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Effects of temperature and radiation on lettuce growing[1]

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Summary

An experiment is described in which lettuce was grown in spring in 9 glasshouses with different temperature regimes. It is shown that the time at which a closed leaf surface is reached depends on a specific heat sum, whereas time of harvest depends on the subsequent total radiation.

Introduction

In the last decade lettuce cultivation has been markedly improved. The introduction of new varieties, the application of carbon dioxide and the improved technical equipment in modern glasshouses have often resulted in higher yields or a shortening of the growth period even at low light intensities during winter.

Due to this development sowing, planting and harvest dates advised for practical purposes have been changed to a large extent (van der Hoeven & Groenewegen, 1970). Also more details are known at present regarding the various environmental requirements of lettuce (Anon., 1969; Klapwijk, 1970; Bensink, 1971). These requirements, however, are not the same throughout the whole growth period.

For practical purposes one may distinguish various periods in the growth cycle of lettuce, namely a period of germination, a period from germination till 100 % soil cover by the leaves and subsequently a period until harvest.

It is obvious that during germination, soil temperature, soil moisture and aeration are important environmental factors, whereas air temperature and light are often of minor importance. With favourable soil moisture conditions between field capacity and pF 2.7, germination can be predicted via the application of heat units (Geslin, 1944; Bierhuizen & Feddes, 1969; Barendrecht, 1971).

In the period from germination till 100 % soil cover light is important for dry matter production and ambient air temperature for leaf development, whereas with full soil cover light is assumed to be the predominant factor. It is often difficult to separate the effects of light and temperature in field experiments because both factors are strongly correlated. However, the ratio light/temperature in spring is much higher than in the autumn, due to the phase lag of temperature behind light.

Comparing heat sum and total radiation with yield of vegetables in both seasons, we found that light is the most important factor for greenhouse cultures in the Nether-

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lands. However, in a regression analysis it was demonstrated that both light and temperature affect yield (Bierhuizen, 1960, 1963).

In an experiment with lettuce in different glasshouses with various temperature regimes, a crop growth analysis was made from germination till 100 % soil cover and thereafter until harvest in order to evaluate light-temperature relationships in both periods.

Material and methods

On 16 February 1971 young lettuce seedlings (cv. 'Noran') were planted in 9 different glasshouses (Table 1) on an area of 1.2 m^2 at a plant distance of 20 × 25 cm. The soil was analysed for the need of fertilizer supply and normal practices were applied during cultivation. Due to frost conditions in the Dutch light many plants died and others were severely damaged. Therefore, the results of this treatment were omitted in the figures.

Weekly photographs of soil cover were made. From these photographs the percentage cover was measured by means of a planimeter. Once a week two plants were harvested from which fresh and dry weight, number of leaves, length and width of the leaf and total leaf area were determined.

Air temperature was recorded continuously. Daily values of Piche and petri dish evaporation and light intensity were measured as well. At regular moments during the day, temperature, relative humidity (with an Assman psychrometer) and light intensity (with a photocell) were measured. Records of short-wave radiation from a solarimeter were obtained from a meteorological station (at a distance of less than 2 km). A regression analysis was made between the various environmental factors (Ebbens & Koomen,

Table 1. Some data of glasshouse types.

Glasshouse	Type	Orientation	Light transmission (%)	Symbols used in graphs
1	Flower glasshouse (temp.regulation)	N-S	47	△—△
2	Flower glasshouse (temp.regulation)	N-S	46	▼—▼
3	One-bay warehouse (warm - dry)	E-W	62	●—●
4	Flower glasshouse (heavily heated)	N-S	46	▲—▲
5	Venlo-glasshouse (heavily heated)	N-S	64	▽—▽
6	Venlo-bay (lightly heated)	N-S	43	□—□
7	Flower glasshouse (lightly heated)	N-S	60	○—○
8	Venlo-bay (non heated)	N-S	65	×—×
9	Dutch light	E-W	76	

1971). The transmission could be calculated from simultaneous integrated light measurements inside and outside the greenhouse. The transmission varied between 43 and 76 % (r = 0.9), depending on shape, structure and orientation of the glasshouse (Table 1).

For each harvest period the total radiation received inside the glasshouse could be integrated as well as the temperature. In some cases a minimum temperature was inserted for the integration. All data were punched on cards and analysed by a computer. A complete survey of the results has been published elsewhere (Ebbens & Koomen, 1971).

Results

Percentage soil cover

In Fig. 1, the effect of time, radiation and heat unit on the percentage of soil cover is shown for the plants in the various glasshouses. It is evident that the variation is large when the parameters time and total radiation are applied, which means that the percentage soil cover is mainly determined by temperature. Some examples may illustrate this. At an equal heat sum in 2 glasshouses of 200 degree days, the percentage cover was equal (19 %), although the total radiation received was 2900 and 4300 cal cm^{-2}, respectively. At an equal radiation of 1600 cal cm^{-2}, the heat sum was 300 and 100 degree days, respectively, and the soil cover was 37 % and 6.5 %.

In Table 2, some results of a crop analysis are given at the data at which almost 100 % soil cover was reached in the different greenhouses. For the heated, medium heated and cold glasshouses the period from planting till almost 100 % soil cover was 33, 47 and 54 days, respectively. The variation in heat sum is small and that of total radiation large. The number of leaves is almost the same. The variation in leaf number can be ascribed to differences in heat unit. At a lower heat unit the total leaf

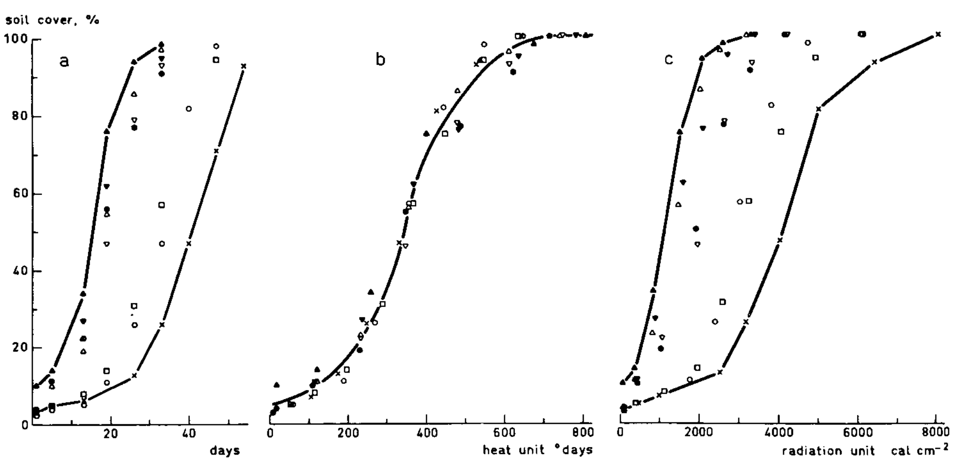

Fig. 1. The effects of time, heat sum and radiation unit on percentage soil cover by the leaves in 9 glasshouses with different temperatures and transmission values. In Table 1 the symbols for the different treatments are represented.

Table 2. Some data of lettuce at almost 100 % soil cover of the various temperature treatments.

Glasshouse No.		Days after planting	Heat unit (degree days)	Total radiation (cal cm^{-2})	Soil cover (%)	Number of leaves per plant	Total leaf surface per plant (cm^2)	Fresh weight (g per cm^2 leaf surface)	weight Fresh (g)	Dry weight (g)	Dry weight (% of fresh weight)
1		33	612	2571	96	35	2118	0.054	117	4.23	3.62
2		33	640	2763	95	33	2276	0.047	117	3.83	3.55
3	heated	33	625	3323	91	36	2169	0.054	108	4.54	4.21
4		33	677	2657	98	39	2642	0.054	147	4.98	3.38
5		33	615	3279	93	34	2042	0.056	119	4.36	3.66
6	medium	47	550	4995	94	31	2046	0.063	115	5.32	4.64
7	heated	47	551	4809	98	31	1607	0.054	86	4.38	5.10
8	cold	54	529	6502	93	31	1554	0.069	94	4.83	5.15
9		54	478	9479	83	30	1362	0.069	107	5.10	5.41

area decreases while fresh weight per unit area increases. Because of the counter-acting effect of leaf area and fresh weight per unit area, the total fresh weight is almost the same. There is a tendency towards a higher dry weight percentage at lower temperatures.

Fresh weight yield

In Fig. 2, fresh weight yield of each treatment is plotted against radiation integrated from planting till harvest. It is obvious from the set of curves that initially growth is rather slow. Above a fresh weight of about 60 g, a rapid linear rise in fresh weight occurs with an increase in radiation. In this range the lines of the different treatments are almost parallel to each other. The delay of the rapid rise at low temperatures is due to a lag in percentage soil cover, as shown for the 2 extreme cases.

Instead of the integrated radiation (Fig. 2), a correction was made in which the percentage soil cover is multiplied with the radiation received and integrated till

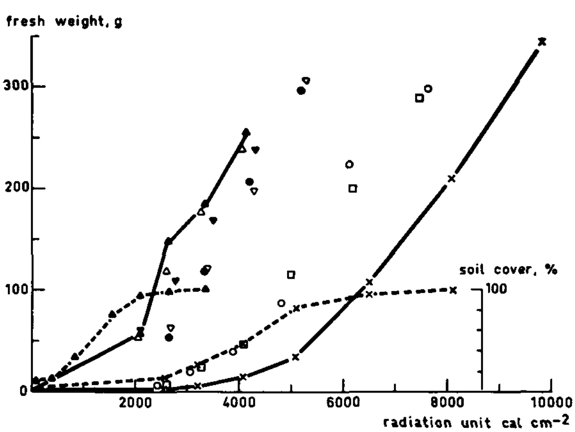

Fig. 2. The effect of total radiation on fresh weight yield in 9 glasshouses. For the two extreme treatments the progress of soil cover is indicated (- - -). In Table 1 the symbols for the different treatments are represented.

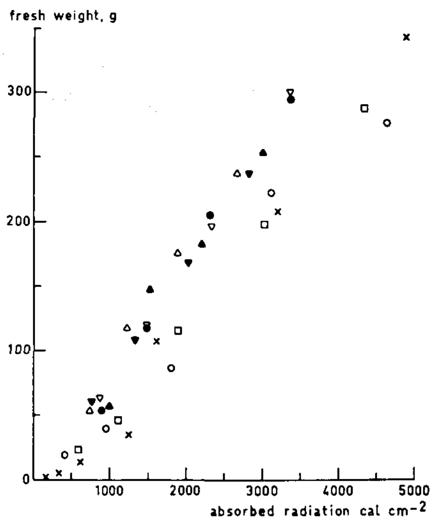

Fig. 3. The effect of radiation, corrected for soil cover on fresh weight yield. In Table 1 the symbols for the different treatments are represented.

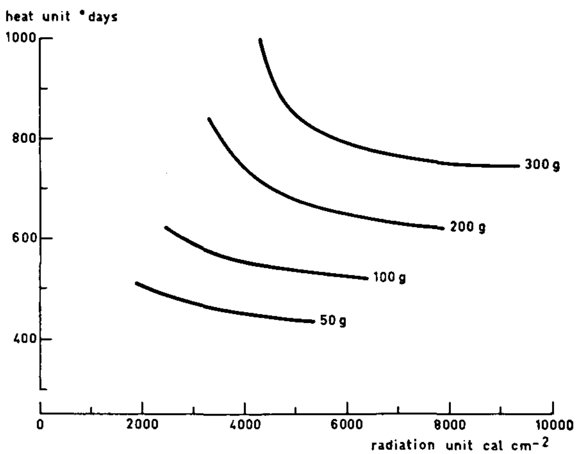

Fig. 4. The combined effect of radiation and heat on fresh weight.

harvest (Fig. 3). It shows that in this way almost a single linear relation exists, the intercept on the x-axis being in the order of 500 cal cm^{-2}.

In Fig. 4 the combined effect of heat unit and radiation not corrected for soil cover on yield is represented. It shows that the necessary radiation for a certain yield is much lower in case heating in a glasshouse is applied: a lettuce head of 300 g, for instance, can be obtained with 700 degree days and 13 500 cal cm^{-2} or 800 degree days and only 6 000 cal cm^{-2}.

Discussion

In the growth cycle of lettuce three periods have been distinguished, viz a period of germination, a period from the young seedling stage until 100 % soil cover and a period thereafter until harvest. In case soil temperature is known and soil moisture conditions are favourable, the period of germination can be predicted with great accuracy (Geslin, 1944; Bierhuizen & Feddes, 1969; Barendrecht, 1971).

Air temperature and or radiation indexes have been applied for the prediction of harvest in which the second and third period often have not been separated. It has been shown that a linear relation exists between total radiation (from planting till harvest) and fresh or dry weight yield of vegetables cultivated in spring and autumn. The line intercepts the abscissa at about 4000 cal cm^{-2} (Bierhuizen, 1960, 1963). Lettuce production in winter planting and harvest dates were also compiled from commercial growers (Anon., 1960). When calculated total radiation was represented against fresh weight again a linear relation was obtained, but with an intercept at about 2000 cal cm^{-2}. The decrease of the intercept may be due to a lower temperature and thus a slower leaf development in the period from planting until 100 % cover, which will influence light interception to a large extent and are not accounted for. However measurements of percentage soil cover by the leaves were lacking.

It has been shown in our experiments with different temperature regimes, that the soil cover depends exclusively on heat sum and not on total radiation or time (Fig. 1). In our case for 100 % soil cover about 600 degree days are required. As the temperature is higher, this heat sum is reached in a shorter period. In that case the total leaf area is greater at the expense of the fresh weight per cm^2 surface and the dry weight percentage, which are lower (Table 2). The number of leaves at 100 % soil cover, however, is almost the same.

Fig. 2, which represents total radiation against fresh weight, shows that initially fresh weight increases slightly, followed by a steep linear increase. The transition occurs at about 100 % soil cover. It is obvious that at a higher temperature the intercept of the linear increase occurs at a much lower radiation value. In case the percentage leaf cover is multiplied with the radiation and subsequently integrated, almost a single linear relation occurs for all treatments over the whole range with an intercept of about 500 cal cm^{-2} (Fig. 3).

In Fig. 4 the combined effect of heat and radiation unit is represented for practical purposes. Via heating thus increasing the heat unit, a large reduction in total radiation is already sufficient to obtain a certain yield. This result may have important practical consequences. It may be useful to induce a high temperature in a glasshouse at the beginning to reach 100 % soil cover as soon as possible, and thereafter to lower the temperature, because radiation then becomes the most important factor (Fig. 3 and 4). It should be mentioned that the experiments were carried out in spring and that in the autumn the relationships may be different.

It is obvious that experiments with temperature treatments during the second period are important to find out which temperature can be allowed without decreasing quality and heading of lettuce.

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