ANALYSIS OF THE RELATIONSHIP BETWEEN TEMPERATURE AND GERMINATION OF SWEET PEPPER

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Abstract

Sweet pepper seed was sown at various temperatures. For the germination percentage (p) versus time (t) a logarithmic equation was applied viz. $p = A\ [1-e^{-k(t-t_o)}]$, in which A represents the maximum germination percentage, k is a value for the time spread in the seed population for germination and t_o is the time for the first seed to germinate. It appears that a heat sum concept could be applied for germination taking into account values of t_o. Since k was relatively constant, the time to achieve a certain germination percentage depends on a heat sum until t_o and a fixed number of hours independent of temperature. Some practical consequences have been discussed.

Introduction

In general, when the percentage of germination is plotted versus time after sowing a series of more or less S shape curves will be obtained at various soil temperatures. The time (t) necessary for 50% germination can be established with great accuracy from such a graphical representation. When t is plotted against temperature often a hyperbolic relation will be achieved according to:

$$S \text{ is } (T - T_{min}) \times t \qquad (1)$$

in which S is the calculated heat sum in degree days

T is the soil temperature in °C

Tmin is the calculated minimum temperature for germination

t is the time in days to achieve 50% germination of the seed lot.

The above mentioned equation assumes a linear relation between temperature (T) and the rate of germination (1/t) from which S and Tmin can be calculated.

Bierhuizen and Wagenvoort (1974) presented a list of these constants for various vegetables. It was demonstrated by Wagenvoort and Bierhuizen (1977) that the values obtained were relatively independent of sowing depth, seed size, cultivar and the amplitude of day and night temperature.

It was felt important to analyse the effect of temperature on germination in more detail because of various reasons e.g.

(1) It has been demonstrated that sometimes the relation between T and 1/t is not linear (Thompson and Fox, 1976). Moreover, above

an optimal temperature for germination, such a linear relation is not valid. It should be realized that the calculated Tmin is an extrapolated value often obtained far beyond the temperature range applied in germination experiences.

(2) The heat unit concept is usually based on data at 50% germination. For practical purposes, one would like to predict germination at other percentages as well. It is important to know whether S only or also Tmin will change at various germination percentages.

(3) A heat unit does not give any information regarding the time spread in germination. From a practical point of view this spread should be small in order to obtain an equal stand of the crop.

(4) A selection on genetical differences in a seed lot might be indicated by the frequency distribution of that seed lot.

In order to analyse in more detail the effect of temperature on germination, experiments were carried out with sweet pepper seed.

Material and methods

Sweet pepper seed cv. Bruinsma Wonder was sown in small containers filled with sand and covered with a thin sandy layer directly after sowing. The containers were placed in rooms with a constant ambient temperature. A series of 10 temperatures were used in the experiment viz. 14, 15, 17, 19, 23, 26.5, 29, 30, 32 and 34°C. Each treatment consisted of 100 seeds in 5 replicates. Because of the small interval between each subsequent temperature, all temperatures were read several times a day from which the average daily value was calculated. The containers were illuminated with TL fluorescent tubes during 24 h and kept moist with regular spraying of water.

The seed was assumed to be germinated when the root showed a small bend. The germinating seeds were counted and taken away at regular intervals during day and night. During these measurements the sandy layer was partly removed.

Results and discussion

The following equation after Milthorpe and Moorby (1974) was applied:

$$p \text{ is } A\,[1-e^{-k(t-t_o)}] \text{ in which} \quad (2)$$

p is the germination percentage at any time t

A is the maximum germination percentage

k is a value for the time spread in the seed population for germination

t_o is the time for the first seed to germinate.

In figure 1, the calculated germination percentage versus time is represented for the various temperatures. It shows that between 14 and 30°C, an increase in temperature decreases the germination period. Above 30°C, the germination period increases.

The above mentioned equation is similar to that applied by Mitscherlich, and assumes that $\frac{dp}{dt} = k\ (A - p)$. This implies that the number of germinating seeds falls continuously onwards from t_o, which is not exactly true. The constants k, A and t_o, however, give an indication of which temperature range is optimal for practical purposes. In table 1 these constants are represented for the various temperatures. The calculations were based on the data between 10 and 100% germination. It shows that the calculated value of A is high and almost 100% at any temperature.

The value of k increases from 14 to 17°C, remaining more or less constant at higher temperatures until 30°C above which it declines. The standard variation of k is relatively high. It is obvious that t_o decreases from low to higher temperatures showing a minimum value at 30°C. This means that the optimal range for germination lies between 17 and 30°C. According to t_o the most rapid germination will be achieved between 23 and 30°C. The constants A and k were used to calculate the curve between germination percentage and time.

Reciprocal values of t_o between 14 and 30°C were plotted against temperature (fig. 2) and a regression analysis for these data was carried out. The calculated heat unit S was 1278 $\pm$ 52.2 degree h and the minimum temperature for emergence Tmin was 10.3 $\pm$ 0.53°C. The minimum temperature calculated in previous experiments (Bierhuizen and Wagenvoort, 1974) was 10.9°C, which value is not significantly different from that reported in this paper. It should be mentioned that in the earlier paper, the heat sum was calculated when the cotyledonous leaves were spread, whereas in the present one the time span was taken when the roots showed a small bend. Moreover, the heat unit was calculated on the basis of 50% germination and in the present one on t_o. For this reason the calculated heat sum between these experiments is not comparable.

Since the value of k is more or less constant within the range for which the heat sum is calculated, the heat sum between 14 and 30°C is valid only until t_o. For a certain germination percentage, a fixed number of hours should be added (vide fig. 1), which time span is independent of temperature. From this preliminary experiment, it is tentative to suggest that temperature is important for initial germination only and is of far less importance later on. This suggestion could be of great importance in practice. When dry seeds are sown in the field, germination will depend to a large extent on temperature. When cold periods occur, the germination period will be long and the probability for diseases and an uneven stand will be high. However, when pre-germination is applied such as in fluid drilling, not only the emergence period in the field is shortened but the germinating seeds might be less sensitive towards unfavourable temperatures when sown in the field. Whether this assumption is valid also for other vegetables depends on the variation in k with temperature.

The frequency distribution of the data with sweet pepper did not permit a further analysis on genetical differences in the seed lot for which another equation representing a sigmoid curve was considered.

References

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Table 1 - The effect of temperature T on maximum germination percentage (A), the spread in the population (k).10^2 standard error se(k).10^2 and the time for the first seed to germinate (t_o) with standard error se (t_o)

T °C	A %	k.10^2 h	se(k).10^2 $\pm$	t_o h	se (t_o) $\pm$
14	100	1.26	0.33	334.3	30.0
15	83	3.86	1.37	255.4	18.6
17	100	5.84	2.25	213.2	12.2
19	88	5.05	1.68	148.7	19.1
23	91	7.28	2.47	92.5	9.5
26.5	100	6.43	1.92	76.0	8.3
29	100	5.68	1.44	70.6	8.1
30	92	8.09	2.59	66.3	7.2
32	100	4.57	1.25	84.0	9.8
34	100	4.14	1.09	89.2	8.4

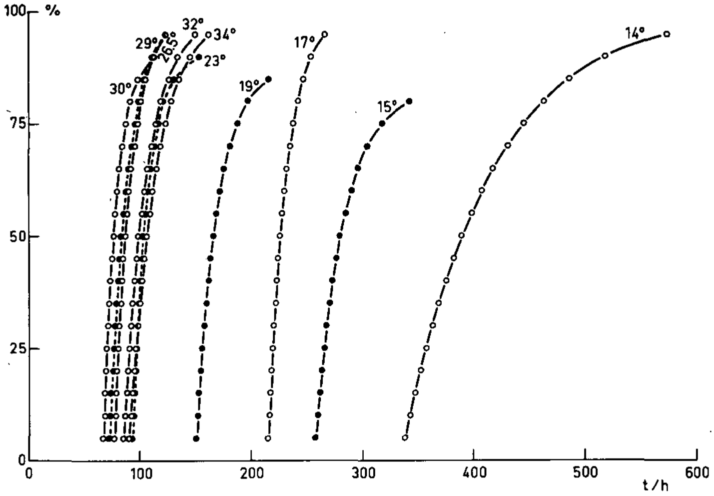

Figure 1 - The calculated relationship between time in hours after sowing and germination percentage at various temperatures.

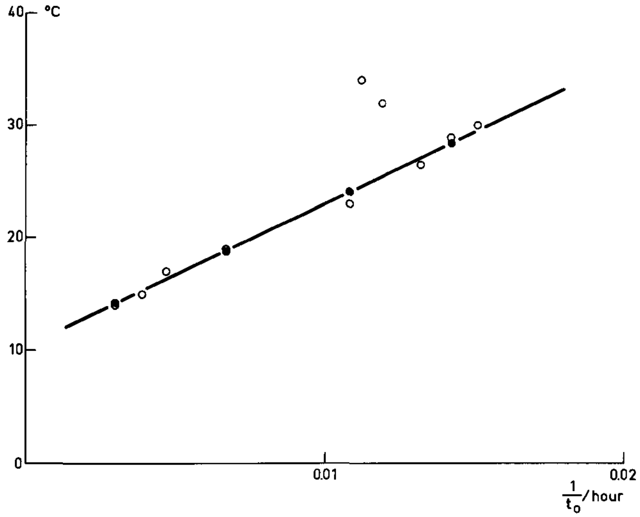

Figure 2 - Regression of temperature on germination rate (reciprocal values of t_o).