THE EFFECTS OF PURINE DERIVATIVES AND OTHER ORGANIC COMPOUNDS ON GROWTH AND CELL-DIVISION IN PLANTS

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This investigation was undertaken mainly with the object of studying the effect of allantoin on cell growth; this compound having been used with considerable success as a cell proliferant in the treatment of ulcers, burns, etc., by Dr. C. J. Macalister (*Brit. Med. Journ.*, Jan. 6th, 1912). In addition to allantoin, other compounds of the same group, and the sodium salts of some organic acids were used in these experiments, which were carried out on similar lines to those employed by Moore and Roaf (*Bio-Chem. Journ.*, 1908, 3, 279) in their work on the effects of inorganic salts upon the growth and cell-division in plants.

The plants used were a common variety of hyacinth with white florets. They were placed in hyacinth glasses, which were enclosed in blue paper bags, in order to prevent the action of light upon the rootlets. The list of solutions employed was as follows:—Allantoin, sodium huminate, sodium nucleate, guanine hydrochloride, xanthine, hypoxanthine hydrochloride, caffeine, sodium malate, sodium urate, sodium oxalate, sodium oleate, sodium linoleate, and Bovril. Two controls were employed, one of ordinary tap-water, and another to which a trace of sodium hydroxide was added, on account of the fact that certain of the solutions when being prepared were made slightly alkaline to phenol phthalein. The solutions were all made up with ordinary tap-water, and in most cases of three strengths, 0·5 per cent., 0·1 per cent., 0·02 per cent.

Measurements of both rootlets and leaves were taken from time to time, and are shown in the accompanying table.

In general terms it may be stated that in the cases of the 0·1 per cent. and 0·02 per cent. solutions of sodium huminate, 0·02 per cent. sodium malate, 0·02 per cent. sodium urate, and 0·02 per cent. sodium oxalate, the rate of growth was distinctly increased, this increase being most

marked in the sodium huminate solutions; 0.1 per cent. Bovril also stimulated the growth but not to so great an extent as the above solutions. In every other case, however, the growth of the bulb was either retarded or completely arrested.

It is also worthy of note that, with the single exception of sodium nucleate, every other solution of 0.5 per cent. strength which was employed entirely arrested the growth of the rootlets and greatly retarded that of the leaves, and in nearly every case the most rapid growth took place in the weakest solutions.

The rootlets of the bulbs grown in the sodium nucleate, sodium oleate, sodium linoleate and Bovril solutions, although comparatively short in length, were very thick.

ALLANTOIN SOLUTIONS

(Lengths in centimetres)

			26 Days	54 Days		97 Days		119 Days		
Strength of Solution			Roots (only)	Roots	Leaves	Roots	Leaves	Roots	Leaves	
Control	(I)	...	7.5	13.0	3.0	13.0	15.5	14.0	30.0	(flowering)
„	(II)	...	8.0	13.0	3.0	13.0	14.5	13.0	20.0	(flowering)
0.1 %	(I)	...	3.0	3.5	1.5	3.5	8.5	4.0	19.0	(flowering)
„	(II)	...	1.5	1.5	0.5	1.5	4.5	1.5	10.0	(flowering)
„	(III)	...	3.0	4.0	1.0	4.0	10.5	5.0	21.0	(flowering)
0.2 %	(I)	...	1.5	1.5	1.0	1.5	4.5	1.5	9.0	(flowering)
„	(II)	...	5.0	5.0	2.5	7.0	8.5	7.0	13.0	(flowering)
„	(III)	...	5.0	5.0	2.5	5.0	10.0	6.0	22.0	(flowering)
0.3 %	(I)	...	No growth	No growth	1.0	No growth	3.5	No growth	6.0	(flowering)
„	(II)	...	5.0	6.5	2.5	8.0	4.5	8.0	6.0	
„	(III)	...	5.5	8.0	2.5	8.0	4.0	8.0	4.5	
0.5 %	(I)	...	No growth	No growth	0.75	No growth	1.5	No growth	3.5	(just com-
„	(II)	...	No growth	No growth	0.5	No growth	2.5	No growth	3.0	mencing
„	(III)	...	No growth	No growth	0.5	No growth	2.0	No growth	3.0	to flower)

SOLUTIONS OF PURINE DERIVATIVES AND OTHER ORGANIC COMPOUNDS

Solution	Strength	25 Days		48 Days		68 Days		90 Days	
		Roots	Leaves	Roots	Leaves	Roots	Leaves	Roots	Leaves
		cms.	cms.	cms.	cms.	cms.	cms.	cms.	cms.
Control (1) ...		3.0	3.5	4.0	5.0	4.5	11.5	6.0	23.0
(Water) (2) ...		2.5	3.5	3.0	6.0	3.5	14.5	4.0	30.0
Control (1) ...		6.0	3.0	8.0	5.0	9.0	14.0	11.0	35.0
(Alkali) (2) ...		5.0	3.5	5.5	7.0	7.5	15.0	10.0	35.0 (B.)
Sodium Huminate	0.5 %	Not growing	3.5	Not growing	4.0	Not growing	5.0	Not growing	5.0
	0.1 %	5.0	2.5	12.0	3.5	16.0	9.0	18.0	30.0 (F.)
	0.02 %	7.0	3.5	13.0	4.5	14.0	11.0	14.0	30.0 (F.)
	0.02 %	5.0	4.0	8.0	5.5	8.5	13.0	9.0	31.0 (F.)
Sodium Nucleate	0.5 %	1.5	3.5	2.0	4.0	2.5	5.0	2.5	7.0
	0.1 %	1.0	3.0	1.5	4.0	2.0	6.0	2.5	27.0 (F.)
	0.02 %	1.5	2.5	2.0	3.5	2.5	6.5	2.5	25.0 (F.)
Guanine Hydrochloride	0.07 %	Not growing	1.5	Not growing	1.5	Not growing	2.5	Not growing	7.0
	0.07 %	Not growing	2.5	Not growing	3.5	Not growing	4.0	Not growing	6.0 (B.)
Xanthine ...	0.03 %	1.5	2.0	3.5	3.0	9.0	9.0	11.0	13.0 (F.)
	0.03 %	1.0	2.0	1.5	3.0	6.0	6.0	10.0	22.0 (F.)
Hypoxanthine Hydrochloride	0.07 %	Not growing	1.5	Not growing	2.0	Not growing	2.5	Not growing	3.0
	0.07 %	Not growing	1.5	Not growing	2.0	Not growing	2.5	Not growing	3.0
Sodium Malate ...	0.5 %	Not growing	2.0	Not growing	2.5	Not growing	3.0	Not growing	3.0
	0.1 %	1.0	2.0	1.0	2.5	1.0	3.0	1.0	4.5 (B.)
	0.02 %	7.0	2.0	9.0	3.5	13.0	10.0	15.0	30.0 (F.)
	0.02 %	7.0	4.0	8.0	6.0	8.5	16.0	9.0	33.0 (F.)
Caffeine ...	0.5 %	Not growing	1.0	Not growing	1.5	Not growing	2.0	Not growing	2.0
	0.1 %	Not growing	1.0	Not growing	2.0	Not growing	3.0	Not growing	6.0
	0.02 %	Not growing	1.5	Not growing	3.0	Not growing	4.0	Not growing	11.5
	0.02 %	1.0	2.0	4.0	4.5	9.5	11.0	10.5	32.0 (B.)
Sodium Urate ...	0.5 %	Not growing	2.5	Not growing	3.5	Not growing	4.5	Not growing	4.0
	0.1 %	Not growing	3.0	Not growing	4.0	Not growing	7.0	Not growing	8.0
	0.02 %	7.0	3.5	9.0	6.0	11.0	16.0	11.0	30.0
	0.02 %	6.0	3.5	9.0	6.0	11.0	14.5	13.0	27.5
Sodium Oxalate...	0.5 %	Not growing	3.0	Not growing	3.5	Not growing	4.0	Not growing	5.0
	0.1 %	1.0	3.5	4.0	3.5	4.0	6.5	5.5	16.0
	0.02 %	4.0	3.5	5.0	6.0	6.5	16.0	8.0	31.0
	0.02 %	8.0	4.0	11.5	6.5	11.5	16.0	13.0	33.0
Sodium Oleate ...	0.5 %	Not growing	3.0	Not growing	3.5	Not growing	4.0	Not growing	4.5
	0.1 %	6.0	3.5	7.0	4.5	8.5	9.5	9.0	12.5
	0.02 %	4.5	4.0	7.0	7.0	8.5	19.5	9.0	32.0
	0.02 %	2.0	4.0	3.0	5.0	3.5	9.0	4.0	12.5
Sodium Linoleate	0.5 %	Not growing	3.0	Not growing	3.0	Not growing	5.0	Not growing	5.5
	0.1 %	3.0	3.5	6.0	6.0	7.0	18.0	8.0	27.0
	0.02 %	2.0	2.5	2.5	3.5	2.5	4.0	3.0	4.5
	0.02 %	3.0	2.5	7.0	4.5	9.0	12.5	10.0	34.0
Bovril ...	0.1 %	4.0	2.5	6.0	4.5	9.0	16.5	9.5	30.0
	0.1 %	3.0	3.0	6.0	7.0	7.5	22.5	9.0	35.0 (B.)

F. = Flowering.

B. = Budding—i.e., floret just making its appearance.

HISTOLOGICAL INVESTIGATION OF THE GROWING CELLS AND DIVIDING NUCLEI UNDER THE INFLUENCE OF THE ABOVE COMPOUNDS

A few of the ends of the growing rootlets were cut off at various times for the purpose of studying the effects of the solutions on cell-division and nuclear changes. These ends were immediately fixed in Flemming's solution, and sections cut and stained for microscopical examination, of which the following are brief notes:—

Sections of Rootlets cut after Seventeen Days' Growth

Control (Water).—Normal condition but not much cell-division.

Control (Alkali).—Frequent cell-division; much more than in the water control. Cell-division figures very regular.

Sodium Huminate (0.1 per cent. Solution).—Cell-division much darker. Divisions less frequent than in the alkaline control and irregular in form. The nuclei often appear in dark rounded masses with clear spaces surrounding them.

Sodium Huminate (0.02 per cent. Solution).—Cell-division more frequent. Chromosomes of irregular length and in beaded rows; different from the continuous rods of the normal preparation.

Sodium Nucleate (0.5 per cent. Solution).—Similar in appearance to the 0.1 per cent. sodium huminate, apparently indicating the presence of more chromatin. A few cell-divisions which are very irregular, showing the tendency of the chromosomes to shorten in length.

Sodium Nucleate (0.1 per cent. Solution).—Same dark rounded nuclei as in the two previous numbers. Only a few cell-divisions, irregular in form.

Sections of Rootlets cut after Twenty-seven Days' Growth

Controls.—Large amount of cell-division.

Allantoin (0.5 per cent. Solution).—Fair number of dividing cells; divisions regular.

Allantoin (0.3 per cent. Solution).—Very small amount of cell-division.

Allantoin (0.2 per cent. Solution).— " " "

Allantoin (0.1 per cent. Solution).— " " "

Sections of Rootlets cut after Thirty-three Days' Growth

Control (Water).—Not much cell-division occurring. Nuclei elongated in form.

Control (Alkali).—Amount of cell-division considerably greater than in the previous control. Divisions quite regular.

Sodium Huminate (0.5 per cent. Solution).—Cell-division practically absent.

Guanine Hydrochloride (0.07 per cent. Solution).—Degenerating.

Hypoxanthine Hydrochloride (0.07 per cent. Solution).—Degenerating.

Sodium Malate (0.5 per cent. Solution).—Degenerating.

Caffeine (0.02 per cent. Solution).—A fair amount of cell-division taking place; divisions irregular.

Sodium Urate (0.1 per cent. Solution).—Most of the roots degenerating.

Sodium Oxalate (0.1 per cent. Solution).—A fair amount of cell-division; divisions remarkably regular.

Sodium Oleate (0.5 per cent. Solution).—Most of the roots degenerating.

Sodium Nucleate (0.02 per cent. Solution).—Large numbers of nucleoli present. Hardly any dividing cells; such as they are, irregular, and majority of nuclei in rounded, resting form.

Xanthine (0.03 per cent. Solution).—Much the same as the previous number, with perhaps a few more cells in dividing condition.

Sodium Malate (0.1 per cent. Solution).—Only a small number of cell-divisions, regular in form.

Sodium Malate (0.02 per cent. Solution).—A fair number of dividing cells, irregular in form.

Sodium Linoleate (0.1 per cent. Solution).—A fair amount of cell-division, regular in form.

Sodium Linoleate (0.02 per cent. Solution).—Large numbers of dividing cells, very irregular and uneven in form, sometimes nearly all the chromatin passing to one of the poles. Chromosomes of very unequal length.

Sodium Oleate (0.1 per cent. Solution).—Considerable amount of cell-division; divisions regular.

Sodium Oleate (0.02 per cent. Solution).—Less cell-division than in the previous number; divisions regular.

Sodium Oxalate (0.02 per cent. Solution).—Large number of cell-divisions, beautifully regular in form.

Sodium Urate (0.02 per cent. Solution).—Divisions less frequent and somewhat irregular. Nucleoli very evident.

The slides of the 0.1 per cent. and 0.02 per cent. solutions of sodium oxalate were of particular interest on account of the remarkable regularity of the cell-divisions.

CONCLUSIONS

1. The growth of the bulbs is stimulated by dilute solutions of sodium huminate, sodium malate, sodium urate, and sodium oxalate, and to a less extent by Bovril. The increase in growth is more marked in the rootlets than in the leaves.

In most cases 0·02 per cent. appears to be the most favourable strength; the growth is considerably less in stronger solutions, and is completely arrested by a 0·5 per cent. solution.

2. Cell-division is stimulated to a considerable extent by dilute solutions of sodium huminate, sodium oxalate, sodium oleate, and sodium linoleate, and to a less extent by sodium malate and caffeine.

3. Both growth and cell-division are inhibited by stronger solutions of the above compounds, and by all solutions of allantoin, guanine hydrochloride, xanthine, hypoxanthine hydrochloride, and sodium nucleate.

This work was undertaken at the suggestion of Professor Benjamin Moore, to whom, as well as to Dr. C. J. Macalister, I am greatly indebted for advice and assistance on many points in connection with it.