in turn will be reflected in precise determination of J. Even for orbits in which atmospheric drag will slightly perturb the periods, the alteration in T_A should be very closely the same as that in T_N, so that the difference should be relatively unaffected by drag.

With the exception of satellite 1958β2 (Vanguard I), the existing satellite orbits are too seriously affected by drag for the above equations to be precisely applicable; and even for Vanguard I precise data on nodical periods have not yet been published. In the absence of such information one can utilize the predicted times of equator crossings, as issued by the Vanguard Computing Center and the Naval Research Laboratory, to derive approximate nodical periods. In this manner values of $(T_A - T_N)$ were calculated and plotted as a function of equator pass number in Fig. 1. The predicted cyclic variation, with minima and maxima corresponding to perigee and apogee occurrences near the node, is indeed evident. The lack of complete symmetry in the curve is a consequence of the fact that values of the nodical period were interpolated to the nearest 0.1 second, while the predicted times of equator crossings were given only to the nearest second.

On the basis of the Vanguard prediction data and Eq. 1, a value for the oblateness parameter has been calculated as $J = 0.001631 \pm 0.000031$. In turn this corresponds to an earth oblateness (*2*) of $1/297.6 \pm 2.7$. This is to be compared with the international value of 1/297.0 and O'Keefe's preliminary value (*4*) of $1/298.3 \pm 0.1$, which was derived from the secular motions of the node and perigee of satellite 1958β2.

Obviously, in spite of the near agreement between the value herein obtained and the other quoted values for the oblateness, little significance can be attached to this figure because of the associated large statistical probable error. However, even from these approximate calculations, it is clear that a significant check on the validity of the theory has been obtained. Since no method for independent determination of the earth's oblateness should be left unexplored, it is urged that every effort be made by tracking stations and computation centers to determine satellite anomalistic and nodical periods accurately.

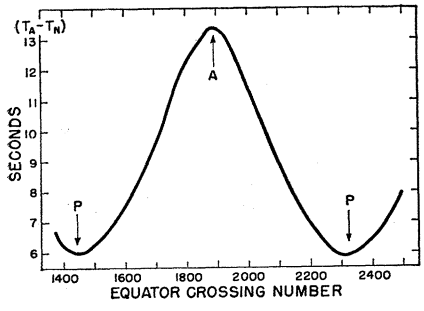

Fig. 1. Difference between anomalistic and nodical periods as a function of equator pass number for satellite 1958β2. Approximate perigee (P) and apogee (A) occurrences at the equator are indicated by arrows (*5*).

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References and Notes

1. Those points on the celestial sphere where the satellite crosses the equator are called the nodes. The point on the orbit nearest the earth is called the perigee, while the major axis, extended indefinitely, is called the line of apsides.
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19 November 1958

Inhibition of Growth of Excised Tomato Roots by 2-Diethylaminoethanol

Abstract. Approximately 40 μ*M* 2-diethylaminoethanol (DEAE) caused 50-percent inhibition of growth of the main axis. Inhibition was relieved by 2-dimethylaminoethanol and choline but not by ethanolamine. A marked morphogenetic effect of DEAE is attributed to differences in sensitivity of main and lateral meristems and to an effect upon the postulated hormonal system controlling apical dominance.

The work reported here forms part of a project designed to study the replacement of vitamin B_6 by ethanolamine (2-aminoethanol) in the nutrition of excised tomato roots (*1*).

Ethylation of the amino group of ethanolamine gives compounds which, because of their structural similarity to the metabolites 2-mono-, 2-di-, and 2-trimethylaminoethanol (choline), are possible antimetabolites which could be useful in the study of the metabolism of ethanolamine. No reports of the effects of such ethylated derivatives on plant growth are known to me, although some indication of the value of these compounds as inhibitors is given from work with animals. Thus the incorporation of the ethyl carbon of ethionine into choline and creatine of rat tissue (*2*) suggested that growth inhibition by ethionine could be due, at least in part, to inhibitory effects of ethyl analogs of choline or substances containing choline. Subsequently (*3*) it was shown that triethylcholine inhibited the growth of rats. The inhibition was relieved by choline and, to a lesser extent, by methionine.

2-Diethylaminoethanol is not a proven antimetabolite. However it forms part of the structure of a number of drugs, and, consequently, it has been studied by animal physiologists who have reported various pharmacological effects (*4*). It is not known whether any such effects are due to interference with choline metabolism. However, in a study of the oxidation of choline-like substances by rat-liver preparations (*5*) it was found that, although choline and a number of structural analogs were oxidized, DEAE was not oxidized. Furthermore, DEAE gave a 25-percent depression of choline oxidation by the homogenate. All these results suggested that DEAE might be valuable as an inhibitor in vivo.

A sample of DEAE was given to me by the Jefferson Chemical Company (New York). This report describes the inhibitory effects of DEAE on growth of excised tomato roots grown in sterile culture and some nutritional experiments on the reversal of the inhibition. The clone of excised tomato roots used as a source of inocula is designated R5 (*6*). The general experimental techniques, and some cultural requirements of the clone, are described elsewhere (*6, 7*). All additions to the basal medium used here were autoclaved in the medium. The measurements recorded are of roots grown for 6 days from 10-mm tips and are measurements of the final length of the main axis per root and of the total length of the ten basal laterals per root. The number of laterals per root in all experiments was found to be proportional to the length of the main axis and is, therefore, omitted from the results.

The effects of a range of concentrations of DEAE on the growth of roots is shown in Fig. 1. There was a marked difference between the growth response to DEAE of the main axis and of the lateral roots. The inhibition of lateral growth at low concentrations was relieved at higher concentrations which inhibited growth of the main axis. The explanation of this differential effect probably lies in the observation (*8*) that apical dominance (inhibition of lateral roots by the main apex) is manifested in excised tomato roots. In the presence of a growth inhibitor, the growth of lateral roots will be controlled by the inhibitions due to both the exogenous inhibitor and the factors causing apical dominance. Presumably, at those concentrations of DEAE which relieved the inhibition of lateral growth caused by low concentrations of DEAE, the simultaneous inhibition of main axis growth resulted in a removal of the factors causing apical dominance. This, in turn, led to an in-

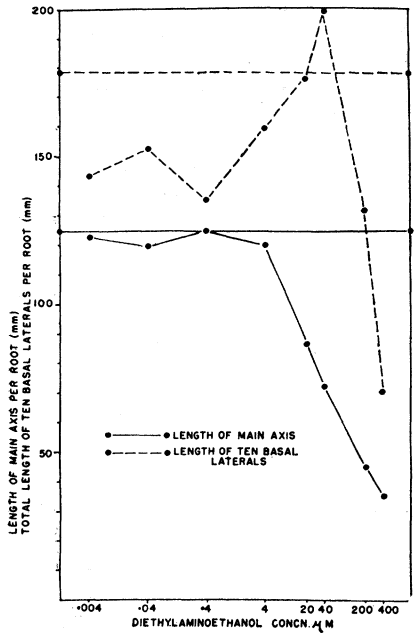

Fig. 1. Effect of 2-diethylaminoethanol on excised tomato roots grown for 6 days from 10-mm tips. Each point is the mean of nine roots. The horizontal lines show the growth in the control.

Table 1. The effect of either choline (experiment 1) or 2-dimethylaminoethanol (DMAE) (experiment 2) on inhibition by 2-diethylaminoethanol (DEAE). The values for experiment 1 are means of nine roots; for experiment 2 the values are the means of 19 roots in the control and low DEAE series and of nine roots in the high DEAE series.

Additions			Feature measured	
DEAE (μM)	Choline (μM)	DMAE (μM)	Main axis (mm)*	Lateral length (mm)†
Experiment 1				
0	0		133.1	200.5
40	0		79.4	202.2
40	.04		81.2	191.6
40	.12		81.5	175.1
40	.4		88.6	218.8
40	1.2		128.4	161.9
40	4.0		96.2	196.1
40	12.0		87.1	183.0
Experiment 2				
0		0	127.4	150.1
40		0	69.7	147.8
40		3.2	83.7	157.1
40		4.0	84.1	158.3
40		8.0	87.7	153.2
40		12.0	77.8	172.4
200		0	36.3	84.8
200		3.2	43.8	109.6
200		4.0	47.1	112.5
200		8.0	50.2	130.0
200		12.0	53.3	104.6

* Length of main axis per root.
† Total length of ten basal laterals per root.

crease in growth of lateral roots. In other words, the inhibition of apical dominance more than offset the inhibition of lateral growth by DEAE.

Because of the differences in the proportions of the lateral roots and the main axis, the difference in morphology was very striking between control roots and those grown in 40-μM DEAE. The dose-response curves obtained with DEAE are not simply a consequence of inhibition as such, because they were not obtained with the antimetabolites sulfanilamide, ethionine, thiouracil, and desthiobiotin when these were added to the basal medium used here. However, dichloroanisole, an antiauxin (*9*), gave curves very similar to those shown in Fig. 1 (*10*). This suggests (i) that the inhibitory effect of DEAE at low concentrations is due to an effect upon the hormonal system which inhibits growth of lateral roots and (ii) that differences in the morphology of root systems (*11*) may result from differences between the endogenous concentrations at which an inhibitor affects the growth metabolism of terminal meristems and those at which it affects the metabolism upon which the hormonal, apical dominance depends.

Ethanolamine did not relieve the inhibition caused by DEAE at a concentration (40 μM) giving approximately 50 percent inhibition in growth of the main axis. The concentrations of ethanolamine tested ranged from 0.12 to 400 μM. These concentrations were not inhibitory when supplied in the absence of DEAE.

Neither choline nor 2-dimethylaminoethanol increased the growth of clone R5 when supplied in the absence of DEAE. The effects of choline or 2-dimethylaminoethanol on inhibition by DEAE are shown in Table 1. Inhibition was relieved, to a greater or lesser extent, by either of these substances. The low level at which they are toxic to excised tomato roots precludes any attempts to determine whether the antagonisms are competitive or otherwise. However, the results presented here show that 2-diethylaminoethanol may be a useful inhibitor in the study of ethanolamine and choline metabolism in plants, and in the study of apical dominance in excised tomato roots.

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Partial Chromatographic Separation of Pentose- and Deoxypentosenucleic Acids

Abstract. From a mixture of tobacco mosaic virus pentosenucleic acid (RNA) and calf thymus deoxypentosenucleic acid (DNA) (2 mg each), 73 percent of the RNA was separated free of DNA by discontinuous elution chromatography with phosphate buffers at *p*H 6.7 on columns of calcium phosphate.

The presently available procedures for the separation of pentosenucleic acids from deoxypentosenucleic acids in complex biological materials have been discussed by Chargaff (*1*), together with their individual advantages and limitations. Included among these is the method of Zamenhof and Chargaff (*2*), which involves the preferential adsorption of RNA on activated charcoal. The recent development of procedures for chromatographic separations of DNA on calcium phosphate columns (*3–5*) has prompted the extension of such techniques to mixtures of RNA and DNA. This we would like to report in this paper (*6*).

The results obtained for the attempted separation of tobacco mosaic virus RNA (*7*) from calf thymus DNA (Worthington), in a mixture of the two acids, by means of this chromatographic adsorbent material are presented in Fig. 1. Chromatography of 2.0 mg tobacco mosaic virus RNA alone (Fig. 1*A*) results in a series of peaks eluted by 0.12. 0.14, 0.16 and 0.20M phosphate buffer eluents at *p*H 6.7. The ratio of optical absorbance of 280 mμ to the optical absorbance at 260 mμ (A_{280}/A_{260}) of these eluates was 0.46. That of the original RNA solution placed on these columns was 0.46.

When a mixture composed of 2.0 mg of tobacco mosaic RNA and 2.0 mg of DNA is chromatographed (Fig. 1*B*), a series of major peaks, as evidenced by the corresponding A_{260} values of the eluates in tubes 31 to 120, appears. The eluates in tubes 31–79 contain RNA, since the A_{280}/A_{260} values are within the limits of 0.46 ± 0.01. Further, no significant