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AMINO ACIDS AND RELATED COMPOUNDS AS INHIBITORS OF LETTUCE GROWTH

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It has been demonstrated previously [1] that the growth of lettuce seedlings may be inhibited if the lettuce fruits have been allowed to imbibe solutions of certain amino acids. Among those which produced over 50% inhibition of hypocotyl or radicle growth when supplied at 1.0 mM concentration were the non-protein amino acids 2-amino-4-methylaminopropionic acid, 2-amino-3-oxalylaminopropionic acid, azetidine-2-carboxylic acid, canavanine, 2,3-diaminopropionic acid, 2,4-diaminobutyric acid, L-3,4-dihydroxyphenylalanine, homoarginine, mimosine, pipecolic acid and homoserine, and the protein amino acids cysteine, lysine, methionine and serine. Of these the most effective growth inhibitors were 2-amino-3-oxalylaminopropionic acid, azetidine-2-carboxylic acid, canavanine, mimosine and pipecolic acid.

The availability of other non-protein amino acids has made it possible to extend this study, and the effects on the growth of lettuce seedlings of 8 additional non-protein amino acids and 2 related compounds are reported in Table 1.

All the compounds tested inhibited radicle growth more than hypocotyl growth. The most effective inhibitors of seedling germination at 1.0 mM concentrations were the basic amino acids enduracididine (3-[2-amino-2-imidazolin-4-yl]alanine) from *Lonchocarpus sericeus* [2], tetrahydrolathyrine from *Lonchocarpus costaricensis* [3], γ-hydroxyarginine from *Vicia* species [4], the imino acid *trans*-4-hydroxyproline, a commercial preparation, and the base 2-aminoimidazole which occurs in species of *Piscidia*, *Mundulea* and *Derris* of the tribe Tephrosieae [5, 6]. 4-Hydroxyarginine, like canavanine in earlier studies, produced major inhibition at 1 mM concentration. The higher homologue 4-hydroxyhomoarginine was much less effective, suggesting that the inhibitory effect of canavanine and 4-hydroxyarginine may be due to their close structural similarity to arginine.

Of the heterocyclic amino acids tested, enduracididine proved more inhibitory than tetrahydrolathyrine. Lathyrine itself produced no inhibition at 1 mM concentrations [1]. Both the imino acids investigated, *trans*-4-hydroxyproline and baikiain, showed a greater inhibition of radicle growth than of hypocotyl growth. This contrasts with the previously observed effects of azetidine-2-carboxylic acid and pipecolic acid [1]. *trans*-4-

Table 1. The effects of non-protein amino acids and related compounds imbibed by lettuce fruits on the subsequent growth of the seedlings. The compounds are arranged in order of effectiveness as inhibitors of radicle growth at 1.0 mM concentration

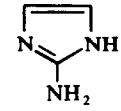
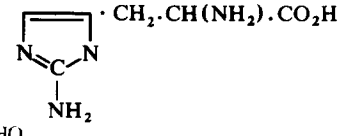
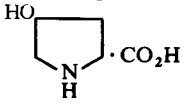
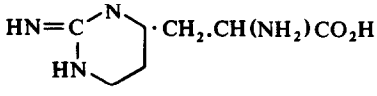
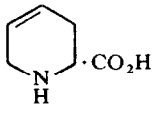
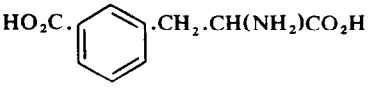
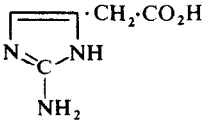
Compound	Structure	Concentration (mM)	Hypocotyl growth (% of control)	Radicle growth (% of control)
4-Hydroxyarginine	$H_2N.C(:NH).NH.CH_2.CH(OH).CH_2.CH(NH_2).CO_2H$	1.0	39	19
		10.0	39	13
2-Aminoimidazole		1.0	27	22
		10.0	5	6
Enduracididine		1.0	48	23
		10.0	34	20
4-Hydroxyproline		1.0	56	24
		10.0	56	18
Tetrahydrolathyrine		1.0	71	25
		10.0	60	14
5-Hydroxynorleucine	$CH_2.CHOH.CH_2.CH_2.CH(NH_2).CO_2H$	1.0	74	38
		10.0	31	19

Table 1. *Continued*

Compound	Structure	Concentration (mM)	Hypocotyl growth (% of control)	Radicle growth (% of control)
Baikiain		1.0 10.0	63 58	45 27
N^6-Acetylornithine	$CH_2CO.NH.CH_2.CH_2.CH_2.CH(NH_2)CO_2H$	1.0 10.0	77 71	59 68
3-Carboxytyrosine		1.0 10.0	89 35	87 16
2-(2-Amino-2-imidazolin)acetic acid [2]		1.0 10.0	100 74	89 60

Hydroxyproline has been shown to inhibit proline synthesis in maize [7] and the hydroxylation of protein bound proline during cell wall formation [8]. However, *trans*-4-hydroxyproline, pipecolic acid and baikiain have not been shown to interfere with the attachment of proline to *t*RNA during protein biosynthesis [9].

EXPERIMENTAL

Fruits of lettuce (*Lactuca sativa* var. Great Lakes) were sown in 0.5% agar containing a measured amount of amino acid or related compound and incubated at 30° for 3 days. Each determination was performed on 100 fruits in batches of 20. Growth was calculated after 3 days by taking measurements of the hypocotyl and radicle lengths and determining a mean for the 100 seedlings. This value is expressed in Table 1 as a percentage of the control.

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