ACCUMULATED TEMPERATURE AND RAINFALL AS MEASURES OF NEMATODE DEVELOPMENT AND ACTIVITY

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Because the females of sedentary root endoparasitic nematodes are able to obtain an uninterrupted supply of food and water, temperature is the factor determining their rate of development in a country like the British Isles where climatic extremes are not experienced. When accumulated temperature above an assumed basal development temperature of 4.4° C is plotted against time, the curves produced closely resemble the curves for the development of Heterodera schachtii on sugar beet. The activity of root ectoparasitic nematodes is influenced by temperature and rainfall. The time during which nematodes are active following rainfall is proportional to the amount that has fallen. An index of activity was derived from accumulated temperature and rainfall and tested against the area of sugar beet reported as stunted by Trichodorus and Longidorus from 1963 to 1974. A significant correlation was obtained between log area stunted and the index calculated over a 5 week period embracing the month of May, but not between log area or accumulated rainfall alone. Temperature and rainfall data used in studying the development of H. schachtii and the activity of Longidorus and Trichodorus were from single weather stations distant from the infested fields. In both studies diurnal temperature fluctuations were disregarded because they are usually small 5 to 10 cm below the soil surface. For nematodes active in the soil surface where diurnal fluctuations are sometimes large, the mean temperature would underestimate the rate of activity or of development because of the Q10 relationship between temperature and rate.

Root endoparasites

After entering the roots of their host plants and beginning to feed, the larvae of sedentary root endoparasitic nematodes such as Heterodera spp. which become females are able to obtain an uninterrupted supply of food and water until they mature and die. Therefore the rate at which they develop is a function of the temperature. Diurnal temperature changes 10 cm below the soil surface are small and can usually be disregarded (Jones, 1974, 1975) but soil temperatures fluctuate from day to day with changes in the prevailing weather, the trend being upwards in Spring and Summer and downwards in Autumn. The rate of growth or development of an organism, R, at a temperature T, is frequently written

\[ R_T = R_Q \frac{T - T_o}{T_o} \]

where R is the rate of growth at some reference temperature. \( T_o \) and Q are constants; Q has a value between 2 and 3. For many agricultural purposes, however, it is more convenient to rewrite this as a first approximation as

\[ R_T = R (T - T_o) k, \text{ say } (T - T_o) k' \]  

(1)
where $k$ is a temperature coefficient, and $T_b$ is the basal temperature below and at which growth is effectively zero. Over a short period, growth is essentially the product of the rate and time and, at a given stage, the development is the sum of all these products over the whole growth period:

$$ D = k' \sum T_n (T_n - T_b) $$

where $T_n$ is the mean daily temperature and $T_n - T_b$ the effective temperature which is summed for $n$ days. Hence plotting $\sum (T_n - T_b)$ against time should produce curves that resemble the development of *Heterodera* females or that of any other root endoparasitic nematode with similar habits.

In Fig. 1, lower curves, the development of *Heterodera schachtii* females on sugar beet sown at intervals is plotted against time from March to November. Development is assessed in arbitrary units derived from the stage reached between root invasion and maturity. Details are in Jones (1950), the only change made being that invasion is assumed to have begun half way between planting and seedling emergence (germination). When the observations were made in 1946 weather data were not taken on the site. Soil temperatures at 0900 hr 10 cm deep have since been obtained from the nearest weather station (Santon Downham, Suffolk) and accumulated effective temperatures plotted for the same intervals (weeks) as those used in measuring development. Basal development temperature was assumed to be 4.4°C. Results are in Fig. 1, upper curves.

The resemblance between the upper and lower curves of Fig. 1 is remarkable considering the distance between the site of observations and the weather station (50 km), the crudity of the criteria used to measure nematode development and the fact that females were collected from a range of depths; from rather less than 10 cm deep when plants were small and from 10 cm deep or deeper when they were large. From February to March and from September onwards seedlings germinated promptly but from May to September germination was sometimes delayed by drought. This might account for the poor fit between the two sets of curves during the earliest stage of development.

**Root ectoparasitic nematodes**

For root ectoparasitic nematodes such as *Trichodorus* spp. living about 10 cm deep, whose activities are greatly affected by moisture, the summation of effective temperature would have to be interrupted for those days when activity, host finding and feeding were curtailed or stopped by moisture deficiency. Alternatively some measure of the time over which a given rate of activity was operating would be necessary. I believe that rainfall provides such a measure. Rainfall can be summed as can temperature. The time during which nematodes are active following rainfall is proportional to the amount of rain that has fallen, large amounts taking a longer and smaller amounts a shorter time to drain away and leave the