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Effects of light and temperature on lettuce seedlings[1]

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Summary

The effects of daily light energy on the growth of young lettuce plants were studied in relation to constant or diurnally changing temperature regimes. Number of leaves, length and width of largest leaf and total leaf area were primarily affected by the daily light energy, secondarily by the temperature regime, diurnal changes in temperature being preferable to constant temperature, especially at low light intensities. The optimum temperature was found to be proportional to the daily light energy.

Introduction

In the Netherlands lettuce is a profitable glasshouse crop, particularly during winter. Not much work has been done on the effect of day and night temperature on the growth of lettuce seedlings under poor light conditions. Information on the relation between light and temperature in their effect on growth is required, especially because more and more growers are specializing in the production of planting material.

Description of experiments

In the phytotron of the Department of Horticulture at Wageningen (Doorenbos, 1964) experiments were carried out to study the relation between the effects of light (intensity and/or daily quantity) and temperature on the growth of lettuce seedlings during the 4 to 6 weeks after cotyledon expansion.

There are two light sources in the phytotron, natural light in the glasshouses, and continuous artificial light by fluorescent tubes, Philips TL 57 and TL 55, 40 W, evenly mixed in a ratio 3:1, in the growth rooms. Less than 24 hours of light per day can be reached by moving the trolleys with the plants into air-conditioned dark-rooms.

Differences in *dayly light energy* on plant level were brought about in two ways:
a. By using natural light in December and January in the glasshouses (average energy of the visible light about 7 cal cm^{-2} day^{-1}) and 8 hours or 16 hours of artificial light of an intensity of 2.5 cal cm^{-2} h^{-1}, measured with a horizontal flat photometer, resulting in a total energy of 20 and 40 cal cm^{-2} day^{-1}, respectively.
b. In the second experiment only artificial light was used. There were four groups of

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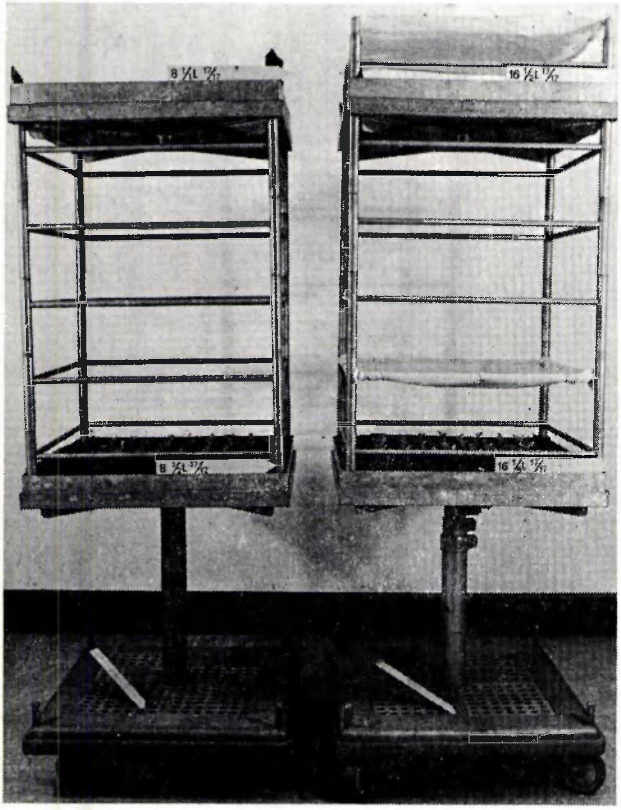

Fig. 1. Platforms with plant position 'high' or 'low', without or with cheese cloth. On lables number of hours light per day, light intensity and temperature treatment are indicated (cf. Table 1).

plants: close to the lamps ('high') or further down ('low'), both irradiated during 8 hours a day, and plants covered with cheese cloth, either in the 'high' or the 'low' position, both irradiated 16 hours a day (Fig. 1).

Table 1. Relative measurements of light energy flux density at 8 or 16 hours of artificial light, 'high' or 'low' position and without or with cheese cloth, with a horizontal light meter placed in a horizontal position or at an angle of 45° (Compare Fig. 1).

Without cheese cloth			With cheese cloth		
treatment	light energy flux density (cal cm^{-2} h^{-1})		treatment	light energy flux density (cal cm^{-2} h^{-1})	
	horizontal	45°		horizontal	45°
8 ½ L 'high'	3.6	2.7	16 ½ L 'high'	2.0	1.4
8 ½ L 'low'	1.8	1.6	16 ¼ L 'low'	1.1	0.7

Table 2 Number of leaves larger than 1 cm and length/width ratio of the largest leaf after 29 days of treatment.

Temperature (°C)			Glasshouse, December and January				Artificial light							
							8 hours light				16 hours light			
light/dark	mean 8 h light	mean 16 h light	number of leaves > 1 cm	length (mm)	width (mm)	length/width ratio	number of leaves > 1 cm	length (mm)	width (mm)	length/width ratio	number of leaves > 1 cm	length (mm)	width (mm)	length/width ratio
25/17	20	22	3.7	58	11	5.3	7.6	84	31	2.7	14.3	179	72	2.5
21/21	21	21	4.0	45	9	5.0	5.3	63	21	3.0	13.0	182	80	2.3
21/13	16	18	3.7	63	10	6.3	6.3	92	36	2.6	12.7	200	95	2.1
17/17	17	17	4.0	66	15	4.4	5.7	62	22	2.8	10.7	185	86	2.2
17/9	12	14	3.3	58	13	4.5	4.3	68	24	2.8	9.3	185	94	2.0
13/13	13	13	3.0	57	13	4.4	3.3	51	18	2.8	7.7	152	70	2.2
Mean			3.6	58	12	4.8	5.4	70	25	2.8	11.3	181	83	2.2

Table 3. Leaf area per plant in cm², after 22 and 45 days of treatment.

Temperature (°C)			Glasshouse December and January		Artificial light			
					8 hours		16 hours	
light/dark	mean 8 h light	mean 16 h light	22 days	45 days	22 days	45 days	22 days	45 days
25/17	20	22	5	6	37	920	180	1200
21/21	21	21	3	3	23	320	160	1700
21/13	16	18	7	13	37	750	180	1600
17/17	17	17	6	41	26	360	140	1300
17/9	12	14	5	30	23	240	160	1300
13/13	13	13	6	63	12	170	110	1000
Mean			5	26	26	460	160	1400

Glasshouse light in December and January. During the first 22 days in December there was hardly any growth. During the next 23 days, in the end of December and the beginning of January, it became clear that mean temperatures around 21 °C were much too high and also a light temperature of 21 °C, as found in 21/13, was worse than 17/17. The lowest day temperature used, 13/13, gave the best results, indicating that 17 °C during the light period probably was already too high at this low daily light energy.

Artificial light during 8 hours a day. Under these conditions the effect of diurnally changing temperatures was very different from the effect of constant ones. In all cases the changing temperature resulted in a leaf area which was 1.5 to nearly 3.0 times as large as the leaf area of the similar, but constant temperature.

On the other hand, differences between 25/17 and 21/13 were relatively small, and so were the differences between 21/21 and 17/17. The temperature regimes of 17/9 and 13/13 resulted in much lower leaf areas than the higher temperatures, but the effect of daily thermoperiodicity was still present.

Comparing 21/21 and 21/13, i.e. the same light temperature with lower dark temperature, the treatment with the lower dark temperature had a marked positive effect on leaf area. However, when 17/17 and 17/9 were compared, this effect was not found, probably because 9 °C is too low a temperature for leaf growth in connection with the daily light energy given by 8 hours of artificial light.

Artificial light during 16 hours a day. At this relatively high light energy the effect of diurnally changing temperature was much less pronounced than at 8 hours of artificial light. Another difference was that the beneficial effect of diurnal changes was stronger at lower than at higher temperatures. At 8 hours light the opposite was the case. After 45 days the leaf area at the highest changing temperature was even lower than at the corresponding constant temperature.

Comparing leaf areas after 45 days at constant temperatures, the temperature optimum was higher with more daily light energy: in the glasshouse it was 13/13, at 8 hours artificial light 17/17 and at 16 hours artificial light 21/21.

When the effect of light given during 45 days in the glasshouse is compared with 8 hours artificial light per day during 22 days, which is roughly the same amount of light energy, it appeared that the optimal temperature range for leaf area was high at the higher light energy per day and low at the lower light energy per day. On the other hand 45 days at 8 hours artificial light per day always showed a better effect than 22 days at 16 hours artificial light. The difference was greater at higher temperatures, and particularly strong at 25/17 and 21/13.

Second experiment

In this experiment with four light conditions and the same six temperature regimes as in the first experiment, measurements were taken after 1, 2, 3 and 4 weeks of treatment of 16, 24, 12 and 12 plants, respectively.

The largest leaf per plant was measured from the second week on. In the fourth week, in treatments 16$^1/_2$ L 'high' (see Fig. 1) at 25/17, 21/21 and 21/13 some leaves withered away. For this reason Fig. 2 presents the aereal part of plants after three weeks of treatment.

The number of leaves larger than 1 cm was higher for the 16 $^1/_2$ L plants than for the 8 $^1/_1$ L plants. This holds true for plants in 'high' as well as 'low' position. In the 4th

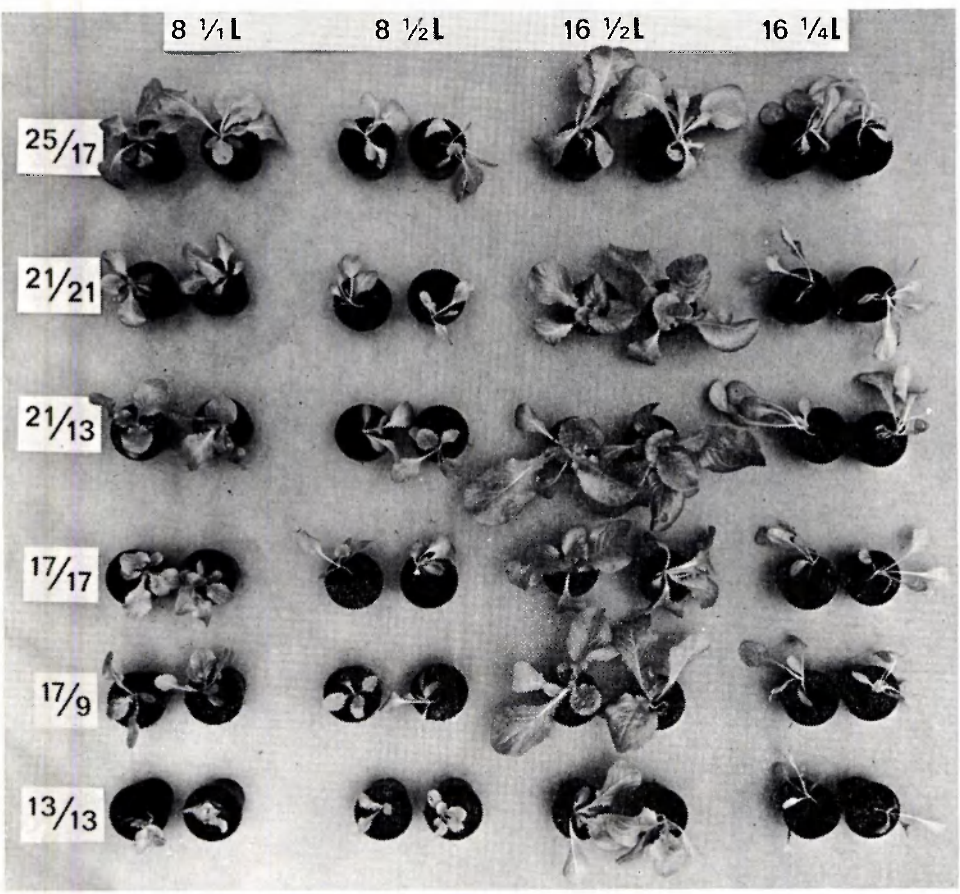

Fig. 2. Two plants of each treatment after three weeks. Light conditions at the top, temperature regimes at the left.

week the number of green leaves in the 8 $^1/_1$ L 'high' became larger than in the 16 $^1/_2$ L 'high' because some leaves of plants in the latter condition had withered.

Plants at higher constant temperatures had more leaves. The same was true at higher changing temperatures. The plants at the changing temperature had more leaves than the plants at the constant temperature of the same mean temperature group: 25/17 > 21/21, 21/13 > 17/17 and 17/9 > 13/13. Treatments at a lower temperature during the dark than during the light, 21/13 versus 21/21, 17/9 versus 17/17, lead to plants with approximately the same number of leaves.

The length of the largest leaf was mainly affected by the length of the light period, 16 $^1/_2$ L and 16 $^1/_4$ L plants having much longer leaves than 8 $^1/_1$ L and 8 $^1/_2$ L (Fig. 2).

Changing temperatures resulted in longer leaves. Lower dark temperatures had a similar effect, though less pronounced.

The width of the largest leaf was influenced by the total daily amount of light. Changing temperatures again resulted in wider leaves.

The ratio between length and with of these largest leaves is relatively low for $^1/_1$ L 'high' and $^1/_2$ L 'high' (about 1.9), which means relatively broad leaves, and high (2.4 – 2.9) for $^1/_2$ L 'low' and $^1/_4$ L 'low' plants. So this parameter was also mainly effected by the daily amount of light received by the plants. Total leaf area (Table 4) of course increases from week to week. An exception formed the 16 $^1/_2$ L 'high' treatment, where in the 4th week some leaves died at the highest temperature treatments 25/17, 21/21 and 21/13, so that the leaf area diminished.

As to the effect of light, the figures at the bottom of Table 4 show that longer but weaker light per day, 16 $^1/_2$ L 'high', resulted in a much larger leaf area than shorter, stronger light of 8 $^1/_1$ L 'high'. At 8 $^1/_1$ L 'high' and 16 $^1/_4$ L 'low' the leaf areas were roughly the same, but the type of plant was quite different (Fig. 2).

In this second experiment, the effects of temperature at the four light treatments did not show large differences. When temperatures were higher, leaf areas were larger. This was true at constant as well as changing temperatures. The difference between the effect of changing in comparison to constant temperatures was similar to experiment one: 25/17 > 21/21, 21/13 > 17/17 (except after 4 weeks at 16 $^1/_2$ L 'high'), 17/9 > 13/13 and also 21/21 > 21/13; on the other hand, there were no differences between 17/17 and 17/9, just like in the first experiment.

Table 4. Leaf area per plant in cm², after 3 and 4 weeks of treatment, at different periods of artificial light per day (8 and 16 hours), different light intensities ($^1/_1$ L, ½ L and ¼ L) and different plant positions ('high' = close to the lamps; 'low' = further down).

Temperature in °C			Artificial light in hours per day and intensity followed by plant position							
light/dark	mean 8 h light	mean 16 h light	8 $^1/_1$ L 'high'		8 ¼ L 'low'		16 ¼ L 'low'		16 ½ L 'high'	
			after 3 weeks	after 4 weeks	after 3 weeks	after 4 weeks	after 3 weeks	after 4 weeks	after 3 weeks	after 4 weeks
25/17	20	22	68	97	34	53	130	110	54	96
21/21	21	21	36	38	23	28	83	70	30	48
21/13	16	18	48	78	30	49	130	120	52	110
17/17	17	17	35	49	25	33	110	140	20	33
17/9	12	14	26	60	15	27	95	140	32	57
13/13	13	13	14	33	10	17	56	84	15	30
Mean			38	59	23	35	100	110	34	62

Discussion

In these experiments light conditions varied from about 7 to 40 cal cm^{-2} day^{-1}. This is comparable to the light conditions in glasshouses from September till April. The temperature, either constant or with a 'dark' temperature lower than the 'light' temperature, varied from 25 till 13 °C. At the lowest light condition during December and January the optimal temperature for growth was 13 °C although even at this temperature hardly any growth took place. As from November till January growth in natural light is poor, seedling production during this period could be more profitable when done with the aid of additional artificial light or in artificial light only (Janssen, 1971, 1972).

From the present study it is clear that the higher the light energy, the less critical the temperature and the smaller the beneficial effect of different 'light' and 'dark' temperatures. A temperature regime of 25/17 is good for seedling growth at the light intensity found in September and October and February and March. Older plants in the heading stage are supposed to grow better at lower temperatures. Went (1957) has shown that in tomato there also is a need for lowering the temperature as the plants become older. A night temperature lower than the day temperature, which was found to give the best results in lettuce seedling growth, is also preferable in tomato growing, especially in conditions of weak light (Went, 1961; Verkerk, 1955).

The 16 $^1/_2$ L 'high' resulted in faster growth than the 8 $^1/_1$ L 'high' treatment. This can only be explained by assuming that the plant is able to use the weaker light more efficiently than the stronger light. In fact, this was found by Brouwer & Huyskes (1968) and Dullforce (1971). This explains how 8 $^1/_1$ L 'high' could result in the same leaf area as 16 $^1/_4$ L 'low', although with a totally different habit of the plants, those in 8 $^1/_1$ L 'high' having broad, relatively short leaves, the 16 $^1/_4$ L 'low' plants with narrow, relatively long leaves. This is in agreement with the findings of Bensink (1971).

It is unknown how far the results obtained in constant light in the phytotron can be applied in natural light in the glasshouse with its large daily fluctuations and seasonal trends. Nevertheless, research in the phytotron may indicate which measures to take in practice. Earlier tomato work gave encouraging results in this respect (Verkerk, 1955).

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