ACTA BOTANICA NEERLANDICA Vol. 4 (3), 1955

EARLY FLOWERING OF DUTCH IRISES 'IMPERATOR' V. LIGHT INTENSITY AND DAYLENGTH

BY

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(*received June 6th, 1955*)

From experiments with Iris Imperator grown under artificial light from fluorescent tubes in order to stimulate early flowering, it could be concluded that the flowering percentage is proportional to the light intensity received in a 16 hour day (HARTSEMA and LUYTEN, 1953, table 5, fig. 6). This daylength was chosen because it equals the natural daylength during the flowering period of bulbous irises (May–June) in our country.

To check these results it seemed desirable to vary the length of day. In 1952/53, therefore, the amount of light given daily was varied by using the same light intensities ($\pm$ 3.3 $\times$ 10^4 erg/sec. sphere 1 cm^2 cross section) for daylengths of 8, 10, 12, 14 and 16 hours. The amount of light given in a 16 hour day was about the same as the maximum quantity in 1950/51. As in previous years, the bulbs were treated at 31° for 2 weeks before planting them at 9° C. Each treatment comprised 32 plants (4 boxes). When the shoots were about 6 cm in length, the plants were placed in a temperature-controlled dark room in small separate compartments with white painted walls. Each compartment was illuminated by 5 40-watt fluorescent tubes, viz: 3 TL 55 (daylight) alternating with 2 TL 22 or 29 (warm red) lamps, hung horizontally over the plants. The light intensities in all experiments were measured (see 1953) with the spherical radiation meter (WASSINK and VAN DER SCHEER, 1951) and expressed in erg per second per sphere of 1 cm^2 cross section (sph. 1 $cm^2\phi$). So far this radiation meter has not been re-calibrated. The temperature was about 15°; a glass plate under the lamps and a small fan in front of it prevented any rise in temperature.

Flowering began 81 days after the commencement of the radiation treatments i.e. 151 days after planting. The results are shown in Table I, A. Although the total amount of light (calculated in calories[1] per day per sphere of 1 cm^2 cross section) ranged from 45.8 to 22.9, the flowering percentages were, unexpectedly, almost the same for the

[1] 1 erg/sec = 8.6 x 10^{-6} cal/hour.

TABLE I.
Iris Imperator: Results of experiments at 15° C.

temp. treatment before planting at 9° C	bulb weight g	transfer to light days after planting	light intensity erg/sec. sph. 1 cm² ∅	hrs per day	total daily amount of light cal/sph. 1 cm² ∅	flowering after days	% flowering	after flowering average length cm		dry weight %	number of plants
								leaves	flowerstalk		
A. 1952/53											
2 wks	14.5	70	3.3×10^4	16	45.4	81	81	76.9	58.1	124.5	26
31° C	– 19	70	3.2×10^4	14	38.5	83	90	80.4	63.6	123.5	29
		70	3.3×10^4	12	34.0	84	78	81.2	64.2	122	27
		70	3.5×10^4	10	30.1	86	90	84.8	59.8	114	29
		70	3.3×10^4	8	22.7	86	96	87.5	63.2	105	27
B. 1953/54											
2 wks	14.0	67	3.4×10^4	10	29.2	78	87	89.8	63.6	106	31
31° C	–17.0	67	3.6×10^4	8	24.8	79	68	87.8	59.0	95	31
		67	3.5×10^4	7	21.1	80	55	89.1	52.1	90	31
		67	3.3×10^4	6	17.0	83	42	87.8	53.4	86	31
		67	3.3×10^4	5	14.2	83	13	85.2	53.4	82	30
		67	2.2×10^4	10	18.9	82	23	89.6	56.6	90	31
		67	1.6×10^4	10	13.8	—	0	89.4	—	82	32
C. 1954/55											
± 20°	10.5–12.5	46	3.4×10^4	16	46.8	92	100	91.1	69.9	} 154.1	32
till 23/9	8–10	46	3.0×10^4	16	41.3	93	100	88.6	69.4		32
+ 1 wk 9°	10.5–12.5	46	3.1×10^4	12	32.0	94	100	94.7	69.8	} 138.6	32
	8–10	46	3.2×10^4	12	33.0	94	100	93.3	67.6		32
	10.5–12.5	46	3.2×10^4	8	22.0	93	91	100.3	65.7	} 115.3	32
	8–10	46	3.2×10^4	8	22.0	97	78	98.4	63.2		32
	10.5–12.5	46	3.3×10^4	6	17.0	100	22	93.9	54.6	} 102	32
	8–10	46	3.4×10^4	6	17.5	98	28	91.8	58.4		32

5 treatments. Under a 8 hour day, flowering was 96 % which is more than in any other group. However, some of the flowers did not open fully, suggesting that the limit of good flowering had been reached here. In all series a number of plants had to be discarded, because growth had stopped before flowering began (see the last row of Table I, A). These plants had poorly developed root systems. In some other plants, the roots were partially shrivelled, which may have been due to an unforeseen shortage of water. It was found later that evaporation and transpiration in the small compartments must be rather high,

especially when the lights are burning and the ventilators running at the same time. Shortage of water, therefore, may have caused the decreasing number of healthy plants, and it may also have caused the decreasing flowering percentages in the longer day experiments. Table I, A shows that under a 16 hour day the leaves and flower stalk were shorter than in the other series; this also may well represent a moisture limitation.

Since the results of 1952/53 did not show decreasing flowering percentages with decreasing daylength, still shorter daylength treatments were tried in 1953/54: viz. 10, 8, 7, 6, and 5 hours, using the same equipment. The temperature treatment of the bulbs was also the same. In this case the flowering percentages were proportional to the total amount of light received (Table I, B). The flowering percentage in a 10 hour day was not as high as expected; and this can be ascribed to the high transpiration and evaporation already mentioned. From the 1952/53 experiments it was concluded that, with a daylength of 8 hours a limit had been reached, because in some plants flowering was unsatisfactory. In 1953/54 all flowers were perfect, but the flowering percentage was lower. We may conclude, therefore, that at daylengths below 10 hours flowering is proportional to the total amount of light received per day. This result was confirmed by 3 additional experiments, in which the light intensities were varied in a 10 hour day. Flowering began 78 days after transferring the plants to the light, 145 days after planting (Table I, B) with flowering percentages of 87, 23 and 0.

In order to explain the results of these two series, it is necessary to postulate that, within the daylength range 10–16 hours, the *assimilation rate* is not proportional to the duration of radiation (HARTSEMA and LUYTEN, 1954). It was hoped to verify this hypothesis by measuring assimilation rates by means of an infra-red absorption apparatus, but so far this apparatus has not proved suitable for this purpose. We hope to be able to verify it in due course.

An attempt has been made, however, to test this hypothesis in another way, viz: by determining the average dry weight of 8 plants of each group after the completion of flowering. Dry weights were expressed as percentages of the average dry weight of 8 bulbs at the beginning of the experiment, since this initial dry weight was not the same in all experiments. In Table I, A it can be seen that the dry weights following daylength treatments between 12 and 16 hour days are about the same; but there is a marked decrease following daylengths of 10 and 8 hours. Whether the shortage of water also influenced the assimilation rate (and by it the final dry weight) cannot at present be decided. In Table I, B, a proportional decrease in dry weight with flowering percentage is apparent.

During the 1954/55 season we were not able to repeat these investigations in order to check our previous results. The growing season of 1954 was so bad that bulbs of the required size were not available. We decided, therefore, to investigate the relation between bulb size and the light requirement for good flowering under different daylengths. Previously (1953 p. 98) we had suggested that smaller bulbs would need more light for forcing than those of normal size. The bulbs were stored at ± 20° C. until September 23rd; on that date they were transferred to 9° C. Before planting on October 1st, bulbs were selected to cover a range of weights between 8 and 12.5 g (viz: 8, 9.5, 10, 10.5, 11, and 12.5 g). For each daylength treatment 8 boxes with 8 plants in each were available. At the end of the experiment, differences between boxes were so small, that it seemed best to summarize the results obtained under each daylength treatment in two groups (8–10 and 10.5–12.5 g).

On November 15th, when shoot length was at least 6 cm, the boxes were placed under the lamps at daylengths of 6, 8, 12 or 16 hours. Flowering began 92 days after transfer to the light i.e. 138 days after planting (Table I, C). Under 12 and 16 hour days, 100 % flowering resulted; under 8 hour days the flowering % was lower and in the 8 and 6 hour series flowering was proportional to the amount of light given. Little influence of bulb size is evident. The plants in 6 and 8 hour days were somewhat flaccid, those in 8 hour days were taller too. In the 6-hour plants, moreover, flowering was irregular, suggesting that they were sensitive to slight variations in environment (either external or internal). Under this daylength in 1953/54 the flowering percentage was 42, whereas for the smaller bulbs of the present year it was 22–28 % (Table I, C).

The final dry weights of the 1954/55 series increase with increasing daylength, a finding which may be ascribed to an increased water supply. The plants received more water than in previous years, and watering began earlier than previously (some 20 days before the start of shoot elongation). Root development was excellent and a more precise investigation of the water requirements over successive periods would seem desirable.

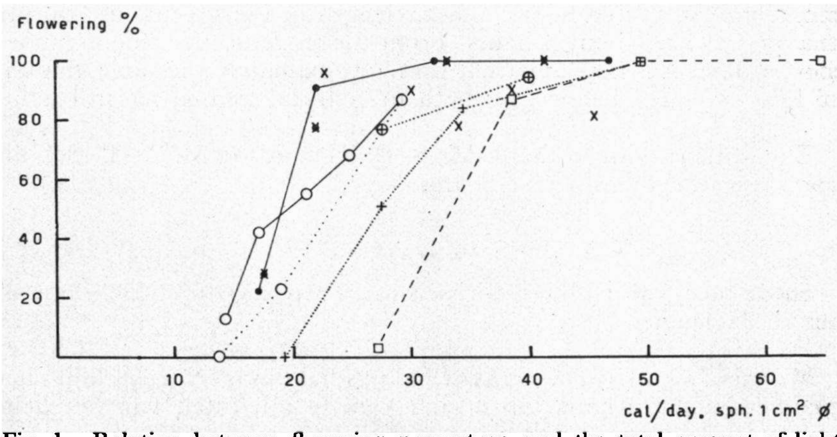

Fig. 1. Relation between flowering percentage and the total amount of light. +.........+ 1950/51, 16 hrs; ⊕.........⊕ 1951/52, 16 hrs; □-----□ 1951/52, 16 hrs 17°C; × × 1952/53, 8, 10, 12, 14, 16 hrs; ○——○ 1953/54, 5, 6, 7, 8, 10 hrs; ○.....○ 1953/54, 10 hrs; •——• 1954/55, 6, 8, 12, 16 hrs; ⁎ ⁎ 1954/55, 6, 8, 12, 16 hrs, smaller bulbs.

The relation between flowering percentage and the total amount of light in calories per day per sphere of 1 cm² ø is illustrated in Fig. 1. It should be pointed out that the solid curves drawn for 1954/55 and 1953/54 and the points plotted for 1952/53 refer to experiments in which the light quantity was varied by using different daylengths, while the dotted line for 1953/54 represents intensity variation in a 10 hour day and the dotted curves of 1951/52 and 1950/51 intensity variations in a 16 hour day (HARTSEMA and LUYTEN, 1953). The broken line of 1951/52 refers to a single experiment at 17° C greenhouse-temperature; it indicates that at this temperature the light requirement for good flowering in a 16 hour day is about the same as at 15°, but that no flowering occurs when less than 27 calories per day per sphere of 1 cm² ø is supplied.

With decreasing daylengths the curve of 1954/55 falls rapidly beyond the 22 calorie point (91 % flowering); while the bulbs of the smallest size show only slight deviations from the larger ones (✕ ✕). The 1953/54 flowering percentages are similar with the exception of the 8 and 10 hour radiations, which show a deviation to higher amounts of light. It can be seen that in 1952/53, 96 % flowering occurred at 23 cal/day. sph. 1 cm² ϕ, whereas in 1951/52, 40 cal/day. sph. 1cm² ø were needed for 94 % flowering. In 1950/51, 100 % flowering occurred at 49 cal/day. sph. 1 cm² ø.

It is of great importance, therefore, whether the total amount of light is given in a short (8 hour) or in a long (16 hour) day; the light requirement is significantly higher in the longer days. It seems that light saturation at an intensity of 3.3×10^4 erg/sec. sph. 1 cm² ø begins after 8 hours. This explains why our finding (1953 p. 102) that the high requirement of light in experiments with artificial light (about 40 cal/day. sph. 1 cm² ø) was not in agreement with the light requirement for good flowering in our greenhouse (about 21.6 cal/day. sph. 1 cm² ø, visible light); the daylength in the greenhouse during that period was about 8 hours. From the present experiments under shorter days, it is now apparent that approximately the same amount of light gives good flowering both in artificial and in natural light.

The authors wish to thank Mr S. D. Richardson M. A., B. Sc., for correcting the English text of this paper.

SAMENVATTING

Snelle bloei van Hollandse irissen var. Imperator V. Lichtintensiteit en daglengte.

Wanneer men Iris Imperator in kunstlicht in bloei trekt, blijkt het bloeipercentage afhankelijk te zijn van de intensiteit van het licht waarmee gedurende 16 uur per etmaal bestraald wordt (HARTSEMA en LUYTEN, 1953). Om deze waarnemingen te toetsen werd de duur van de belichting verminderd, terwijl de intensiteit gelijk bleef. De verkorting van de belichtingstijd tot resp. 14, 12, 10 en 8 uur gaf

vrijwel geen vermindering van de bloei (Tabel I, A), hoewel de totale hoeveelheid licht per dag tot de helft teruggebracht was. Tabel I, B toont aan dat verdere verkorting van de belichtingstijd wel tot vermindering van het bloeipercentage leidt. Belicht men gedurende *10 uur* per etmaal met afnemende lichtintensiteiten, dan ziet men ook de bloeipercentages afnemen. In 1954/55 bleek dat zelfs bollen van afnemende grootten (ter bestudering van de samenhang tussen bolgrootte en bloeipercentage) bij belichting gedurende 16 en 12 uur per etmaal alle bloeiden; bij 8 uur bloeide resp. 91 en 78 %, terwijl bij 6 uur slechts 22–28 % tot bloei kwam (Tabel I, C). Het blijkt dus, dat bij voldoende lichtsterkte ook kleinere bollen goede bloei kunnen geven, maar tevens blijkt dat ook deze kleine bollen niet gedurende 16 uur per etmaal belicht behoeven te worden, doch dat vermoedelijk met 10 uur volstaan kan worden.

Wij menen uit deze resultaten te kunnen concluderen, dat de grootte van de assimilatie niet evenredig is met de belichtingstijd (HARTSEMA en LUYTEN, 1954). Wij stellen ons voor deze hypothese te toetsen door de grootte van de assimilatie te meten met behulp van de infrarood-absorptie methode, zodra het betreffende toestel betrouwbare resultaten geeft bij metingen over lange tijdsduur. In de na de bloei bepaalde drooggewichten (zie Tabel I, A–C) zien wij aanwijzingen dat de assimilatie bij de gebruikte lichtsterkte niet evenredig met de duur van de belichting toeneemt.

Fig. 1 geeft een overzicht van de resultaten van 1950/51 tot 1954/55 waaruit men ziet dat voor goede bloei bij belichting gedurende 16 uur 40–49 cal per dag per bol van 1 cm^2 ϕ nodig waren, terwijl bij belichting gedurende 8 uur 91–96 % bloei bereikt werd met 23 cal. per dag per bol van 1 cm^2 ϕ. Dit verklaart waarom wij in 1953 (p. 102) geen overeenstemming vonden tussen de grote hoeveelheid licht ($\pm$ 40 cal per dag per bol van 1 cm^2 ϕ), die voor onze proeven in kunstlicht nodig was, en de totale hoeveelheid zichtbare straling nodig voor goede bloei in de kassen ($\pm$ 21.6 cal per dag per bol van 1 cm^2 ϕ) waar de natuurlijke daglengte slechts 8 uur bedroeg. De resultaten van de proeven in kortere dagen laten thans zien dat dezelfde hoeveelheid licht goede bloei geeft zowel in kunstlicht als in natuurlijk licht.

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