AN APPLICATION OF THE GOMPERTZ GROWTH EQUATION TO HYPOCOTYL ELONGATION IN CHILLED AND NON-CHILLED COTTON SEEDLINGS

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Transparent soil tanks, immersed in temperature-controlled water baths, are being utilized to study the effects of brief exposures to chilling temperatures on subsequent hypocotyl elongation in cotton. The use of transparent soil tanks allows the nondestructive observation of hypocotyl and radicle lengths of a population of germinating seedlings over a period of time. Data from such studies is being used to extend the applicability of an existing computer model, developed by Dr. D.F. Wanjura, to cold-stress conditions. Wanjura's model successfully simulates emergence of cotton seedlings subjected to a range of fluctuating soil conditions (temperature, physical impedance, and moisture), but works less well under soil conditions resulting in extreme seedling stress. His model simulates the effect of chilling below 15.5C by imposing a time delay, equal to the length of the chilling period. We have observed in a number of experiments, however, that the seedling response to at least one chilling regime (7C for a 24-hr. period) is more complex than just a temporary cessation of growth during the period of chilling. There is a readily observed shift in the hypocotyl growth curve after chilling in which seedling growth accelerates (relative to controls), resulting in a maximal hypocotyl length that is similar to that of control seedlings (maintained at a constant 20C) and which occurs at approximately the same time. We also have observed that the nature of the shift in growth rate due to chilling appears to be a function of the physiological stage at which the 24-hr. chilling period occurs.

The Gompertz growth equation provides an extremely satisfactory mathematical model for the asymmetric sigmoidal growth of cotton hypocotyls. The basic equation is:

$$y = A^{-e^{b(c-t)}}$$

Where y is the hypocotyl length at any time "t", A is the assymptotic (maximal) hypocotyl length, b is the weighted mean relative growth rate, and c is the time at which maximum growth rate occurs (point of inflection). In order to simplify the exponent, t represents the time in hours/96 hr. This form of the Gompertz equation not only provides an excellent fit to cotton hypocotyl elongation data but consists only of parameters having obvious physiological significance (i.e., no undefined "constant").

Pregerminated seedlings (dry seeds planted in moist paper towels and germinated for 48 hr. at 20C) were selected for uniformity and planted in soil tanks at the beginning of an experiment. Although the use of pregerminated seedlings minimized subsequent variance in hypocotyl lengths within a seedling population, the variance was found to increase with time. The variance was stabilized in time by performing a logarithmic transformation of the raw data.

A logarithmic form of the Gompertz equation $\ln y = \ln A^{-e^{b(c-t)}}$ was thus used and geometric, rather than arithmetic, means calculated from the hypocotyl data. The following table summarizes the results of a representative experiment in which pregerminated seedlings were either maintained at 20C or chilled for 24 hr. at 7C during the second day after planting and then returned to 20C. Control soil tanks were replicated 4 times and chilled tanks 5 times, with 34 seedlings planted per tank. The predicted values for hypocotyl length were obtained by use of the Gompertz equation, after substituting parameters derived for each set of data by means of an iterative non-linear least squares procedure. The parameters derived for the control population were A= 3.8949, b= 1.7763, and c= 1.1909; for the chilled population A= 3.8157, b= 1.8236, and c= 1.4924. A comparison of these parameters reveals that 1) the maximum (potential) hypocotyl length is largely unaffected by this chilling treatment, 2) the weighted mean relative growth rate was higher in the chilled seedling population, and 3) the chilled seedlings reached their point of maximum growth rate approximately 29 hr. after the controls did. It appears that this equation provides an excellent means of quantitating shifts in hypocotyl growth following a chilling treatment (or any other stressful situation).

The flexibility of the Gompertz equation for this type of study appears to be excellent. It has been applied to the array of hypocotyl elongation data used by Wanjura to verify his seedling emergence model (54 data sets obtained at various combinations of constant soil temperature, soil moisture, and soil compaction) and found to provide a good-to-excellent fit in all cases. Predictable shifts occur in the three parameters in response to changes in each of the soil factors, indicating that the equation should be adaptable to a step-input approach to simulating fluctuating

Hypocotyl growth in pregerminated cotton seedlings grown at 20C, with or without a 7C chilling treatment at 24 to 48 hours after planting.

Time (days)	Hypocotyl length (cm) of control seedlings			Hypocotyl length (cm) of chilled seedlings		
	Observed	Predicted	Obs.-pred.	Observed	Predicted	Obs.-pred.
4	1.0	1.0	0	-	0.3	-
5	1.6	1.6	0	0.8	0.8	0
6	2.2	2.2	0	1.4	1.4	0
7	2.7	2.7	0	2.1	2.0	+0.1
8	3.1	3.1	0	2.6	2.6	0
9	3.4	3.3	+0.1	3.0	3.0	0
10	3.5	3.6	-0.1	3.3	3.2	+0.1
11	3.6	3.7	-0.1	3.4	3.4	0
12	3.7	3.7	0	3.6	3.6	0
13	3.8	3.8	0	3.6	3.7	-0.1
14	3.8	3.8	0	3.8	3.7	+0.1

soil environments. Dr. Wanjura has agreed to cooperate with us in an attempt to substitute the Gompertz equation for the autocatalytic equation now used in his hypocotyl elongation model, which should result in a greatly improved seedling emergence model. We plan to use the soil tank approach to verify the response of the "improved" model to fluctuating soil temperatures, as well as conducting appropriate field studies.

PIMA COTTON PLANTING SEED

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Seed from the Pima Regional tests in 1974 located at Safford, Salome, Phoenix (CRC) and Marana in Arizona and El Paso, Texas were saved for planting in 1975. The Pima lines were S-4, P-28, P-29 (S-5) and P-30. Seed from P-30 was not saved from Texas.

The seed were acid delinted and an equal number counted into packets for planting. Seed from Texas were divided and half treated with adenosine monophosphate (AMP) or cyclic adenosine monophosphate (CAMP). The seeds were planted at Phoenix, Marana and Safford and emerged seedlings counted twice weekly until the count remained constant. The results are presented below.

Percent Final Emergence

Location of Test

Seed Source		Safford	CRC	Marana	Avg.
Safford	P-28	54.0 abc	41.0 ab	56.9 ab	50.6 ab
	P-29	49.3 abc	62.0 ab	48.4 a	48.5 ab
	P-30	59.2 abc	61.3 ab	71.3 ab	64.0 ab
	S-4	68.8 bc	52.5 ab	55.2 ab	58.8 ab
Avg.		57.8	54.2	58.0	55.5
Salome	P-28	53.4 abc	51.6 ab	56.3 ab	53.8 ab
	P-29	42.4 abc	62.0 ab	63.0 ab	55.8 ab
	P-30	56.0 abc	68.6 ab	72.9 ab	65.9 ab
	S-4	51.0 abc	67.6 ab	40.7 a	53.1 ab
Avg.		50.7	62.4	58.2	57.2
CRC	P-28	49.2 abc	62.9 ab	46.7 a	53.0 ab
	P-29	70.3 c	55.6 ab	64.8 ab	63.6 ab
	P-30	48.9 abc	80.8 b	72.1 ab	67.2 ab
	S-4	62.5 abc	74.0 b	60.1 ab	65.5 ab
Avg.		57.7	68.3	60.9	62.3

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