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Effect of light intensity, temperature and daylength on the rate of leaf appearance of maize

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Summary

Maize plants were sown periodically from 1 February until 25 November (7 series) at 16°C and 25°C in greenhouses, light intensity being about 75% of natural radiation. Part of the plants were grown in natural daylength, part in long day (17 hours).

Light intensity and temperature affected relative growth rate (RGR) considerably, daylength had a negligible effect. At 16°C RGR was about half of that at 25°C.

Not only dry matter production but also the rate of leaf appearance and the development rate (DR) have strongly been affected by light intensity and temperature. DR at 25°C was twice as high as at 16°C.

Introduction

It is well-known that light intensity considerably affects photosynthesis of maize within a wide range (Böhning and Burnside, 1956; Gaastra, 1959) and that temperature affects growth rate (van Dobben, 1962; Grobbelaar, 1963; Alberda, 1969 and Gmelig Meyling, 1969).

Other observations suggest that the rate of leaf appearance is also affected by light intensity and temperature. Daylength, moreover, might be important in the rate of development.

To gain more information about the separate effects of light intensity, temperature and daylength each within the range of natural conditions, an experiment was set out in 1968.

Experimental design and method of investigating

The maize variety C.I.V. 2 was sown peridodically (7 series) from 1 February until 25 November at two different temperatures (ca. 16°C and ca. 25°C) in greenhouses, light intensity being about 75% of natural radiation. The plants were grown in Mitscherlich pots (three plants per pot) filled with 6 litres sandy clay soil which had been supplied with the required nutrients, especially nitrogen and water supply being kept at an optimum.

Each series was sampled (two pots per sample) three times for both temperatures i.e. the first at emergence to determine the initial weight, the second at a time between appearance of the 7th and 9th leaf and the third at appearance of the male inflorescence (♂). The data from the first and second samplings were used to determine average relative growth rate from emergence to appearance of the 7th - 9th leaf, leaf area and the rate of leaf emergence. The data of the last sampling were used in determining the average relative growth rate and the development rate of the whole growing period from emergence to appearance of the male inflorescence (Fig. 7).

To study the daylength effect a number of plants from each series was grown in long day by lengthening the natural photoperiod with weak artificial light to a length of 17 hours.

During sampling the number of visible leaves were counted, the last not completely developed leaf included and estimated to a tenth part of its completely developed size (10/10); total leaf area was also measured and fresh and dry weight were determined of the up- and underground plant parts.

The radiation data were obtained from the montly surveys of the Laboratory of Physics and Meteorology of the Agricultural University at Wageningen.

The first mentioned components were determined with the following formulae:

a. average relative growth rate (RGR):
$(\log_e W_2 - \log_e W_1) / (t_2 - t_1)$, expressed in g g^{-1} day^{-1}
where W = weight and t = time;

b. leaf area ratio (LAR):
total leaf area / total dry matter; expressed in cm^2 mg^{-1} dry matter;

c. Net assimilation rate (NAR):
RGR/LAR, expressed in mg dry matter cm^{-2} day^{-1}

d. Leaf appearance rate:
total number of visible leaves / number of days, expressed as the number of visible leaves day^{-1}

e. Development rate (DR):
1 / number of days from emergence to appearance of male inflorescence (♂), expressed as development rate day^{-1}

Results and discussion

As is shown in Fig. 1 radiation in the summer months in 1968 was below the average. The longest daylength in the latitude of Wageningen (51, 97° N lat.) is 17 h. This also was the photoperiod attained by weak additional light, for half the number of plants, to study the effect of light intensity and daylength separately.

Fig. 2, in which at both temperatures the average relative growth rate from emergence to appearance of the 7th - 9th leaf has been reffected for plants in natural daylength as well as for plants with additional light to 17 h, shows that light intensity and temperature affect RGR considerably, but that daylength has a negligible effect.

At about 16°C RGR, throughout the year, will be about half of that at 25°C. Other studies confirm that maize responds sharply in this range of temperatures. Work of de Wit et al. (1970) on actual and potential production of maize in different climatological areas shows that the production of maize in the Netherlands is mainly dependent on temperature.

Net assimilation rate (NAR), which is also an important quantity in determining RGR, in maize is considerably affected by light intensity and by temperature (Fig. 3). The scatter in the points, especially at high light intensities, is therefore probably the result of that in addition to a higher light intensity in the summer months and a probably somewhat higher temperature – 1 to 2°C above that conditioned – the plants were subjected to more shading due to the higher rate of leaf development and the larger leaf sizes (Table 1). Moreover some treatments were placed among other experiments and this could also lead to small

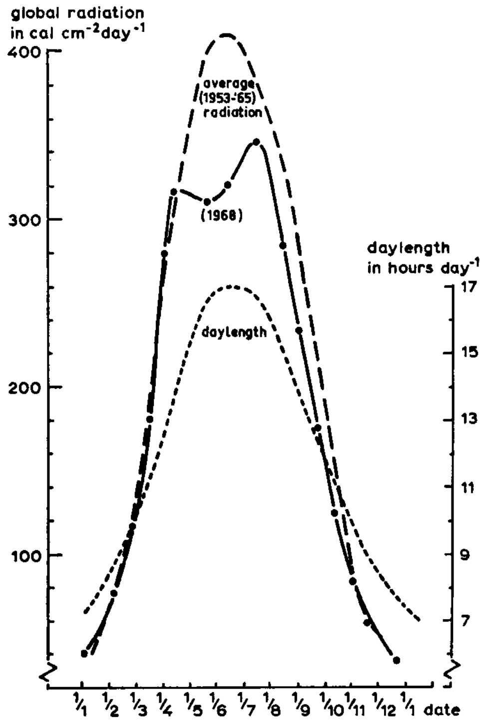

Fig. 1. Average daily global radiation and day length at Wageningen in the course of the year.
——— radiation 1968
— — — av. radiation 1953 - 1965
- - - - - - - daylength.

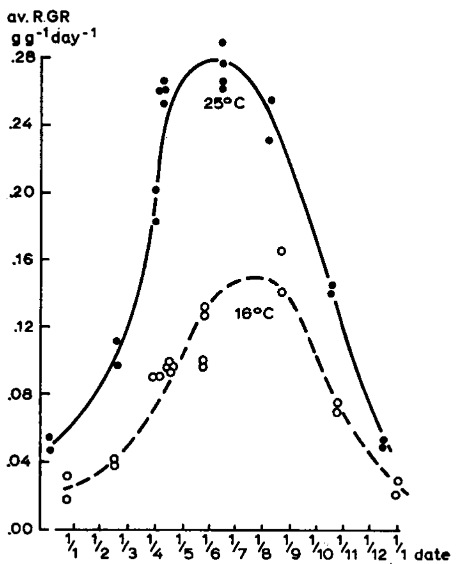

Fig. 2. Relation between average relative growth rate (emergence up to the 7th - 9th leaf stage) and growing season in the course of the year at about 16°C (o) and about 25°C (•).

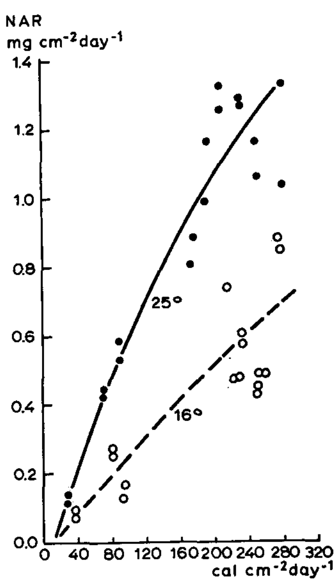

Fig. 3. Relation between average net assimilation rate (emergence up to the 7th - 9th leaf stage) and average radiation at about 16°C (o) and about 25°C (•).

Table 1. Effect of light intensity and temperature on length and width of the 5th leaf.

Average light intensity	Average 16°C		Average 25°C	
(cal cm^{-2} day^{-1})	length (cm)	width (cm)	length (cm)	width +cm)
80	28.60	2.80	53.00	2.45
280	41.20	3.88	67.80	3.82

differences in the micro climate.

Fig. 4 reflecting leaf area ratio against time shows that this is inversely proportional to light intensity, which was also demonstrated by Blackman et al. (1955) as well as in a study of onions (Butt, 1968). The value is highest at low light intensities, viz. about 0.4 cm^2 mg^{-1} dry matter, and decreases to nearly half this value during summer. The effect of temperature on LAR is clearly present at mainly higher light levels. This is also mentioned in the literature, e.g. for sunflower (Blackman, 1956).

In the winter months these LAR values could be considered as an adjustment to low light intensity, when reversely a decrease of this LAR at high light intensities would be of advantage, which cannot be simply assumed. A general sympton is that leaves increase in thickness at higher light intensities, and presumably, SLW (specific leaf weight) was higher at high light intensities than at low ones (Blackman et al., 1955).

Fig. 5 shows the effect of light intensity, temperature and daylength on the rate at which the subsequent leaves grow visible. Here, we see the same trend as in RGR (Fig. 2), almost no effect of day length (Table 2), but an appreciable effect of light intensity as well as

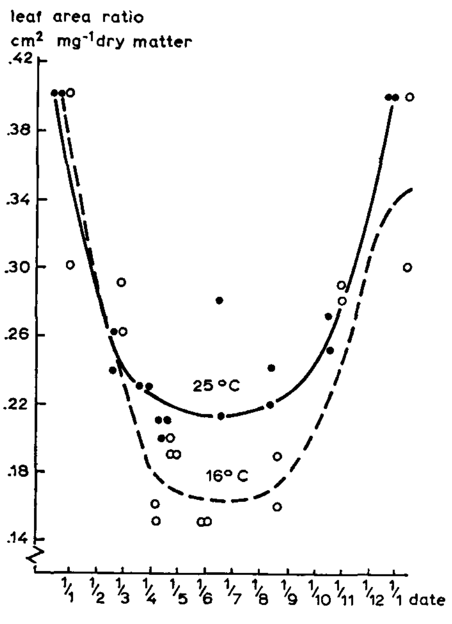

Fig. 4. Relation between leaf area ratio (emergence up to the 7th - 9th leaf stage) and growing season in the course of the year at about 16°C (o) and about 25°C (•).

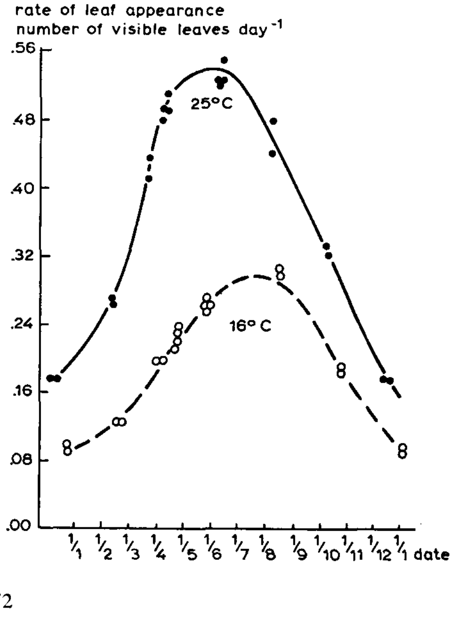

Fig. 5. Relation between rate of leaf appearance (emergence up to the 7th - 9th leaf stage) and growing season in the course of the year at about 16°C (o) and about 25°C (•).

Table 2. Effect of daylength on rate of leaf appearance up to the 7th - 9th leaf stage in the number of visible leaves per day.

About 16°C					About 25°C				
av. day-lenght (h day^{-1})	av. light intensity (cal cm^{-2} day^{-1})				av. day-length (h day^{-1})	av. light intensity (cal cm^{-2} day^{-1})			
	35	89	224	244		28	69	204	248
9.9	0.09	—	—	—	8.7	0.18	—	—	—
12.0	—	—	0.24	0.26	10.6	—	0.26	—	—
12.2	—	0.13	—	—	12.0	—	—	0.51	0.52
17.0 [1]	0.10	0.13	0.22	0.25	17.0 [1]	0.18	0.27	0.49	0.53

[1] Natural daylength supplied with artificial light till 17 hours per day.

temperature. That leaf production is proportional to light intensity was already demonstrated by Clements et al. (1929) in sunflowers, by Milthorpe (1945) in flax and by Butt (1968) in onions.

With regard to temperature effect Gallagher and Lof (1971) found a positive relation between rate of leaf appearance and temperature and similar effects were mentioned by Watson and Baptiste (1938) in fodder beets and by Khalil (1956) in wheat.

The rate of leaf appearence similar to RGR at all light intensities is at 16°C about half of that at 25°C. During the summer months a new leaf grows visible once every two days at 25°C, and once every 4 days at 16°C.

Since both RGR (Fig. 2) and rate of leaf appearance (Fig. 5) show an identical trend throughout the year, these two quantities will be closely correlated, which is shown in Fig. 6. Both at 16°C and at 25°C the points are situated almost on a straight line, and thus,

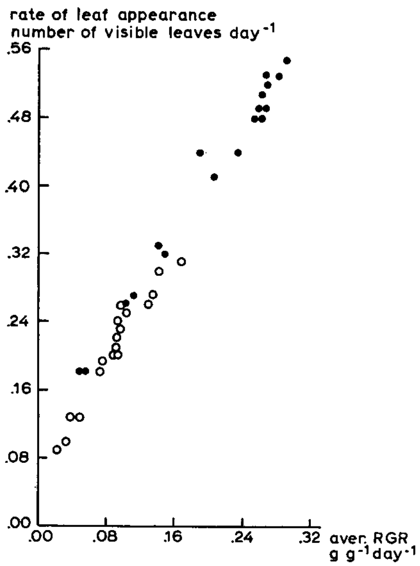

Fig. 6. Relation between rate of leaf appearance and average relative growth rate (emergence up to the 7th - 9th leaf stage at about 16°C (o) and about 25°C (•).

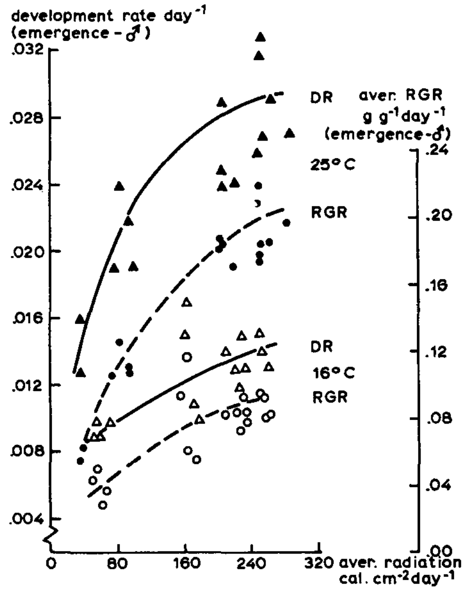

Fig. 7. Relation between development rate (DR) (emergence up to appearance of the male inflorescence (♂)) and average light intensity on the one side and average relative growth rate (RGR) (emergence up to appearance of the male inflorescence (♂)) on the other side at about 16°C (o) and about 25°C (•).

the average RGR for the maize variety used can be approximated from the rate of leaf appearance, irrespective of temperature.

Furthermore, it can be concluded that the rate of leaf appearance evidently is the visible result of the interaction of leaf area ratio (LAR) with nett assimilation rate (NAR).

Cooper (1966) in a study of *Paspalum dilatatum*, a tropical grass species, found at about 27°C similar results. Here too, lower values of LAR were associated with higher of NAR, RGR and rate of leaf appearance at increasing light intensity.

The line in Fig. 6 intersection the ordinate may be due to the first leaf being formed with the aid of reserve nutrients. Proceeding from seed there is already a reasonably well developed leaf, before there is any suggestion of weight increase.

Reproductive development tends to correspond closely to that of relative growth rate dependent on light intensity and temperature (Fig. 7). This figure again clearly shows temperature and light intensity effects on development rate (DR), whereas the effect of

Table 3. Effect of daylength on development rate from emergence to the appearance of the male inflorescence (♂) development rate per day.

about 16°C				about 25°C		
av. day-length ($h\ day^{-1}$)	av. light intensity ($cal\ cm^{-2}\ day^{-1}$)			av. day-length ($h\ day^{-1}$)	av. light intensity ($cal\ cm^{-2}\ day^{-1}$)	
	206	220	225		245	250
12.0	0.014	—	0.015	12.0	0.032	0.033
17.0 [1]	—	0.013	0.012	17.0 [1]	0.026	0.027

[1] Natural daylength supplied with artificial light till 17 hours per day.

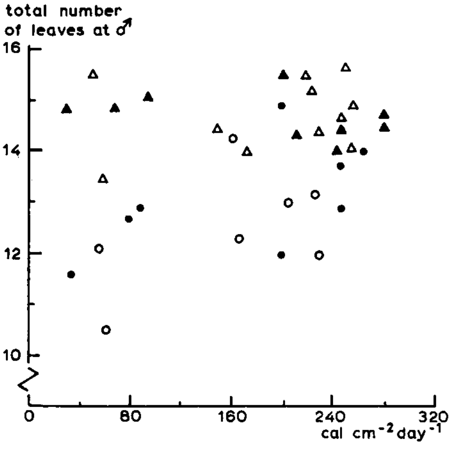

Fig. 8. Relations between total number of leaves at the moment of appearance of male inflorescence (♂) and light intensity at about 16°C (open symbols) and about 25°C (solid symbols). Circles: daylength ± 15 h day^{-1}; triangles: daylength > 15 h day^{-1}.

day length only was of some importance at higher temperatures in this experiment (Table 3).

On the total number of leaves at emergence of the male inflorescence (♂) hardly any effect could be established from light intensity or temperature (Fig. 8), which is of course reasonable in the light of leaf emergence rate as well as development rate at 25°C being twice as hight at all light intensities as at 16°C.

Daylength effect on the total number of leaves formed is also dependent on the variety and in this experiment was indeed present, but not prominent (in long day averaging 14.2 and in short day 12.8 leaves).

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References

Alberda, Th., 1969. The effect of low temperature on dry matter production, chlorophyll concentration and photosynthesis of maize plants of different ages. *Acta bot. neerl.* 18: 39-49.

Blackman, G. E., 1956. Leaf growth in relation to crop yield. In: F. L. Milthorpe (Ed.), The growth of leaves, p. 178-191. Butterworth, London.

Blackman, G. E., J. N. Black & A. W. Kemp, 1955. Physiological and ecological studies in the analysis of plant environment. X. An analysis of the effects of seasonal variation in day light and temperature on the growth of *Helianthus annuus* in the vegetative phase. *Ann. Bot. N.S.* 14, No 76: 527-548.

Böhning, R. H. & C. A. Burnside, 1956. The effect of light intensity on apparent photosynthesis in leaves of sun and shade plants. *Am. J. Bot.* 43: 557-561.

Butt, A. M., 1968. Vegetative growth, morphogenesis and carbohydrate content of the onion plant as a function of light and temperature under field and controlled conditions. Thesis Agricultural University, Wageningen, pp. 211.

Clements, F. E., J. E. Weaver & H. C. Hanson, 1929. Plant competition, p. 202-289. Carnegie Institute of Washington.

Cooper, J. P., 1966. Developmental genetics. *Rep. Welsh Pl. Breed. Stn:* 12-34.

Dobben, W. H. van, 1962. Influence of temperature and light condition on dry matter distribution, development rate and yield in arable crops. *Neth. J. agric. Sci.* 10: 377-389.

Gaastra, P., 1959. Photosynthesis of crop plants as influenced by light, carbon dioxyde, temperature and stomatal diffusion resistance. *Meded. LandbHogesch., Wageningen* 59 (13), pp. 68.

Gallagher, J. N. & H. Lof, 1971. Dynamics of leaf growth in maize. Intern *Rapp. Afd. theor. Teeltk., LandbHogesch. Wageningen*, pp. 41.

Gmelig Meyling, H. D., 1969. Effect of light energy in relation to temperature on the rates of development and growth of some agricultural crops. *Jaarb. Inst. biol. scheik. Onderz. Landb-Gewas.:* 27-36.

Grobbelaar, W. P., 1963. Responses of young maize plants to root temperatures. *Meded. Landb-Hogesch., Wageningen* 63 (5).

Khalil, M. S. H., 1956. The interrelation between growth and development of wheat as influenced by temperature, light and nitrogen. *Meded. LandbHogesch., Wageningen* 56 (7).

Milthrope, F. L., 1945, Fibre development of flax in relation to water supply and light intensity. *Ann. Bot. N.S. 9:* 31-53.

Watson, D. J. & E. C. D. Baptiste, 1938. A comparative physiological study of sugar beet and mangold with respect to growth and sugar accumulation. I Growth analysis of the crop in the field. *Ann. Bot. Lond.* 2: 437-480.

Wit, C. T. de, R. Brouwer & F. W. T. Penning de Vries, 1970. The simulation of photosynthetic systems. In: Prediction and measurement of photosynthetic productivity. *Proc. I.B.P./P.P. Tech. Meet.* (Trebon, 14-21 Sept. 1969): 47-71.