

The exceptionally high levels of serine in the leaves of  $\text{NH}_4$  tomato plants (Table 1) can be explained from such considerations. The initial step in photosynthesis in tomato is fixation of  $\text{CO}_2$  by ribulose-1,5-diphosphate with the subsequent formation of 3-phosphoglyceric acid (PGA). If the normal pathways for the disposition of PGA (carbohydrate synthesis, TCA cycle) are blocked, PGA would accumulate and promote production of serine.

Our findings indicate that the altered amino acid composition associated with ammonium toxicity is a function not only of the enhanced biochemical transformations in the root and the resultant change in translocation patterns of amino acids, but also is a function of secondary events of ammonium-induced Ca deficiency.

#### Literature Cited

- Alt, D., and H. J. Hackbarth. 1970. The mineral content of young tomato plants grown in nutrient solutions with systematically varied ion contents and predominantly high concentrations. *Gartenbauwissenschaft* 35:29-43.
- Barker, A. V., D. N. Maynard, and W. H. Lachman. 1967. Induction of tomato stem and leaf lesions and K deficiency by excessive  $\text{NH}_4$  nutrition. *Soil Sci.* 103:319-327.
- \_\_\_\_\_, R. J. Volk, and W. A. Jackson. 1966. Growth and nitrogen distribution in bean plants (*Phaseolus vulgaris* L.) subjected to ammonium nutrition. I. Effect of carbonates and acidity control. *Soil Sci. Soc. Amer. Proc.* 30:228-232.
- Becking, J. H. 1956. On the mechanism of ammonium uptake by maize roots. *Acta Bot. Neerl.* 5:1-79.
- Beevers, L., and R. H. Hageman. 1969. Nitrate reduction in higher plants. *Ann. Rev. Plant Physiol.* 20:495-522.
- Bennet, W. F., J. Peseck, and J. J. Hanway. 1964. Effect of  $\text{NO}_3$  and  $\text{NH}_4$  on growth of corn in nutrient solution sand culture. *Agron. J.* 56:342-345.
- Blair, G. J., M. H. Miller, and W. H. Mitchell. 1970. Nitrate and ammonium as sources of nitrogen for corn and their influence on the uptake of other ions. *Agron. J.* 62:530-532.
- Clark, H. E. 1936. Effect of ammonium and nitrate nitrogen on the composition of the tomato plant. *Plant Physiol.* 11:5-24.
- Coic, Y., C. Lesaint, and F. Le Roux. 1962. Comparaison du maïs et de la tomate quant à l'effet de la nature nitrrique ou ammoniacale de la nutrition azotée sur l'absorption et le métabolisme des anions-cations. *C. R. Acad. Sci.* 254:549-551.
- Fried, M., F. Zsoldos, P. B. Vose, and I. L. Shatokhin. 1965. Characterizing the  $\text{NO}_3$  and  $\text{NH}_4$  uptake process of rice roots by use of  $^{15}\text{N}$  labeled  $\text{NH}_4\text{NO}_3$ . *Physiol. Plantarum.* 18:313-320.
- Gehrke, C. W., D. Roach, R. W. Zumwalt, D. L. Stalling, and L. L. Wall. 1968. Quantitative gas liquid chromatography of amino acids in proteins and biological substances. Analytical Biochemistry Laboratories, Inc. Columbia, Miss.
- Hoagland, D. R., and D. I. Arnon. 1950. The water-culture method for growing plants without soil. *Calif. Agr. Expt. Sta. Cir.* 347.
- Kirkby, E. A., and K. Mengel. 1967. Ionic balance in different tissues of the tomato plant in relation to nitrate, urea, or ammonium nutrition. *Plant Physiol.* 42:6-14.
- Maynard, D. N., A. V. Barker, and W. H. Lachman. 1968. Influence of potassium and the utilization of ammonium by the tomato plant. *Proc. Amer. Soc. Hort. Sci.* 92:537-542.
- McKee, H. S. 1962. Nitrogen metabolism in plants. Clarendon Press, Oxford, p. 16-18.
- Prianishnikov, D. N. 1929. Zur Frage nach der Ammoniakernahrung hoherer Pflanzen. *Biochem. Z.* 207:341-349.
- Puritch, G. S., and A. V. Barker. 1967. Structure and function of tomato leaf chloroplasts during ammonium toxicity. *Plant Physiol.* 42:1229-1238.
- Vines, H. M., and R. T. Wedding. 1960. Some effects of ammonia on plant metabolism and a possible mechanism for ammonia toxicity. *Plant Physiol.* 35:820-825.
- Warburg, O., and E. Negelein. 1920. Über die Reduktion der Salpetersäure in grünen Zellen. *Biochem. Z.* 110:66-118.
- Weissman, G. S. 1964. Effect of ammonium and nitrate nutrition on protein level and exudate composition. *Plant Physiol.* 39:947-952.
- Wilcox, G. E., J. E. Hoff, and C. M. Jones. 1973. Ammonium reduction of calcium and magnesium content of tomato and sweetcorn and influence on incidence of blossom-end rot of tomato fruit. *J. Amer. Soc. Hort. Sci.* 98:86-89.
- Wonder, I. O., and J. W. Sites. 1956. The effect of  $\text{NH}_4^+$  and  $\text{NO}_3^-$  with and without pH control, on the growth of rough lemon seedlings. *Proc. Amer. Soc. Hort. Sci.* 68:211-226.

## Activity of Foliar Applied Ancymidol on Girdled *Chrysanthemum morifolium* Ramat<sup>1</sup>

D. Weisser<sup>2</sup> and R. M. Sachs  
Department of Environmental Horticulture  
University of California, Davis

**Abstract.** In 'Bright Golden Anne' chrysanthemums girdling below the treated leaves does not reduce, rather it may enhance, growth retarding activity of foliar applied ancymidol. Experimental evidence with  $^{14}\text{C}$  sucrose shows that the compound does not pass the girdle to enter the root system, and it is assumed that ancymidol transport is similarly restricted. Our results indicate that the major site of action of ancymidol is in the shoot tissues. One suggestion accounting for greater activity of soil, as compared to foliar, applications is that the chrysanthemum root system may absorb ancymidol more rapidly than the leaves.

Most investigations with ancymidol<sup>3</sup> on chrysanthemums

and some other species indicate that soil applications are more active than foliar applications (1, 3)<sup>4</sup>. For many cv. of *Chrysanthemum morifolium* approx 0.25 to 0.5 mg added as a soil drench provides control equivalent to a double application of 100 ppm spray containing about 2.5 mg ancymidol per plant (3). One reason for the 5 to 10 fold greater activity of soil applications may be related to much greater absorption by the roots than the leaves. Also it is possible that ancymidol is mainly active in the root system. Reid and Carr (6) found reduced gibberellin levels in xylem exudates of *Impatiens glandulifera* and *Pisum arvense* within 12 hours after soil treatment with chlormequat. Carr, Reid, and Skene (2) and Skene (8) found in xylem exudates of *Vitis vinifera* cv. Black

<sup>1</sup>Received for publication September 3, 1973.

<sup>2</sup>Present address: Department of Floriculture and Ornamental Horticulture, Cornell University, Ithaca, New York.

<sup>3</sup>Ancymidol -  $\alpha$ -cyclopropyl- $\alpha$ -(4-methoxyphenyl)-5-pyrimidinemethanol; sold as A-REST® (Elanco Products Co.). This research was supported in part by a grant from Elanco Products Company, Indianapolis, Indiana.

<sup>4</sup>Unpublished results of Dr. T. Furuta (Calif. Agr. Ext. Serv., Univ. Calif., Riverside), Dr. R. Hasek (Calif. Agr. Ext. Serv., Calif., Davis), and Drs. A. M. Kofranek and R. M. Sachs (Dept. Env. Hort., Univ. Calif., Davis) all substantiate this observation for chrysanthemum.

Corinth and *Lupinus* sufficient gibberellin activity to account for stem elongation of the entire shoot system. Thus, in chrysanthemum, if the root system were the major source of gibberellins for the shoot system and ancymidol inhibited gibberellin biosynthesis, one would expect ancymidol to be most active when applied directly to the roots.

Our study was undertaken to determine: a) if ancymidol must reach the roots to elicit growth retardation and, b) what influence confining the compound to the shoot system would have upon its biological activity in the plant.

#### Materials and Methods

*Chrysanthemum morifolium* Ramat cv. Bright Golden Anne plants, approx 13 cm tall with 3 to 4 expanded leaves were girdled or left intact. The girdle was accomplished by excising a 1 cm wide band of tissue, to such a depth that the phloem and cambium were removed below the lowest leaf. Plants were irrigated with half-strength Hoagland's solution and maintained in a greenhouse under long day conditions (natural daylengths plus 4 hours incandescent light, providing 10 ft-c illumination at the plant tops) and 15°C night temp.

Ancymidol, 0.5 ml of a 264 ppm solution containing 0.2% surfactant and buffered to pH 7.0 with  $5 \times 10^{-4}$  M Tris, was applied to the 2 lowermost leaves immediately above the girdle. There were 6 plants per treatment and each experiment was repeated twice. Results of the 3 experiments were similar but only the data from one is reported. To test the effectiveness of the girdle as a barrier to basipetal transport,  $^{14}\text{C}$ -sucrose (uniformly labelled, 5 mc/mM),  $15 \times 10^6$  dpm in 50  $\mu\text{l}$  aqueous droplets, was applied to the under surface of the lowermost leaf. Transport of  $^{14}\text{C}$  to the roots and shoot apices was measured at the termination of the experiment by determining radioactivity in methanolic extracts of tissue samples. A liquid scintillation counter was used to measure radioactivity; quench correction curves were determined with an external standard. Growth retarding activity was calculated as percent reduction in rate of stem elongation of treated as compared with control plants.

#### Results and Discussion

Foliar applied ancymidol inhibited internode elongation in the girdled and non-girdled plants (Table 1). Girdled plants were inhibited more than ungirdled plants. It is clear from studies with  $^{14}\text{C}$  sucrose that the girdle effectively blocked transport to the root system for at least 7 days (Table 2). Also, there was considerably more  $^{14}\text{C}$  transported to the shoot apices in girdled than in ungirdled plants. Thus, if ancymidol is transported in a manner similar to the  $^{14}\text{C}$  from sucrose, one may conclude that, its transport to the root system was prevented by the girdle and more ancymidol was transported to the shoot apices in girdled than in the ungirdled plants. Greater retardation in the girdled, than in the ungirdled, plants provides support for the latter suggestion.

The results prove that in chrysanthemum the main site of action of ancymidol is the shoot system and that retardation is independent of ancymidol-induced effects upon the root system. If we accept the hypotheses that a) gibberellins

Table 1. Growth retardation of 'Bright Golden Anne' chrysanthemum induced by ancymidol in girdled and ungirdled.<sup>2</sup>

	Control ungirdled	Ancymidol ungirdled	Control girdled	Ancymidol girdled
Elongation (mm/7 days)	87 <sup>a</sup>	78 <sup>b</sup>	68 <sup>c</sup>	50 <sup>d</sup>
% Inhibition		10		26

<sup>2</sup>Means followed by different letters are significantly different from one another at the 5% level by Duncan's multiple range test.

normally control the rate of stem elongation in chrysanthemums, and b) ancymidol blocks gibberellin action (4) or biosynthesis, then the most important site of gibberellin action or biosynthesis in chrysanthemums is in the shoot system. Direct observations of chrysanthemums treated with other growth retardants and gibberellic acid suggest that within the shoot system the subapical, or primary elongating, meristematic tissues are major targets for effective retardation or acceleration of stem elongation (3, 7).

Table 2.  $^{14}\text{C}$  transport in girdled and ungirdled 'Bright Golden Anne' chrysanthemums.  $^{14}\text{C}$  sucrose was applied to the leaf above the girdle. Counts corrected for background.

	$^{14}\text{C}$ (cpm)	
	Root system	Shoot apices
Ancymidol, ungirdled	326	154
Ancymidol, girdled	0	1133

The higher activity found with root applications of ancymidol on chrysanthemums may be due to a) more active absorption by the root system than by the leaves or b) higher concn of ancymidol in the subapical meristematic tissues when applied as a drench, rather than as a foliar spray.

#### Literature Cited

1. Besemer, S. T. 1972. Comparison of Quel® and Cycocel® for reducing height of two poinsettia cultivars - progress report. *Flor. Rev.* 150(3892):37-38, 77.
2. Carr, D. J., D. M. Reid, and K. G. M. Skene. 1964. The supply of gibberellins from the root to the shoot. *Planta* 63:382-392.
3. Larson, R. A., and K. Kimmins. 1972. Response of *Chrysanthemum morifolium* 'Ramat' to foliar and soil applications of ancymidol. *HortScience* 7:192-193.
4. Leopold, A. C. 1971. Antagonism of some gibberellin actions by a substituted pyrimidine. *Plant Physiol.* 48:537-540.
5. Jones, R. L., and I. D. J. Phillips. 1966. Organs of gibberellin synthesis in light-grown sunflower plants. *Plant Physiol.* 41:1381-1386.
6. Reid, D. M., and D. J. Carr. 1967. Effects of a dwarfing compound; CCC, on the production and export of gibberellin-like substances by roots. *Planta* 73:1-11.
7. Sachs, R. M., and A. M. Kofranek. 1963. Comparative cytohistological studies on inhibition and promotion of stem growth in *Chrysanthemum morifolium*. *Amer. J. Bot.* 50:772-779.
8. Skene, K. G. M. 1967. Gibberellin-like substances in root exudate of *Vitis vinifera*. *Planta* 74:250-262.