis*-chrysanthemate at 0.18 mM. Rooting in mung bean (*Phaseolus radiatus* L.) hypocotyls was also stimulated by the sodium salt at 0.06–0.6 mM. Rooting of kidney bean (*Phaseolus vulgaris* L.) hypocotyls was also clearly enhanced by sodium (±)-*cis*-chrysanthemate at 0.18–6 mM.

Recently, some papers have reported the plant growth regulatory activities of certain insecticidally active chrysanthemic acids and their esters (Crammer et al. 1985, Herve and Motillon 1981). Certain chrysanthemic acids and their derivatives were reported to inhibit lettuce radicle growth and seed germination (Crammer et al. 1985). Decamethrin inhibited the gibberellin-stimulated growth of rice (Herve and Motillon 1981). We report the promotive effects of certain chrysanthemic acids and sodium chrysanthemate on adventitious root formation in excised cucumber (*Cucumis sativus* L.) cotyledons, and mung bean (*Phaseolus radiatus* L.) and kidney bean (*Phaseolus vulgaris* L.) hypocotyls.

Materials and Methods

Chemicals

The following chemicals were all synthesized at our institute: (±)-*cis*-chrysanthemic acid (melting point 111–112°C, purity 99%); (+)-*cis*-chrysanthemic acid (melting point 45–47°C, purity 98%); (−)-*cis*-chrysanthemic acid (melting point 43–46°C, purity 98%); (±)-*trans*-chrysanthemic acid (melting point 53–54°C, purity 99%); and sodium (±)-*cis*-chrysanthemate (purity 97%). Other reagents used were of analytical grade and obtained from commercial suppliers.

Excised Cucumber Cotyledon Root Formation Test

Cucumber seedlings were cultured as previously described (Zhao et al. 1988a,b). Cucumber (*Cucumis sativus* L. cv. Jinyan No. 4) seeds were sown on 0.7% agar and grown in the dark at 26°C. Cotyledons were excised from 3-day-old seedlings and cotyledon root formation tests were carried out as previously described (Zhao and Huang 1990, Zhao et al. 1988a). Test samples were dissolved in 95% ethanol to give the following concentrations: 0.06, 0.6, 1.8, 6, 18, and 60 mM. The above solutions (0.3 ml) were evenly dropped onto individual 6-cm filter paper disks and the solvent evaporated. To each treated disk, 3 ml of distilled water were added in the bottom of a 6-cm petri dish; each disk contained 0.006, 0.06, 0.18, 0.6, 1.8, and 6 mM of each sample, respectively. Disks treated with 95% ethanol (which was evaporated) were used as controls. Ten cotyledons were placed on each disk. The excised cucumber cotyledons were then incubated in the dark (26°C). Five days later, the number of roots formed at the bases of 10 cotyledons was counted. Each treatment was replicated four times.

Mung Bean Root Formation Test

The mung bean root formation test was performed as described by Hess (Weaver 1972) with the following modifications: (1) mung bean seeds (*Phaseolus radiatus* L. cv. Maolu) were used; (2) the vermiculite was replaced by sand; (3) six mung bean cuttings were placed in each 50-ml Erlenmeyer flask containing 35 ml test solution; (4) sodium (±)-*cis*-chrysanthemate was dissolved in distilled water; (5) indole-3-butyric acid (IBA) was made by dissolving 3 mg IBA in 0.6 ml of 0.1 N NaOH, and making a dilution series; and (6) distilled water was used as control. Each treatment was replicated four times.

Table 1. Effect of (±)-*cis*-chrysanthemic acid and IAA on the rooting of excised cucumber cotyledons (26°C, dark).

Treatment (mM)		No. of roots on 10 cotyledons	Promotion (%)
Control		14.0 ± 2.4	
(±)-*cis*-			
Chrysanthemic acid	0.006	19.2 ± 0.9	37.1
	0.06	29.7 ± 2.0	112.1
	0.18	37.7 ± 6.8	169.2
	0.6	42.2 ± 3.7	201.4
	1.8	17.0 ± 4.3	21.4
IAA	0.17	44.7 ± 2.6	219.2

Values are mean ± SD.

Table 2. Interaction of (±)-*cis*-chrysanthemic acid and IAA on the rooting of excised cucumber cotyledons (dark, 26°C).

Concentration of (±)-*cis*-chrysanthemic acid (mM)	No. of roots on 10 cotyledons	
	Control	IAA 0.017 mM
0	17.5 ± 3.1	27.2 ± 5.7
0.006	24.2 ± 2.2	29.7 ± 4.3
0.06	33.2 ± 6.1	45.5 ± 2.8
0.18	38.2 ± 4.5	49.0 ± 5.5
0.6	44.0 ± 3.7	52.5 ± 2.0
1.8	25.7 ± 3.7	35.5 ± 3.1

Values are mean ± SD.

Table 3. Effect of several isomers of chrysanthemic acid and IAA on the rooting of excised cucumber cotyledons (dark, 26°C).

Treatment (mM)		No. of roots on 10 cotyledons	Promotion (%)
Control		12.5 ± 1.2	
(+)-*cis*-			
Chrysanthemic acid	0.18	31.5 ± 2.8	152.0
(±)-*cis*-			
Chrysanthemic acid	0.18	31.0 ± 4.6	148.0
(−)-*cis*-			
Chrysanthemic acid	0.18	38.2 ± 4.9	205.0
(±)-*trans*-			
Chrysanthemic acid	0.18	26.0 ± 4.3	108.0
Na (±)-*cis*-			
Chrysanthemate	0.18	39.5 ± 4.6	216.0
IAA	0.18	37.0 ± 2.4	196.0

Values are mean ± SD.

Kidney Bean Root Formation Test

The kidney bean root formation test was done as described by Shibaoka et al. (1967) with the following modifications: (1) kidney bean seeds (*Phaseolus vulgaris* L. cv. Qiukang No. 19) were used; (2) sawdust was replaced by sand; (3) the hypocotyl length was 5 cm; (4) the basal portions of seven cuttings were dipped into each 100-ml beaker containing 50 ml test solution for 20 h; (5) after washing the basal parts with distilled water, the cuttings were transferred to distilled water and kept under 190 $\mu Em^{-2} s^{-1}$ at 24 ± 1°C throughout the experiment; (6) sodium (±)-*cis*-chrysanthemate was dissolved in distilled water; (7) IAA solution was made by dissolving 3 mg IAA in 0.4 ml 95% ethanol, then diluting with distilled water as required; and (8) distilled water was used as the control. Each treatment was replicated four times.

Results and Discussion

Effects of Chrysanthemic Acids on Rooting in Excised Cucumber Cotyledons

(±)-*cis*-Chrysanthemic acid at 0.006–1.8 mM significantly promoted adventitious root formation in excised cucumber cotyledons. The optimal concentration was 0.6 mM. Rooting in excised cucumber cotyledons was also significantly promoted by IAA at 0.17 mM (Table 1).

The IAA-induced adventitious root formation in excised cucumber cotyledons was significantly stimulated by (±)-*cis*-chrysanthemic acid at 0.006–1.8 mM. The effect of (±)-*cis*-chrysanthemic acid on IAA-induced rooting was additive (Table 2).

The adventitious root formation in excised cucumber cotyledons was significantly enhanced by several isomers of chrysanthemic acid and sodium (±)-*cis*-chrysanthemate at 0.18 mM. In those compounds tested, sodium (±)-*cis*-chrysanthemate exhibited the highest promotive activity and (±)-*trans*-chrysanthemic acid the lowest. Rooting in excised cucumber cotyledons was also promoted by IAA at 0.18 mM (Table 3).

*Effect of Sodium (±)-*cis*-chrysanthemate on Rooting in Mung Bean Cuttings*

Rooting in mung bean cuttings was significantly promoted by sodium (±)-*cis*-chrysanthemate at 0.06–0.6 mM. The optimal concentration was also 0.6 mM, at super-optimal concentration rooting decreased markedly. IBA at 0.0049 mM also obviously promoted rooting (Table 4).

*Effect of Sodium (±)-*cis*-chrysanthemate on Rooting in Kidney Bean Cuttings*

The rooting of kidney bean cuttings was significantly promoted by sodium (±)-*cis*-chrysanthemate at 0.18–6 mM with 1.8 mM as the optimal concentration, above that the rooting of cuttings was mark-

Table 4. Effect of sodium (±)-*cis*-chrysanthemate on rooting of mung bean cuttings.

Treatment (mM)		No. of roots on 6 cuttings	Promotion (%)
Control		51.0 ± 5.6	
Na (±)-*cis*-chrysanthemate	0.006	50.0 ± 8.1	−1.9
	0.06	84.2 ± 10.1	65.0
	0.18	127.0 ± 12.1	149.0
	0.6	178.5 ± 14.0	250.0
	1.8	38.0 ± 15.7	−25.4
IBA	0.0049	104.5 ± 17.5	104.9

Values are mean ± SD.

Table 5. Effect of sodium (±)-*cis*-chrysanthemate and IAA on rooting of kidney bean cuttings.

Treatment (mM)		No. of roots on 7 cuttings	Promotion (%)
Control		105.5 ± 11.0	
Na (±)-*cis*-chrysanthemate	0.18	174.0 ± 12.7	64.9
	0.6	199.0 ± 13.7	88.6
	1.8	276.0 ± 20.7	161.6
	6	128.5 ± 35.5	21.8
IAA	0.057	161.0 ± 10.0	52.6

Values are mean ± SD.

edly decreased. IAA at 0.057 mM obviously stimulated rooting in kidney bean cuttings (Table 5).

In summary, the results in this study indicate that (±)-*cis*-chrysanthemic acid at 0.006–1.8 mM, several isomers of chrysanthemic acid and sodium (±)-*cis*-chrysanthemate at 0.18 mM significantly promote adventitious root formation in excised cucumber cotyledons (Tables 1–3). Sodium (±)-*cis*-chrysanthemate at 0.06–0.6 mM obviously stimulates rooting in mung bean cuttings. Sodium (±)-*cis*-chrysanthemate at 0.18–6 mM also clearly enhances the rooting of kidney bean cuttings. The mechanism of action of the chrysanthemic acids and their derivatives is still not clear and deserves further examination. The above findings may have practical importance.

Acknowledgments. The authors thank Professor L. Y. Zheng and Professor M. K. Fan for critical reading of the manuscript.

References

Crammer B, Goldschmidt Z, Ikan R, Spiegelstein H (1985) Thermal acid-catalyzed rearrangement of trans-methyl chrysanthemate to lavandulyl derivatives and their effect on lettuce seedling growth. J Agric Food Chem 33:1148–1152

Herve JJ, Motillon J (1981) Pyrethroids as plant growth regulators. (Roussel-Uclaf) French Patent 2461458

Shibaoka H, Mitsuhashi M, Shimokoriyama M (1967) Promotion of adventitious root formation by heliangine and its removal by cysteine. Plant Cell Physiol 8:161–170

Weaver RJ (1972) Plant growth substances in agriculture. W. H. Freeman and Company, San Francisco, p 41

Zhao ZR, Huang GQ (1990) A new root-formation test. Acta Bot Sin 32:815–818

Zhao ZR, Wu ZL, Zheng QL (1988a) The use of "filter paper method" in determining plant hormones. Chinese Bull Bot 5:57–59

Zhao ZR, Zheng QL, Li GR, Shi YN, Chen RY (1988b) Study on the plant growth-regulating activities of cytisine. Acta Bot Sin 30:377–381