ON THE FLOWER FORMATION, THE DORMANCY AND THE EARLY FORCING OF STRAWBERRIES

H. JONKERS

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(SAMENVATTING: OVER DE BLOEMAANLEG, DE WINTERRUST
EN HET VROEGE FORCEREN VAN AARDBEIEN)

PROEFSCHRIFT

TER VERKRIJGING VAN DE GRAAD
VAN DOCTOR IN DE LANDBOUWKUNDE
OP GEZAG VAN DE RECTOR MAGNIFICUS IR. W. F. EIJSVOOGEL,
HOOGLERAAR IN DE HYDRAULICA, DE BEVLOEIING,
DE WEG- EN WATERBOUWKUNDE EN DE BOSBOUWARCHITECTUUR,
TE VERDEDIGEN TEGEN DE BEDENKINGEN
VAN EEN COMMISSIE UIT DE SENAAT
VAN DE LANDBOUWHOGESCHOOL TE WAGENINGEN
OP WOENSDAG 23 JUNI 1965

DOOR

H. JONKERS

H. VEENMAN & ZONEN N.V. – WAGENINGEN – 1965

STELLINGEN

I

In de omschrijving van fruitteelt als de teelt van eetbare vruchten aan houtige gewassen verdient het aanbeveling het woord 'houtige' te vervangen door 'overblijvende'.

II

Er wordt nog onvoldoende gebruik gemaakt van de mogelijkheden, die dagverlenging met zwak gloeilicht biedt voor een betere beworteling bij stekken van een aantal houtige gewassen.

III

Het voordeel van uitbuigen in de spilleteelt berust primair op het sparen van takken en niet op een bevordering van de bloemaanleg.

P. J. A. L. DE LINT. Stelling VIII. Diss. L. H. 1960.
H. JONKERS. De Fruitteelt 1960: 372-374.

IV

Met betrekking tot de bloemaanleg heeft de overgang van volwassen fase naar jeugdfase zeer waarschijnlijk plaats via een ééncelstadium.

V

Door WOYKE is definitief aangetoond dat de geslachtsbepaling bij de honingbij niet berust op de verhouding van aantal geslachtschromosomen en stellen autosomen, zoals MANNING verdedigde, maar zeer waarschijnlijk op een allelenserie, net als bij *Bracon hebetor* Say (= *Habrobracon juglandis* Ashmead).

J. WOYKE. J. Apic. Res. **2**, 1963: 19-24.
J. MANNING. The Microscope **9**, 1952: 93-98.

VI

Dagverlenging met zwak gloeilicht vermindert bij de vroege aardbeiforceerteelt het gevaar voor *Botrytis cineria* Pers. door de invloed op plant en schimmel beide.

R. J. LUKENS, Am. J. Bot. **50**, 1963: 720-724.

VII

De uitspraak in de praktijk dat voor de glasteelt aardbeiklonen met zwak virus meer voldoening kunnen geven dan virusvrije, geldt wel bij onvoldoende teeltbeheersing, maar is in zijn algemeenheid verwerpelijk.

W. S. ROGERS and M. G. FROMOW. Annu. Rep. East. Malling Res. Sta. 1957: 50.

Dissertatie H. JONKERS
Wageningen, 23 juni 1965

VIII

Boomkwekers dienen eerder ingelicht te worden over veranderende overheidsadviezen voor fruittelers aangaande de onderstammen- en rassenkeus dan heden het geval is.

IX

Door publikatie van oplagecijfers en verspreidingsareaal kan bij wetenschappelijke tijdschriften de doelgerichtheid voor auteurs vergroot worden.

X

De titel van het tijdschrift 'Mededelingen van de Landbouwhogeschool Wageningen' spreekt in het buitenland onvoldoende aan en als nieuwe hoofdtitel wordt aanbevolen: 'Bulletins Wageningen Agricultural University'.

XI

Aan de grotere mogelijkheden van een nieuwe aanplant in een nieuwe fruitstreek, vergeleken met de vernieuwing in een oude streek, is sociologisch en economisch nog te weinig aandacht besteed.

XII

Vestiging van tuinbouwbedrijven langs de Dedemsvaart biedt perspectief voor de welvaart en ontwikkeling van Rouveen.

XIII

De waarde, die studie aan de Landbouwhogeschool voor meisjes kan hebben, wordt in bepaalde bevolkingsgroepen onvoldoende beseft.

XIV

De vele chemische substanties, die in het milieu van de mens worden gebruikt, zijn of worden onvoldoende getoetst op hun mutagene werking.

XV

De theocratie, de staatsvorm die de erkenning uitdraagt dat alle gezag terug gaat op GOD en aan Zijn wetten onderworpen is, heeft meer visionaire dan praktische waarde bij de vormgeving van het staatkundige leven.

H. JONKERS en A. POL. Chr. Hist. Tijdschr.
9 (4) 1964: 15-32.

WOORD VOORAF

Bij het verschijnen van dit proefschrift wil ik hartelijke dank brengen aan allen die tot mijn vorming en tot het gereed komen van dit werkstuk hebben bijgedragen.

Moeder, graag wil ik dat dit stuk aan u vreugde schenkt, na de jarenlange opofferingen voor onze studie; met eerbied denk ik aan Vader terug en in dit verband aan zijn liefde voor jonge mensen, planten en boeken.

Al de onderwijzers, leraren, docenten, lectoren en hoogleraren die mij in hun kennis lieten delen dank ik daarvoor.

U, hooggeleerde Wellensiek, hooggeachte promotor, ben ik erkentelijk voor de grote vrijheid bij het onderzoek en de ruime mogelijkheden die mij gegeven werden. Uw onvoorstelbare werkkracht en tijdbeheersing hebben al in een vroeg stadium van mijn studie indruk op mij gemaakt en het is een voorrecht bij u te werken. Voor veel vruchtbare critiek ben ik u dankbaar.

Nu we spoedig uit het bedrijfsgebouw zullen verhuizen naar het nieuwe laboratorium, weledelzeergeleerde Verkerk, is er een gevoel van heimwee naar de goede jaren die voorbijgingen en de vele gesprekken die we voerden. Dankbaar ben ik voor de onbaatzuchtige, waardevolle raadgevingen.

Op ons laboratorium zijn velen mij behulpzaam geweest, waarvan ik de volgenden met name wil noemen voor hun aandeel: Henk Blok en Loes van der Werf voor technische assistentie, Sabarte Belacortu voor toezicht op de plantenteelt, vooral Arens voor de verzorging van veel proeven, Joh. van de Peppel voor elektrische installaties, Mevr. de Pauw voor aanschaf van materialen, Thea Ponger voor typewerk, Reyer Jansen en Henk van Lent voor foto's en tekeningen en Mej. Wolda voor literatuur. Het levendige gevoel van saamhorigheid maakte het werken tot een plezier.

Aan de weledelgestrenge heren Den Drijver en Gerritsen en aan de heren Blommers en Knecht wil ik mijn bewondering doen blijken voor hun werk op de drukbezochte proeftuin te Zaltbommel, ten behoeve van de Nederlandse aardbeientelers.

Tenslotte past mij bovenal dank aan de Schepper voor het privilege te mogen werken in een Natuur waarin harmonie en schoonheid zijn te vinden.

CONTENTS

1. GENERAL

1.1. Forcing in the Netherlands

The fruit of the strawberry plant is a delicacy which is grown and eaten in many areas of the world from the equator to the arctic circle (37).

Already several centuries ago gardeners of castles and country-estates in the Netherlands were able to produce ripe fruits earlier than normal (50, 110). Sometimes they were in competition to have the fruits on dates as early as possible in the year.

Although nowadays frozen and canned strawberries are available at any time of the year, there is still a place for out-of-season fresh strawberries, especially early in spring and high prices are paid for them.

The production of marketable strawberries outside their natural season will be defined as 'forcing'. This 'forcing' can be split up into 'preparing' the plant to be forced and the proper forcing. These phases occur during periods of weak growth and vigorous growth respectively.

In the Netherlands several papers on the forcing of strawberries appeared from 1930–1942 and from 1959-onwards: Roodenburg (131–137, 142), Riemens (125, 126), van den Muyzenberg (108–114), Schalk (145), PGEM (2–5, 18, 53) and Blommers and Knecht (13–16, 81, 88, 89). The 2 peaks in Dutch literature are connected with the economic conditions of the country. Forcing of strawberries is an indication of luxury. The most extensive paper was written by van den Muyzenberg in 1942 (110), but war conditions and economic reasons have prevented the use of his methods for producing fruit all the year round. However, the interest for year-round culture is reviving (14), though the procedure is not realised in practice yet.

In 1965 the most important centre in the Netherlands can be found around Zaltbommel in the 'Bommelerwaard'. One grower has even built a greenhouse of 3000 m^2 for this culture (13). In 1963 there were 138 ha with strawberries under glass (52).

Prices in early spring are rather high, see figure 1. This shows 2 irregular points at the beginning of the season, which are due to the delivered amounts of product, being too small for wholesalers.

The economical prospects for forced strawberries are good (54) and an estimated increase of 600 new greenhouses for this culture seems to be justified (52).

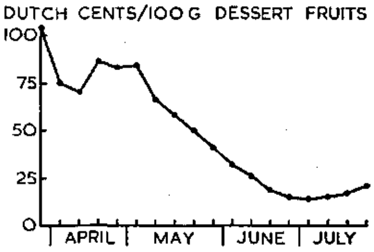


Figure 1. Average auction prices at Zaltbommel from 1961–63.

1.2. PROBLEMS ON FLOWERING, DORMANCY AND FORCING

If forcing in a heated greenhouse starts before the 3rd week of January, plants often fail to grow well. In practice this has been ascribed partly to the state of dormancy, which would not be ended by that time. Experiments were carried out with artificial chilling of the cv. 'Deutsch Evern' in Zaltbommel during 1957. This was thought to break dormancy, though research, up to then, had not given a clear answer on the question of how much chilling was needed (110, p. 65; 125, 126, 136). But after 2 years it was concluded (15), that no positive reaction to chilling could be found. Just at that time (142, 145) the difficulties were overcome by daylength extension with weak incandescent light, which promoted elongation of leaf petioles and fruit trusses. This is used in practice nowadays and has made it possible to start on the 15th of January (2–5, 18, 53). However, the production did not increase much.

The problem of scientific interest remained, whether the dormant period of the early cv. 'Deutsch Evern' could be influenced by a chilling period, especially since GUTTRIDGE (60), VOTH and BRINGHURST (174) and BRINGHURST, VOTH and VAN HOOK (26) had shown that chilling gives an invigorating effect, be it with other cultivars.

This was the beginning of the experiments reported here, which also tried to answer related problems on flowering and 'earliness' in forcing, viz.:

a. What are the special characteristics of an early cultivar?
b. Is flower induction in the strawberry plant due to the disappearance of an inhibitor, to the production of a floral stimulus or to both?
c. What is the influence of a chilling-treatment on the flower initiation of vegetative and generative plants?
d. Does a dormant period exist in 'Deutsch Evern'? Can it be broken by chilling? How much chilling is required? Can this chilling be replaced by long days, by sprays with gibberellic acid, or by both?
e. Can successful forcing start before the 15th of January each year?

1.3. MATERIALS AND METHODS

Cultivars. As an early cultivar the old 'Deutsch Evern' was often used and in some cases the newer 'Glasa'. These, and the later cultivars, sometimes used, are octoploids and described in detail in 123. In experiment 14, diploids were used, viz. *Fragaria vesca*, cultivars 'Baron von Solemacher' and 'Rügen'. In most experiments young certified runner plants were obtained in July from commercial nurseries.

Planting. The young plants were put in clay-pots of 16 or 20 cm diameter. Steamed potting soil was used. Only occasionally extra fertilizers were given.

Conditions of growth. Many experiments were carried out in a greenhouse with 3 compartments, which could be heated independently to temperatures above those in the open. Some experiments were done wholly under artificial light conditions, in a shed, or in growth cabinets, described in details by GERMING (51, see his figures 1–3 and 8), and were kindly placed at my disposal.

Light conditions. Extension of the daily light or interruption of the night was done by incandescent bulbs of 25, 40 or 100 Watts, mounted in small reflectors of white enamel at their inner side. These lamps were usually 50–60 cm above the benches with plants and 75 cm from each other. In one case HPL-lamps were used. Fluorescent light was given from tubes mounted with five in one rack of 60 × 150 cm, with the tubes at distances of 12 cm each.

Chilling. Plant chilling was given at 2, 5 or 8 °C in cold storage rooms, where potted plants were placed in benches filled with peat. The duration and quality of the light during the cold period will be described when discussing the experiments in question. Seed vernalization was applied to germinated seeds in Petri dishes, on wet filter paper. The dishes were placed at 5 °C and received 8 hours of fluorescent light of weak intensity.

1.4. ABBREVIATIONS AND SYMBOLS

The following abbreviations and symbols, beyond the standards, will be used:

CL = continuous light
cv. = cultivar
d. = days
GA_3 = gibberellic acid
IL = incandescent light
-L = without extra light
LD = long day
SD = short day
TL = fluorescent tube light
w. = weeks

2. FLOWER FORMATION

2.1. IN NATURE

During 1960 young runner plants, nearest to the mother plants in the field, were fixed in alcohol-formalin at weekly intervals from September 15 to November 30. The flower formation in the main crown was studied under a dissecting microscope. The stages of development of the first flower of the inflorescence, as described by VAN DEN MUYZENBERG (110, p. 8), are followed and these are comparable to those of other research workers (30, 147, 175). The stages are shown in plate 1. Originally there were differences from plant to plant. On average, stage II was reached by September 22 and stage VIIb by October 28, with the transitional stages on dates in between.

The first stages of flower formation have often been described and for reviews see 30, 33, 110, 175. In the temperate zones of the northern regions these first stages are found between August 20 and September 20. According to ROODENBURG (136) the cv. 'Deutsch Evern' starts between August 15 and 30, with variations of 3 weeks from one year to another. Some workers have found a sudden change, others a gradual development. The very first stage cannot be recognized easily, as it belongs to a continuous process of development (76).

CHRISTOFF (30) has found that pollen grains are not formed in the open before March 15. His remarks that petails remain rather small for a long period, can be approved of.

Absence of flowering in spring leading to 'blind plants' is seldom described and occurs only after special treatment as: transplanting, cold treatment, frost damage or when growing seedlings (38, 48, 67, 85, 129, 181).

During 1961 and 1962 experiments 1 and 2 were carried out to see whether early cultivars, as used in forcing, are starting first with fruit bud formation and also to learn from which stage of development forcing can lead to a complete fruit truss.

Experiment 1. In 1961 young runner plants of 7 cultivars were potted on July 20 and placed in the open. At weekly intervals, from August 17 to October 15, four plants were fixed for dissecting and four plants were forced at 21°C in LD. For each group of forced plants, the observations on fruit bud development were continued during 7 weeks. From table 1 it is clear that:

a. After a later date of plant treatment more plants became generative (except from 28/9 to 5/10). However, this increase was very variable per cultivar and plant treatment. This points to individual plant differences.

b. In comparing the figures, which are underlined, it can be seen that in 4 cultivars all plants were generative earlier in the forcing-treatments and in 2 cultivars the date was the same for both treatments.

c. There is no close correlation between season of fruit ripening and start of flower initiation. Nevertheless the late cv. 'Jucunda' is very late in flower initiation.

TABLE 1. *Experiment 1.* Number of plants (out of 4) with a fruit bud, in 7 cultivars of different season of fruit ripening. Studied in fixed material or by greenhouse forcing for 48 days from the indicated dates in 1961.

Cultivar	Ripening	Treatment	Date of plant treatment								Total
			August			September				Oct.	
			17	24	31	7	14	21	28	5	
Deutsch Evern	early	fixed	0	0	0	2	0	3	4	4	13
		forced	0	0	0	0	1	4	$\overline{4}$	4	13
Glasa	early	fixed	0	0	1	2	1	$\overline{4}$	4	4	16
		forced	0	1	0	2	4	$\overline{4}$	4	4	19
Jucunda	late	fixed	0	0	0	0	$\overline{2}$	0	1	0	3
		forced	0	0	1	0	0	0	1	0	2
Redgauntlet	middle	fixed	0	2	4	3	2	4	4	4	23
		forced	2	4	$\overline{4}$	4	4	4	4	4	30
Regina	early	fixed	0	$\overline{0}$	3	2	2	4	4	4	19
		forced	1	2	3	2	4	$\overline{3}$	4	4	23
Senga-Sengana	middle	fixed	0	0	1	2	$\overline{3}$	2	4	4	16
		forced	0	2	0	2	0	2	$\overline{4}$	2	12
Talisman	late	fixed	0	0	0	2	2	4	$\overline{4}$	4	16
		forced	0	1	1	1	2	$\underline{\overline{4}}$	3	4	16
		total	3	12	18	24	27	42	49	46	221

TABLE 2. *Experiment 2.* Number of plants (out of 8) with a fruit bud, in 7 cultivars of different season of fruit ripening. Studied in fixed material or by greenhouse forcing for 53 days from the indicated dates in 1962.

Cultivar	Ripening	Treatment	Date of plant treatment								Total
			August		September				October		
			23	30	6	13	20	27	4	11	
Deutsch Evern	early	fixed	2	4	2	8	8	8	8	8	48
		forced	1	2	0	$\overline{6}$	8	8	8	8	41
Glasa	early	fixed	4	6	7	7	$\overline{8}$	8	8	8	56
		forced	0	4	7	7	$\overline{8}$	8	8	8	50
Jucunda	late	fixed	0	0	0	2	$\overline{7}$	8	8	8	33
		forced	0	0	0	1	2	$\overline{6}$	6	6	21
Redgauntlet	middle	fixed	0	1	6	4	8	8	8	8	43
		forced	0	0	6	4	$\overline{8}$	8	8	8	42
Regina	early	fixed	7	7	7	3	$\overline{8}$	8	8	8	56
		forced	0	0	0	3	$\overline{8}$	8	8	8	35
Senga-Sengana	middle	fixed	5	4	7	1	$\overline{7}$	7	7	8	46
		forced	0	0	0	1	6	5	6	$\overline{8}$	26
Talisman	late	fixed	6	8	8	4	7	8	8	$\overline{8}$	57
		forced	0	$\overline{6}$	2	4	4	$\underline{8}$	7	8	39
		total	25	42	52	55	97	106	106	110	593

Experiment 2. This is a replication of experiment 1, but now in 1962, with the double number of plants, potted on August 1. From table 2 it can be seen that the conclusions a and c from table 1 hold true for 1962, but conclusion b must be modified. In this year all plants of one group were generative on the same date for both forcing and fixing, or the fixed plants were first. A comparison of tables 1 and 2 shows great differences between the cultivars in the two years, especially with 'Jucunda' and 'Redgauntlet'. It is likely that individual plant differences must be related to small differences in size.

This can explain why some authors have found all plants becoming generative at the same date (76, 99), while others described that first runner plants start first (124, 143, 148), or even that a plant of medium size, in a long runner series, may be first (LESHEM, personal communication). It is sure that vegetatively propagated June-bearing cultivars and many seedlings do need a minimal leaf area for induction (83, 110) and a close correlation can be found between leaf area and number of trusses (74, 181). This will be discussed in more detail later. From the tables 1 and 2 no close correlation can be found between beginning-dates of initiation this year and season of ripening next year. WALDO (175) and CHRISTOFF (30) have shown that early cultivars do not begin late in initiating and this can be confirmed here.

2.2. SHORT-DAY TREATMENTS

When artificial SD treatments are given, what is the minimal number of cycles, needed for the first stages of bud development to be seen under a microscope and for the formation of a truss during forcing in LD? This was studied in experiment 3.

Experiment 3. During August 1961 young runner plants of 'Deutsch Evern' were grown at 21 °C in LD. SD treatments were started on September 1 at 18 °C and continued for 10, 14, ... 30 cycles, followed by fixing or forcing of the plants in LD. As soon as stage II was found, a plant was counted as generative. From table 3 it is clear that 14–18 SD cycles were necessary to get trusses during the LD aftertreatment, while 22–26 cycles were needed before initiation was seen under the dissecting microscope. Macroscopically all plants had a bud after 54 days since the start of the SD treatment.

TABLE 3. *Experiment 3.* Number of 'Deutsch Evern' plants (out of 4) with a fruit bud. Studied microscopically in fixed material or by greenhouse forcing for 48 days, after the indicated number of SD cycles at 20 °C.

Plant treatment	Number of SD cycles						Total
	10	14	18	22	26	30	
Fixed	0	0	0	2	4	4	10
Forced	0	3	4	4	4	4	19
Total	0	3	4	6	8	8	29

Some observations on the relationship between temperature and daylength were made during experiment 4.

Experiment 4. Young vegetative runner plants of 4 cultivars were grown from August 15 to December 13, 1962, at 15, 18 and 21 °C in the shortening-normal daylength or in daylength extended to 16 hours by IL. Flower formation appeared to be influenced more by daylength than by temperature, as table 4 shows. However, it decreased in 'Talisman' in –L, as the temperature increased. The results of this experiment in relation to dormancy will be discussed on p. 24.

TABLE 4. *Experiment 4.* Percentage of plants (out of 16), flowering after 120 days at the indicated temperatures. –L = natural daylength from 15/8 to 13/12/62. +L = natural daylength extended by incandescent light to a total of 16 hours.

Cultivar	15 °C		18 °C		21 °C	
	–L	+L	–L	+L	–L	+L
Deutsch Evern	100	6	100	13	100	0
Redgauntlet	100	38	100	31	94	25
Senga-Sengana	31	0	69	0	50	0
Talisman	88	0	50	0	13	0

For SD induction a minimal leaf area is necessary, as has already been mentioned. This was observed in experiment 5.

Experiment 5. During August 1961 young runner plants of 'Deutsch Evern' were grown vegetatively at 21 °C in LD. From September 1 onwards, plant series were composed with 0, 1, ... 5 or all expanded leaves. When a new leaf had expanded completely, the oldest was removed. Plants without leaves died. During 31 days, from September 29 to October 30, half of the plants were grown in SD, followed by LD. Control plants were exposed to LD permanently.

TABLE 5. *Experiment 5.* Number of 'Deutsch Evern' plants (out of 3) with a fruit bud, and number of days to the first bud. Plants were grown with an interruption of 31 days in SD, followed by LD, or in LD.

Observation	Daylength	Number of leaves					
		1	2	3	4	5	all
Number of plants with a fruit bud	SD	0	0	2	3	3	3
	LD	0	0	0	0	0	0
Number of days to first visible bud from start of SD	SD	–	–	74	64	56	53
	LD	–	–	–	–	–	–

Table 5 shows that fruit buds were only found after SD and in plants with at least 3–4 leaves. When more leaves were present, this accelerated the bud formation, probably due to a higher level of carbohydrates. In permanent LD no fruit buds were formed.

SUDDS (164, 1928), who worked with 'Howard 17', was the first to mention that accelerated fruit bud formation in the strawberry could be evoked by shortening the daylength to 8 hours. This was soon confirmed for other cultivars by DARROW and WALDO (41), EGUCHI (46, 47), GREVE (57), VAN DEN MUYZENBERG (108, 110) and many other workers. From table 6 it can be seen that the minimal number of SD cycles varies with the cultivar, but this may also be due to differences in plant age, daylength and temperatures, that were used. Both WENT (181) and ITO and SAITO (80) have found that above or below 17 °C a few cycles more were necessary.

TABLE 6. The minimal number of SD cycles for the flower induction, as mentioned in the literature.

Cultivar	Number of SD cycles	Hours of light/day	Temperatures	Reference-number	Author(s)	Year
Deutsch Evern	7–14	6–10	summer	110	VAN DEN MUYZENBERG	1942
Marshall	9	8	17°–23 °C	181	WENT	1957
Missionary	7	10	21 °C	74	HARTMANN	1947
Robinson	8–12	4–12	17°–24 °C	80	ITO and SAITO	1962
Royal Sovereign	8–10	13	summer	61	GUTTRIDGE	1958
Sparkle	20	12–14	21 °C	56	GOSSELINK	1959
Sparkle	21	11	15 °C	7	AUSTIN et al.	1961
Sparkle	15	8	20 °C	105	MOORE and HOUGH	1962

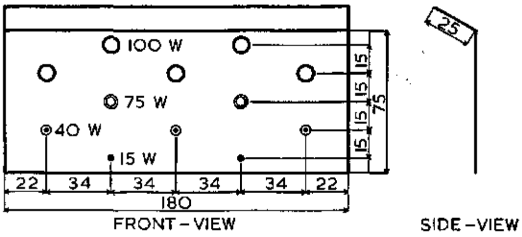
2.3. LONG-DAY TREATMENTS

In studying flower formation, control plants must be kept vegetative. In autumn this needs a high temperature and extension of the natural daylength. Experiment 6 was carried out to find the minimal light intensities which were sufficient for this purpose.

Experiment 6. From September 1, 1961, sixteen rows of 4 plants of 'Deutsch Evern' were grown at 18 °C, at regular distances from a vertical reflecting screen containing 5 lamps, type TL 65 Watt, Philips no. 29. These were 150 cm long and 14 cm apart from each other. This TL extended the natural daylength to 16 hours. The distance from the screen to the first row of plants was just as the distances between the rows. The intensities were measured with a very sensitive ammeter, connected to a spherical photometer, which has been described by WASSINK and VAN DER SCHEER (177). The intensities went down from 2500 μW/cm^2 in the first row to 78 μW/cm^2 at the 16th row. All plants had a fruit bud after 82.5 days, with a very small variance. Hence this light did not inhibit the initiation. A group of control plants in daylight, extended to 16 hours by IL at the same temperature, did not show any fruit bud after 120 days.

Some observations were also made about dormancy and these will be discussed on p. 24.

FIGURE 2.
Experiment 7. Dimensions in cm of the vertical screen, which consisted of reflecting tin-plate with incandescent lamps of varying wattage.



This experiment was repeated in 1962 with a similar screen, but now filled with incandescent lamps, in experiment 7.

Experiment 7. From August 15 to October 29, 1962, young runner plants of 'Deutsch Evern' were grown vegetatively at 21 °C in LD. From October 29, 1962 to March 23, 1963 a total of 23 rows, of 4 plants each, was used. The first row was placed at 25 cm from the screen and each row at 25 cm from the former. This vertical screen, see figure 2, extended natural daylength to a total of 16 hours. Every day, as the screen lighted up, the last 2 rows were covered as controls. From table 7 it can be seen that 4 classes of flower formation could be recognized:

Class *a:* No fruit buds were formed.

TABLE 7. *Experiment 7.* Number of 'Deutsch Evern' plants (out of 4 in each row) with a fruit bud, and the number of days to the first fruit bud, the class of flower formation and intensity of light. Rows at varying distances from a vertical screen with incandescent light, that extended the natural daylength to 16 hours.

Number of the row	Distance from the screen in cm	Number of plants with a fruit bud	Days to the first fruit bud	Class of flower formation	Intensity measured in μA
1	25	0	–	a	404
2	50	0	–	a	234
3	75	1	(130)	b	152
4	100	2	(123)	b	104
5	125	2	(90)	b	65
6	150	1	(88)	b	38
7	175	4	93	c	32
8	200	4	87	c	28
9	225	4	101	c	24
10	250	4	90	c	22
11	275	4	84	d	20
12	300	4	84	d	19
13	325	4	83	d	18
14	350	4	84	d	15
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
30	800	4	81	d	2
31	control	4	85	d	0
32	control	4	85	d	0

Class *b:* Some plants were vegetative and some became generative, but very slowly.

Class *c:* Fruit buds were formed, but more slowly than in the controls.

Class *d:* Fruit buds were formed as quickly as in the controls.

The increase of the temperature, at plant height, was measured with a transistor millivoltmeter (mV 31, Knick, Berlin-Zehlendorf). For row 1–6, nearest to the screen, this increase was in degrees C: 5, 4, 2.5, 1.5 and 0.8 respectively. This may have given an extra inhibition and it is sure that at 21 °C at least 40 μA (= 240 $\mu W/cm^2$ = 2400 $erg/cm^2/sec$ = 400 lux) are necessary to keep the plants vegetative for a long period.

Two types of TL lamps were compared with IL regarding their influence on fruit bud formation in experiment 8.

Experiment 8. Four vegetative 'Deutsch Evern' plants were placed into each of 3 compartments with continuous artificial light of TL no. 29, TL no. 55 or IL and kept there for 3 weeks. This installation was kindly placed at my disposal by the Director of the Laboratory for Plant Physiological Research of the Agricultural University of Wageningen, Prof. Dr. E. C. Wassink, and also Mr. J. Bensink deserves thanks for his help. The average day temperatures were 22.1, 21.4 and 23.1 °C respectively. The aftertreatment was given in a greenhouse with a day temperature of 18 °C, a night temperature of 13 °C and LD. Slowly the plants became generative, in the order: TL no. 29, TL no. 55 and IL. See table 8.

TABLE 8. *Experiment 8.* Effect on vegetative 'Deutsch Evern' of 3 weeks continuous light of 3 types of lamps, followed by LD at 18 °C during the day and 13 °C during the night. Four plants per treatment.

Observation	Type of lamp		
	TL no. 29	TL no. 55	IL
Plants with a fruit bud after 90 days	3	1	0
Days to budding as above	73	76	–
Days to budding in all plants	89 ± 17	126 ± 17	157 ± 7
Trusses/plant after 175 days	4.5	3.8	2.8

A marked difference was also noted in the colour of the first runners and petioles: they were red in TL and green in IL.

The importance of the light source was also demonstrated in the following experiment.

Experiment 9. Young runner plants of 'Deutsch Evern' and 'Glasa' were grown vegetatively from August 1 to December 31, 1963 at 21 °C in LD. Three plants of each cultivar then remained during 4 weeks in the greenhouse and rooms with artificial light of our recently established phytotron, as described in 44. Plants were given 8–9 hours of daylight or 16 hours of TL light no. 33, both at 9, 12, ... 24 °C, with an aftertreatment at 18 °C and LD. All plants became generative. From table 9 it can be seen that the mean number of days to budding did not differ much. The number of fruit trusses per plant tended to

TABLE 9. *Experiment 9.* Number of days to budding and number of trusses per 3 plants, at 18°C in LD, after exposure to different light and temperature treatments for 4 weeks.

Cultivar	Daylength in hours	Nature of the light	Temperature in °C						Average
			9	12	15	18	21	24	
Number of days to budding									
Deutsch Evern	8–9	natural	60	61	54	52	56	53	56
	16	TL	51	53	55	49	57	47	52
Glasa	8–9	natural	56	60	56	59	61	57	58
	16	TL	59	55	55	62	53	50	56
		Average	57	57	55	56	57	52	
Number of trusses per 3 plants									
Deutsch Evern	8–9	natural	4	6	9	12	11	8	8
	16	TL	11	12	9	15	8	13	11
Glasa	8–9	natural	3	3	3	3	4	4	3
	16	TL	3	4	5	6	7	8	6
		Average	5	6	7	9	8	8	

increase with the temperature. The higher numbers which originated during the TL treatments must be ascribed to the higher amount of total light energy in the artificial rooms, compared with the greenhouses at that time of the year. At all temperatures 16 hours of TL no. 33 were inductive and this confirms the results of experiments 6 and 8.

In many plant species the formative effect of IL is much stronger than this effect of TL, especially if given as daylight extension (17, 28, 45, 103, 144). For the strawberry BORTHWICK and PARKER (21) have found the same. Though ROODENBURG (137) did not use TL in comparing a number of lamp types, he mentioned that the spectral region around 900 mμ, being the zone of near infrared, was very important for this formative effect. In the zone between 720–1000 mμ IL contains 13.6% and TL less than 0.1% of the spectral distribution (32, p. 183, Table 1). The spectral differences of the existing TL types are rather small. For a LD effect ROODENBURG (141) would prefer a tube, giving more dark red. As such a tube is not yet in production, mixed light of TL and IL is advisable (103) for growth rooms.

Several so-called short day plants, as the strawberry, can initiate fruit buds even in continuous light, e.g. in blue light (140), or blue and green light (101).

2.4. TEMPERATURE

2.4.1. High temperatures

As will be discussed later in studying dormancy, vegetative plants were grown at 3 temperatures and 2 daylengths in experiment 10, and this also led to observations on fruit bud formation, which will be discussed now.

Experiment 10. During 1961 groups of 16 young runner plants of 'Deutsch Evern' and 'Talisman' were grown from August 1 and 'Deutsch Evern' only from September 1 at 15, 18 and 21 °C, in separate compartments of a greenhouse in normal daylight with or without extension to 16 hours by IL of about 2000 erg/cm^2/sec. From table 10 we see:

a. During natural daylength (–L) all plants flowered. In the cv. 'Deutsch Evern' the number of days to budding was about the same at the 3 temperatures and 2 dates of entering the greenhouse. In 'Talisman' the number of days was much higher, although it was reduced at a higher temperature.

TABLE 10. *Experiment 10.* Percentage of plants flowering and days to budding from 1/8/61 in 2 cultivars, as affected by the growing-period in 1961–1962, the daylength and the temperature. –L = natural daylength.
+L = natural daylength extended to 16 hours by incandescent light

Observation	Cultivar	Growing-period in 1961–1962	–L			+L		
			15°C	18°C	21°C	15°C	18°C	21°C
Percentage of flowering	Deutsch Evern	1/8–1/5	100	100	100	100	55	70
		1/9–1/3	100	100	100	100	88	63
	Talisman	1/8–1/5	100	100	100	100	100	100
Days to budding	Deutsch Evern	1/8–1/5	112	109	112	191	(240)	(235)
		1/9–1/3	107	113	109	142	(166)	(206)
	Talisman	1/8–1/5	177	166	144	208	222	213

b. With daylength extension (+L) the temperature became very important. With 'Deutsch Evern' all plants flowered at 15°C, slowly, but in fewer days when they entered the greenhouse later. Budding at 18 and 21 °C was incomplete and very slow. With 'Talisman' all plants had budded after 7 months at the 3 temperatures, without much difference in number of days to do so.

The result about runner formation will be discussed on p. 23 in its relation to dormancy.

In the U.S.A., and especially California, cool summer temperatures accelerate flower formation (9, 43, 91), and this was also shown in Japan (80). WENT's rule: A lowering of the temperature needs an increase of light intensity during a long day for the suppression of flower formation, together with the general impression that the inhibitory action of the light starts at 10–15°C (43, 80, 110, 180, 181), can explain my results.

Little is known about very high temperatures, near 30°C. ITO and SAITO (80) did not get induction in the cv. 'Robinson' after 20 cycles at 30°C, even at daylengths of 0–8 hours.

2.4.2. *Effect of low temperatures on plants and seeds*

During experiments on the chilling of dormant plants a temperature of 5°C was found to be inductive for flower formation. The question therefore arises whether strawberry plants can be vernalized, when we define vernalization as: The necessary or accelerating-effect of a low temperature for the induction of fruit buds, realized afterwards at higher temperatures.

Experiment 11. From August 1, 1961 young runner plants of 'Deutsch Evern' were grown vegetatively at 21 °C in LD. Periodically 9 plants were placed in a cold room at 3–5 °C, where they remained for 0, 2, ..., 8 w. at 16 hours of TL of weak intensity. The aftertreatment for all groups started on November 10, 1961 at 21 °C in LD. From table 11 it is clear that although 4 w. were enough for induction in all plants, curiously not all flowered after 6 or 8 w. at 3–5 °C, while the number of days to budding shows a somewhat irregular course.

TABLE 11. *Experiment 11.* Number of 'Deutsch Evern' plants (out of 9) with a fruit bud, and days to budding, as influenced by a varying number of weeks at 3–5 °C, followed by LD at 21 °C.

Observation	Weeks at 3–5 °C				
	0	2	4	6	8
Plants with a fruit bud	0	2	9	6	8
Days to budding	–	36	29	41	27

Since we know that plants can be induced to flower at 3–5 °C, the question came up whether they would react differently upon IL or TL at this temperature.

Experiment 12. Vegetative 'Deutsch Evern' plants were treated for 6 w. at 3–5 °C and 8 or 16 hours IL or TL of 6,000 and 12,000 erg/cm^2/sec respectively, measured at the top of the plants. The aftertreatment was given at 21 °C in LD.

Observations were made on bud formation for 30 d. Out of 16 control plants, at 21 °C in LD, 2 plants showed 1 fruit truss each, while the others stayed vegetative. Table 12 shows that most plants became generative, without any difference due to daylength or lamptype, given during the cold period. This experiment was repeated after reconstruction of the cold rooms, which made it possible to study the effect of continuous IL also.

TABLE 12. *Experiment 12.* Flower formation in 'Deutsch Evern', as affected by daylength and light quality for 6 w. at 3–5 °C. Aftertreatment in LD at 21 °C. Sixteen plants per treatment.

Flower formation	Daylength in h.	Light quality	
		IL	TL
Percentage	8	88	88
	16	94	100
Trusses	8	1.6	2.0
	16	2.5	2.1

Experiment 13. The cv. 'Glasa' was used, as it branches less than 'Deutsch Evern'. Vegetative plants were placed at 3–5 °C for 4, 8 or 12 weeks, with 8, 16 or 24 hours IL, or 8 or 16 hours TL. For a more regular pattern of light distribution, IL was used, obtained from Philips 'Philinea'-tubes, instead of bulbs as in experiment 12. At plant level, the energies from IL or TL were measured 2,700

and 9,000 erg/cm^2/sec respectively. The aftertreatment of the plants was given at 21–23°C in LD (daylight and HPL-lamps). Buds were counted during a period of 70 days. Plants which stayed vegetative, were dissected under a microscope at the end of the experiment, but no fruit buds could be detected. Out of 40 control plants, which had received permanent LD, during the whole period only 1 plant had a truss. From table 13 three conclusions can be drawn, viz.:

TABLE 13. *Experiment 13.* Effect on number of plants with buds, and days to budding, in 8 vegetative plants of 'Glasa', of light quality and daylength during a varying number of weeks at 3–5°C, as determined during an aftertreatment in LD at 21°–23°C during 70 days.

Light quality	Daylength	Weeks at 3–5°C			Average
		4	8	12	
Plants (out of 8) with buds					
IL	SD	8	7	3	6.0
	LD	8	3	3	4.7
	CL	8	5	2	5.0
TL	SD	2	7	3	4.0
	LD	8	7	6	7.0
	Average	6.8	5.8	3.4	
Days to budding					
IL	SD	43	37	31	37
	LD	45	36	16	32
	CL	47	37	13	32
TL	SD	43	37	32	37
	LD	45	32	26	34
	Average	45	36	24	

a. At all treatments the plants could initiate fruit buds.

b. The number of flowering plants decreased as the duration of the cold period increased, with one exception in TL and SD.

c. If the plants flowered, the average number of days to budding decreased with increasing duration of the cold period. This was particularly clear in 12 w. of cold combined with IL as LD or CL.

Some plants were left at 3–5°C for 212 d. At the end of that time buds were visible macroscopically, but only if IL was given as LD or CL. Hence realization took place at 3–5°C and for this process IL was required, given as LD or CL.

As plants can be induced at 3–5°C, would seed vernalization be effective?

Experiment 14. Germinated seeds of the diploid *Fragaria vesca* cultivars 'Baron von Solemacher' and 'Rügen' and seeds of selfed octoploid 'Deutsch Evern' were given 0, 2, ..., 10 w. of cold at 3–5°C. From the same date all groups received an aftertreatment, consisting of SD or LD (daylight extended to 16 hours by IL) in a greenhouse with an average temperature of about 20°C.

TABLE 14. *Experiment 14.* Days to budding after cold treatments of seeds, in diploid and octoploid seedlings, determined in SD or LD. Eighteen or more plants per treatment.

Origin of seedlings	Ploidy	Daylength	Weeks of cold treatment					
			0	2	4	6	8	10
Baron von Solemacher	2n	SD	115	115	116	122	130	109
		LD	63	60	61	63	62	73
Rügen	2n	SD	109	105	111	111	102	102
		LD	62	64	61	61	65	64
Deutsch Evern	8n	SD	146	127	139	141	144	141
		LD	more than 184 days					

No effect of seed vernalization was found. See table 14. In the diploids the number of days to budding was much less in LD than in SD. The octoploid seedlings made their buds in SD only and then very slowly. The meristems of the octoploids in LD were studied under a dissecting microscope after 184 d. Some generative plants were found in all groups, but no effect of seed vernalization could be detected.

The possibility to induce flower initiation in strawberry plants at 5°C was described in 1934 by EGUCHI (47), but little attention has been given to it in the literature.

In the cv. 'Kogyoku', placed for 5 w. at 5°C, EGUCHI and TAKAHASHI (49) recently have noted great individual plant differences in bud initiation. ITO and SAITO (80) showed in an elegant way that 'Robinson' did not need more than 240 hours at 9°C for induction, even if intermediate periods of 23°C were given, which however might not exceed 8 hours per day. Recently it also appeared that generative runner plants, stored for several months at low temperatures, have to be planted out in summer a few weeks earlier than normal. Otherwise they sometimes do not initiate many new fruit trusses (67, 129). This interesting feature may have to do something with the irregular flowering of the plants, as shown in table 13.

When forcing starts at different dates in winter and spring, it is of interest to know whether bud initiation stops before spring, or goes on during the short spring days in nature. According to several authors it does not stop (36, 91, 106, 115, 151, 176, 179), but others suggest that no initiation takes place after the period of winter chilling (71b, 110, 127, 130). Probably it varies with cultivar, daylength and also with winter or spring temperatures. This is known from U.S.A. regions with mild winters (151). DARROW and WALDO (43) and VAN DEN MUYZENBERG (110) have mentioned that plants, which are forced before they have had winter temperatures, flower continuously, even in LD, while plants, forced after the winter period, only flower once. Through all this, the question arises whether SD can be inductive after a cold period.

2.5. INTERACTION OF COLD AND SHORT DAY

Periodically during autumn and winter in 1961–1962 plants were forced. In experiment 15 a new SD period was given after forcing, to see whether all plants could produce the same amount of new buds.

Experiment 15. Plants of 'Deutsch Evern' were forced at 18 °C until 12/4/62 with supplementary TL for assimilatory purposes. Table 15, column 2, shows the number of trusses produced by that date and 4 plants out of each treatment are shown on plate 2. Out of each treatment 8 plants were selected. Four plants were given 8 w. of SD, followed by LD. The other 4 plants were grown constantly in LD. From table 15, column 3 it appears that practically no new fruit trusses were made after 8 w. of LD, but from column 4 it appears that plants given 8 w. of SD initiated many new fruit trusses. Plants of all forcing-dates could be reinduced to the same degree.

TABLE 15. *Experiment 15.* Formation of fruit trusses in 'Deutsch Evern' plants during a forcing-period from different dates till 12/4/62, and during 10 w. in LD, after 8 w. of SD or LD from the end of forcing. Four plants per treatment.

Initial date of forcing in 1961–1962	Number of fruit trusses per plant		
	During a forcing-period till 12/4/62	During 10 w. in LD after 8 w. of	
		LD	SD
15/9	13	0	7
30/9	12	0	9
15/10	12	0	9
30/10	12	0	13
15/11	11	1	10
30/11	8	1	8
15/12	8	1	11
30/12	5	1	10
15/1	3	2	9
30/1	4	1	7

The interaction of cold and SD was also studied in vegetative plants.

Experiment 16. Vegetative runner plants of 'Deutsch Evern' were grown during 1 month in LD at 21 °C. They were then divided into 4 groups which received the following treatments, as indicated in table 16:

permanent LD = control
6 w. of cold, followed by LD
6 w. of LD, 4 w. of SD, followed by LD
6 w. of cold, 4 w. of SD, followed by LD

All treated plants became generative. During 6 w. of cold, followed by 4 w. of SD significantly more trusses were initiated than during 6 w. of cold alone, but not significantly less than during 4 w. of SD alone. During this treatment the buds were already being formed as the number of days to budding from the start of the aftertreatment in LD was reduced sharply to 4.3 d.

TABLE 16. *Experiment 16.* Percentage of flowering, trusses per plant and days to budding, as influenced by 6 w. of cold, by 4 w. of SD or by 6 w. of cold, followed by 4 w. of SD, and determined in LD at 21 °C. Twenty 'Deutsch Evern' plants per treatment. A different letter means a significant difference ($P \geqslant 0.95$).

Treatment	Percentage of flowering	Trusses per plant	Days to budding from 1st LD
LD → LD	0	0	–
6 w. of cold → LD	100	1.2(a)	21.7
LD → 4 w. of SD	100	2.0(b)	26.4
6 w. of cold → 4 w. of SD	100	1.7(b)	4.3

Another experiment with 2 cultivars and many combinations of cold followed by SD, or SD followed by cold, failed as several control plants began to flower. This deserves further attention.

In perennial plants the formation of gibberellin-like substances during the cold period is almost generally accepted in literature. In several strawberry cultivars sprays with gibberellic acid (GA_3) seem to inhibit flower formation (70, 71f, 119, 121, 167). As GA_3 has been used in the forcing-experiments, to be described in chapter 4, the interaction of GA_3 sprays and SD on flower initiation was studied.

2.6. INTERACTION OF GIBBERELLIC ACID AND SHORT DAY

Experiment 17. Sixty young runner plants of 'Deutsch Evern' were grown vegetatively from August 1 to October 1, 1962, at 21 °C in LD. These plants were then exposed to 4 w. of SD at 18 °C. Gibberellic acid was applied in three sprays, every 2 days, either before the SD, during the 1st week of SD, during the 4th week of SD or after the SD. A concentration of 15 ppm was chosen as 0–50 ppm were often used to promote fruit truss elongation (71e, 71g, 71i, 95, 102, 121, 153, 159, 186) and 50–200 ppm can cause abnormal stem elongation (71e, 121, 167). Also 60 control plants in permanent LD were sprayed,

TABLE 17. *Experiment 17.* The influence of three sprays of GA_3 (15 ppm) before, during or after a SD treatment of 4 w., on days to budding, truss elongation and truss weight and number of open flowers. A letter in common means: no significant difference ($P \geqslant 0.95$).

Period of GA_3 sprays	Days to budding	Length of truss in cm		Weight of truss in g per 12 plants	Number of flowers per 12 plants
		Average	Longest		
No	64.2 (a)	15.9	24.7	42.5	74
Before SD	62.3 (a)	13.3	23.3	39.0	72
Start of SD	59.8 (ab)	16.6	21.9	32.0	71
End of SD	55.8 (bc)	21.6	26.0	48.0	132
After SD	54.2 (c)	21.3	31.7	76.0	204

but these plants did not flower, except 3. After 4 w. of SD all plants flowered. According to table 17, GA_3 sprays, given at the end or after SD, reduced the number of days to budding, increased the truss length, the weight of the truss and the number of open flowers. No inhibition of flower induction was found.

2.7. TRANSPORT OF AN INHIBITORY ACTION AFTER LONG-DAY TREATMENTS

It is an intriguing problem whether flower induction in the strawberry is brought about after the disappearance of a transportable inhibitor produced in LD, or by a transportable flower stimulus produced in SD, or by both. HARTMANN (74), working with runner series of the cv. 'Missionary', has found evidence for a flower promotor, but GUTTRIDGE (59, 62, 63), using runner series of other cultivars, concludes to an inhibitor system. LOCKHART (96) regretted that GUTTRIDGE did not use series of control plants, with the runner cut, after the start of the inductive treatments on mother or daughter plants. ZEEVAART (185, p. 308) has expressed scepticism against GUTTRIDGE's theory, although work of his own with strawberries was not mentioned. In the experiments 18 and 19 a contribution is given to the solution of this problem.

Experiment 18. Runner series of 'Deutsch Evern' were grown at 21°C in LD in wooden boxes. Pairs of two young plants were used, connected with a runner. The oldest will be called 'mother', the youngest 'daughter', though in fact they had nearly the same age. Three weeks of SD or LD were then given at 20°C to mother and/or daughter plant. In the differential treatments the runner was led through a groove, which was covered with cotton-wool. The results are presented in table 18. There was not much difference in leaf number (row 1). Nearly all plants given SD, made fruit buds, see row 2, but only 2 out of 6 daughter plants, connected with a mother plant in LD, did so, see column 7. This points to an inhibitory action from the mother plant, transported via the runner, as is also evident from a smaller number of fruit trusses (row 3, column 4) and a retarded bud formation (row 4, column 7). Runner production, a

TABLE 18. *Experiment 18.* Flower and runner formation induced in runner series by 3 w. of SD. Cv. 'Deutsch Evern'. The brackets mean: An average of less than 6 plants.
M = Mother plant.
D = Daughter plant.

1	2	3	4	5	6	7	8	9
	Kind of plant and daylength							
Observation	M -	D	M -	D	M -	D	M -	D
	SD -	SD	SD -	LD	LD -	SD	LD -	LD
1. Leaf number after SD	8 -	7	7 -	6	7 -	7	7 -	6
2. No. of budded plants	6 -	6	6 -	0	1 -	2	0 -	0
3. Trusses per plant	2.7 -	1.6	1.3 -	0	0.2 -	0.5	0 -	0
4. Days to budding	43 -	44	39 -	∽	(35) -	(73)	∽ -	∽
5. Runners per plant	0 -	0.3	0.2 -	3.3	2.8 -	2.2	2.2 -	3.5

typical LD effect, was promoted in the SD daughter plant, connected with the LD mother, as follows from a comparison of row 5, column 3 and 7.

In a replicated experiment with mother and daughter plants of different ages, some control plants flowered. But even under these conditions, there was no flower promoting effect of the SD treatments. In experiment 19 'Glasa' plants were used, which can be kept vegetative in an easier way than 'Deutsch Evern'.

Experiment 19. Young runner plants of the cv. 'Glasa' were grown vegetatively at 21 °C in LD in a greenhouse. They all originated from mother plants which had never flowered. The young plants were put in the open and runners were directed through cotton-wool filled grooves in wooden frames. SD treatments were given for 4 w. by putting black plastic covers upon the frames from 16.30–8.30 daily. The plants in LD obtained daylight, extended to 16 hours by IL. In half of the series the mothers and daughters were separated at the start of the SD treatments. Plants in LD kept their leaves or were defoliated besides 1 or 2 young leaves, because after complete defoliation the plants do not survive. Plants in SD were not defoliated. Some plants of this experiment are shown in plate 3. After 6, 7 or 8 w. from the first short day, 1, 1 and 3 or 1 control plant(s) and 2, 2 and 5 treated plants respectively were fixed in alcohol-formalin and dissected under a microscope, to study the stages of bud development. The observations are given in table 19 and lead to the following remarks:

a. Columns 2–7 show that most plants in the control series, with only LD treatments, inclined to bud initiation after 8 w. Under these conditions, it must be possible to detect an inhibitory or promotive action in the differential treatments, if either one would exist.

b. One LD plant in each of the combinations LD^-/LD^- (column 13) and SD^+/LD^+ (column 18) showed stage VII. For this irregular behaviour no explanation can be offered.

c. After 6 w. all plants given a SD treatment (columns 15, 17, 19, 21, 24, 26, 28, 30), had fruit buds of the stages VI or VII.

d. There is no indication of flower promotion by a SD donor (being a mother or a daughter) in a LD^+ plant (column 16) or a LD^- plant (column 20).

e. When we compare the bud stages of the SD^+ plants out of the combinations LD^+–SD^+ (column 24) and LD^+/SD^+ (column 26), there are weak indications for flower inhibition, expressed as a retardation in the SD^+ plants, which are connected with the LD^+ plants by a runner.

This result might be in accordance with GUTTRIDGE's theory on a transport of an inhibiting-substance, produced in LD.

It is likely that different systems, occurring in the cultivars used by HARTMANN (74) and GUTTRIDGE (59, 62, 63), may explain their different results. Especially as HARTMANN's cultivar could be induced by leaves in SD on a plant, of which all the other leaves were kept in LD. This is not possible e.g. in 'Deutsch Evern' as VAN DEN MUYZENBERG has shown (110).

The picture of the flower formation in the strawberry, obtained by the

TABLE 19. *Experiment 19.* The stages of bud development of individual plants after 6, 7 or 8 w. from the start of a differential SD or LD treatment, given during 4 w. to mother and daughter plants. Cv. 'Glasa'. + or – (as a suffix) = with or without leaves. – or / = runner intact or cut.

1	2 3	4 5	6 7	8 9	10 11	12 13		
	Treatments of mother and daughter plants as controls							
Observation after	LD$^+$–LD$^+$	LD$^+$/LD$^+$	LD$^+$–LD$^-$	LD$^-$–LD$^+$	LD$^-$–LD$^-$	LD$^-$/LD$^-$		
	Bud stages							
6 w.	I–I	I/I	I–I	I–I	I–I	I/$\underline{\text{VII}}$		
7 w.	I–I	I/I	I–I	I–II	I–I	I/II		
8 w.	I–II	I/II	I–I	I–II	I–I	I/I		
	II–IV	II/IV	II–I					
	IV–I	IV/IV	II–I					
14	15 16	17 18	19 20	21 22	23 24	25 26	27 28	29 30
	Treatments of mother and daughter plants							
	SD$^+$–LD$^+$	SD$^+$/LD$^+$	SD$^+$–LD$^-$	SD$^+$/LD$^-$	LD$^+$–SD$^+$	LD$^+$/SD$^+$	LD$^-$–SD$^+$	LD$^-$/SD$^+$
	Bud stages							
6 w.	VI–I	VII/I	VI–I	VI/I	I–VI	I/VI	I–VII	I/VI
	VI–I	VII/$\underline{\text{VII}}$	VI–I	VII/I	I–VII	I/VII	I–VII	I/VII
7 w.	VII–I	VII/I	VII–I	VII/I	IV–$\underline{\text{VI}}$	I/$\underline{\text{VII}}$	I–VII	I/VII
	VII–II	VII/II	VII–II	VII/II	IV–VII	IV/dead	V–VII	II/VII
8 w.	VII–I	VII/I	VII–I	VII/I	I–VII	I/VII	I–VII	I/VII
	VII–I	VII/I	VII–I	VII/I	II–$\underline{\text{VI}}$	II/$\underline{\text{VII}}$	I–VII	I/VII
	VII–I	VII/I	VII–I	VII/I	II–$\underline{\text{VI}}$	II/$\underline{\text{VII}}$	I–VII	I/VII
	VII–I	VII/I	VII–I	VII/I	II–$\underline{\text{VI}}$	II/$\underline{\text{VII}}$	II–VII	II/VII
	VII–III	VII/II	VII–IV	VII/I	IV–$\underline{\text{VI}}$	II/$\underline{\text{VII}}$	IV–VII	II/VII

phytotron experiments of WENT (181) in the U.S.A. and ITO and SAITO (80) in Japan seems to be more suggestive for the disappearance of an inhibitory action than for the appearance of a flower promoter. In the following summary the results regarding flowering are from the authors mentioned, while the results regarding inhibition have been derived:

Temperature	Flower induction	Flower inhibition
Below 9°C	Yes	No
10–15°C	In SD, and LD (partly of low intensity)	In LD of high intensity
15–25°C	In SD only	In LD
25–30°C	No (not many data)	Yes (not many data)

This makes it tentative to describe an everbearing cultivar, which probably originated as a mutation in a June-bearing cultivar (35), as a cultivar which does not produce any flower-inhibiting substance.

3. DORMANCY

When certain strawberry cultivars have been exposed to autumn days during a rather long period, low temperatures are necessary to induce good growth, which involves the formation of large leaves, long petioles, fruit trusses and runners as prerequisites for an optimal production.

The need for low temperatures became clear in the U.S.A. Growers in southern states had to buy their plants in northern regions or from cool nurseries up in the mountains, as in California, see VOTH in 158. Experimentally this stimulating-effect of cold was shown by GUTTRIDGE (60) and VOTH and BRINGHURST (174).

The state of dormancy is characterized by a negative attribute viz. as the state in which the plant does not grow well under otherwise good conditions. During this state only small leaves and trusses are formed. VAN DEN MUYZENBERG (110) has described different stages as: preliminary, deep, after and enforced rest. However, as these stages are arbitrary and not clear cut, the general term 'relative dormancy', according to VEGIS (172), is preferred.

3.1. THE ONSET OF DORMANCY

In experiments, which were partly described earlier, it was studied whether daylength or temperature was the most important in stopping the growth of the strawberry. Temperatures of 21, 18 or 15°C were chosen, as the average day temperatures in nature are going down along this range from August to the end of September.

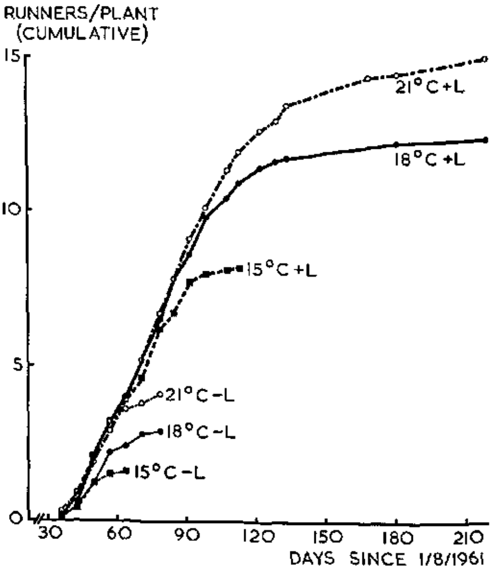


FIGURE 3.
Experiment 10. The cumulative number of runners/plant during 219 days since 1/8/61 in the cv. 'Talisman'. The plants were grown at 3 temperatures during shortening natural daylength (—L) or extended day to 16 hours (+L). A LD is more important for a prolonged runner formation than a higher temperature.

Beginning with experiment 10 two cultivars were grown, as described on p. 12, during 9 months at 3 temperatures, in natural daylength or daylength extended to 16 hours by IL. Runner formation is one of the characteristics of non-dormant plants. From figure 3, showing the duration and number of runners in the cv. 'Talisman', it is clear that +L extended the period and increased the number of runners at all temperatures, but more so at 18 and 21°C than at 15°C. The behaviour of the cv. 'Deutsch Evern' was similar.

As already described on p. 7 four cultivars were used in experiment 4 during 1962/63 and the same treatments were given as in experiment 10. After 4 months 4 plants out of 16 per cultivar were used for measurements. Per plant 3 petioles of the youngest full grown leaves were taken. The areas of 3 top leaflets of each

TABLE 20. *Experiment 4.* Leaf, crown and root growth in 4 cultivars, as affected by temperature and daylength, measured after a growing-period from 15/8–15/12/62. Sixteen plants per treatment. Exceptional pairs of figures are underlined.
–L = shortening natural daylength.
+L = shortening natural daylength extended to 16 hours by IL.

Observation	Cultivar	15°C		18°C		21°C	
		–L	+L	–L	+L	–L	+L
Length of petiole in cm	Deutsch Evern	4.3	8.4	3.6	11.2	8.5	16.0
	Redgauntlet	3.8	13.5	5.0	14.7	8.9	15.6
	Senga-Sengana	5.6	12.7	7.2	15.5	10.4	17.3
	Talisman	4.0	12.3	5.4	12.7	7.4	14.3
Number of leaves	Deutsch Evern	24	23	19	22	21	12
	Redgauntlet	22	13	19	13	20	13
	Senga-Sengana	27	17	31	23	24	27
	Talisman	24	14	16	13	25	13
Leaf area in cm²	Deutsch Evern	6	17	6	18	11	25
	Redgauntlet	6	19	8	17	11	16
	Senga-Sengana	6	15	8	16	8	13
	Talisman	5	19	7	17	8	19
Number of crowns	Deutsch Evern	3.8	4.5	3.3	3.3	2.8	1.0
	Redgauntlet	4.0	2.0	3.0	1.3	2.5	1.3
	Senga-Sengana	5.8	3.5	5.0	3.5	4.3	3.3
	Talisman	3.8	3.8	3.3	1.5	3.3	1.3
Dry weight of leaves and crown in g	Deutsch Evern	6.1	9.5	5.8	8.9	6.6	6.3
	Redgauntlet	8.2	9.3	8.5	7.6	7.6	6.2
	Senga-Sengana	8.0	8.0	10.4	9.3	6.5	9.7
	Talisman	6.4	7.9	3.4	5.7	5.8	4.7
Dry weight of roots in g	Deutsch Evern	2.6	1.9	2.1	1.7	1.3	1.7
	Redgauntlet	3.2	1.8	2.1	0.9	1.6	1.1
	Senga-Sengana	2.0	1.5	1.2	1.2	1.8	1.9
	Talisman	2.0	1.2	0.7	1.0	0.9	0.6
Ratio dry weight (leaves + crown)/ roots	Deutsch Evern	2.3	5.1	2.8	5.4	5.3	3.8
	Redgauntlet	2.6	5.2	4.1	8.3	4.8	5.8
	Senga-Sengana	4.1	5.2	8.5	7.5	3.7	5.0
	Talisman	3.2	6.7	4.7	5.9	6.5	8.2

plant were drawn on parchment paper, cut out, weighed and related to a known area. The 4 cultivars varied similary, as table 20 shows. Comparing plants without (–L) and with daylength extension (+L), the former have shorter petioles, more and smaller leaves, more crowns, more dry weight of roots and a smaller ratio between dry weights of (leaves + crown) to roots. In both daylengths at a higher temperature the petioles are mostly longer and the dry weights of roots lower.

It is concluded that shortening natural days of autumn decrease the amount of growth above ground in relation to root growth. Although it is probably that low temperatures accelerate the process, daylength is most important in stopping the growth of the strawberry in autumn.

However, it is not only the duration but also the quality and the intensity of the light, which influence the onset of dormancy. During experiment 6, as described on p. 8, all plants, growing at varying distances from a screen with TL, extending the shortening natural daylength to 16 hours, stopped their extension growth at nearly the same date and took a dormant appearance. On the other hand, when a screen of IL was used, plants were growing during a longer period.

As an indicator for plant activity, plant height was measured after 10, 14 and 19 weeks, since the start of screen lighting in experiment 7, described on p. 9. Control plants on rows 28 and 29 of the same greenhouse compartment did not receive IL. From figure 4 we see:

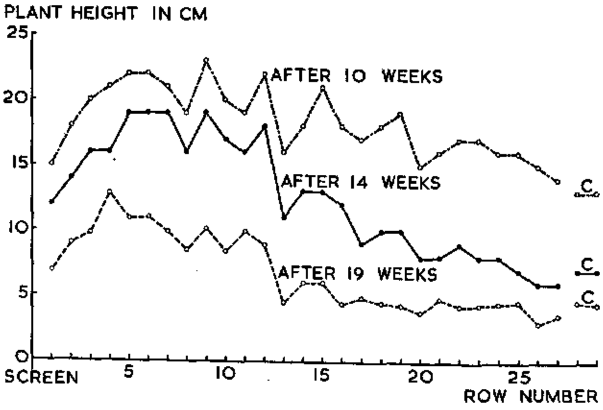


FIGURE 4.
Experiment 7. Plant height in rows at varying distances from a screen with IL and measured after 10, 14 and 19 weeks of LD.

a. A decrease of plant height with duration of the experiment.
b. A plant height which is below the optimum in the 3–4 rows nearest to the screen. This is probably due to a rise in temperature.
c. After 19 weeks, plants in the rows 13 and further from the screen, were similar to the controls in rows 28 and 29. These plants in row 13 had received less than 900 erg/cm^2/sec. It must be reminded, however, that several plants nearer to the screen than row 13 also initiated fruit buds. Intensities of IL when used as daylength extension and which can keep plants growing, may not be high enough to keep the same plants vegetative.

3.2. DURATION OF THE DORMANT PERIOD

To study the dormant period, during several seasons young runner plants, potted in August, were grown in the open. At regular intervals plants were forced in a greenhouse or under artificial light.

3.2.1. Greenhouse experiments

Experiment 20. From 15/9/60 to 1/3/61 lots of 16 plants were brought into a greenhouse at regular intervals and forced at 18°C in natural daylight, which was extended to 16 hours by weak IL. The observations are summarized in table 21. Plants of all initial dates of forcing have produced fruit buds, flowers and fruits. Hence no absolute dormancy was observed. But the length of the fruit trusses after 60 d. of forcing was minimal when forcing started during the first weeks of November. These plants produced only small numbers of fruits. Plate 4 demonstrates the habits of the plants after 60 d. of forcing. Since the daily amount of light energy decreases sharply in autumn, it must be decided whether the plant condition or the changing environment or both are responsible for this minimum.

TABLE 21. *Experiment 20.* Number of days to 1st fruit bud, open flower and ripe fruit, length of truss and number of fruits in 'Deutsch Evern' after 12 initial dates of forcing at 18°C and LD.

Initial dates of forcing in 1960–1961	Number of days to 1st fruit bud	open flower	ripe fruit	Length of truss after 60 d.	Number of fruits after 90 d.	120 d.
15/9	23	34	76	19.4	3.3	9.8
29/9	16	30	79	14.8	2.5	9.0
15/10	11	22	85	9.6	1.6	2.7
1/11	4	14	86	6.6	0.9	2.0
15/11	7	22	74	6.2	1.6	1.7
29/11	12	26	72	9.8	5.4	5.4
15/12	7	21	71	11.6	4.1	6.8
29/12	6	27	69	13.0	4.7	5.5
15/1	9	29	67	14.8	4.5	5.3
29/1	8	22	63	18.1	4.6	4.6
15/2	5	19	55	17.2	7.6	7.6
1/3	–[1]	15	46	17.5	9.6	9.6

[1] not observed.

During 1961/62 this experiment was repeated. Some results about flower formation have already been described on p. 16. The natural daylength was not extended, or extended by TL to 16 hours (weak or strong). This TL did not enhance elongation. However, a sudden change occurred when forcing started from 15/12 or later. Though the trusses did not elongate much better, the leaves were larger and the petioles longer. Table 22, columns 3 and 4, show a sharp drop in number of days from flower to fruit and total number of days to 1st fruit for plants forced since 15/12 and later. The number of fruits (column 5) shows a decrease and an increase. Four plants out of each group are shown on plate 2.

TABLE 22. *Experiment 15.* Number of days to 1st open flower, from flower-fruit and to 1st fruit, and number of fruits per plant till 12/4/62, in 'Deutsch Evern', after 10 initial dates of forcing at 18°C and LD.

1	2	3	4	5
Initial date of forcing in 1961–1962	Number of days			Number of fruits per plant till 12/4/62
	to 1st open flower	from flower-fruit	to 1st fruit	
15/9	68	95	163	6.4
30/9	46	103	149	5.8
15/10	34	110	144	4.2
30/10	25	101	126	5.0
15/11	24	88	112	3.0
30/11	28	76	104	1.6
15/12	31	49	80	2.7
30/12	27	40	67	1.8
15/1	25	37	62	5.7
30/1	34	40	64	4.9

3.2.2. *Under artificial light*

Experiment 21. Four growth cabinets of about 1 × 1 × 1 m were used. The roof of each box had 7 tubes of TLF 65 Watts/no. 33 and 4 incandescent bulbs of 75 Watts. Tubes and bulbs were placed outside the cabinets above a plate of glass. Per day 16 hours of light were given at 18°C and 8 hours of darkness at 13°C. Tubes were 60 cm above the level of the pots. Light energy, as measured with a spherical photometer, connected with a micro-ammeter, averaged 900 μA (= 5,400 μW/cm^2 = 54,000 erg/cm^2/sec) at plant height. Each growth cabinet could contain 16 potted strawberry plants. Forcing at regular intervals between 20/9/63 and 16/1/64, with lots of 8 plants each and lasted 120 days. A minimum of elongation was found in the petiole and the fruit truss when plants were forced, beginning on 16/11/63. Elongation was much better, when forcing started on 16/1/64. The results will be presented in table 27, to be discussed on p. 30. Cf. also figure 5 on p. 44.

3.3. INFLUENCING THE DORMANT PERIOD

3.3.1. *By long day*

When plants are forced in a greenhouse during December, January or February, the elongation of petioles and trusses can be promoted by daylength extension with IL. Further details about the duration and the intensity of this light, and the interactions with GA$_3$ sprays can be found in chapter 4, when the results of forcing-experiments will be discussed.

3.3.2. *By chilling*

In the cv. 'Lassen' chilling-requirements were fulfilled after 30 days at or below 7.2°C (174). In 'Climax' and 'Royal Sovereign' 36–72 days at 1.6–4.5°C were enough (60). To determine the chilling-requirements of 'Deutsch Evern', temperatures of 8, 5 or 2°C were used during a number of weeks.

Experiment 22. Young runner plants of 'Deutsch Evern' were potted during the first week of August 1961 and grown in the open. Cold periods were given from October 30 or November 15 or 30, at 8, 5 or 2°C (16 hours of weak TL) during 0, 2, ..., 8 w. Altogether 45 treatments, with 8 plants each. After the chilling, the forcing was carried out in a shed with artificial light. The potted plants were placed in benches, filled with peat. Racks with 5 TL lamps (65 Watts/no. 33), 15 cm from each other, were mounted 25–28 cm above the plants. These received an average energy of 32,000 erg/cm²/sec, as measured with a spherical photometer connected with a micro-ammeter AEG 0–100 μA. The lamps burnt constantly, at 18°C. The air was refreshed very often. After the fruit harvest, petioles and trusses were measured. A summary of the main effects, after a complete analysis of variance, is given in table 23. With a later beginning-date of chilling, the number of trusses/plant decreased and the truss length increased. Chilling temperatures, only influenced the petiole length, in such a way that 5°C acted as an optimum. With the period of chilling, the petiole length increased, the number of trusses/plant decreased and the truss and stalk length increased. Though these effects are significant, they are small.

TABLE 23. *Experiment 22.* Main effects of 3 beginning-dates of chilling, 3 chilling-temperatures and 5 periods of chilling in a factorial experiment. Significant effects are underlined ($P \geqslant 0.95$).

Observation	Beginning-date of chilling in 1961			Chilling-temperature			Period of chilling in w.				
	30/10	15/11	30/11	8°C	5°C	2°C	0	2	4	6	8
Petiole length in cm	8.1	8.0	7.4	7.5	8.5	7.4	6.5	6.6	8.1	8.6	9.2
Number of trusses/plant	6.2	5.9	4.8	5.6	5.7	5.5	6.0	5.7	5.6	5.3	5.6
Truss length in cm	12.2	12.7	14.0	12.7	13.2	13.0	10.5	11.6	12.7	14.4	15.5
Stalk length of truss in cm	4.7	5.1	5.2	4.7	5.5	4.7	3.3	3.8	4.7	6.0	7.0

Experiment 23. During 1962 experiment 22 was repeated. The chilling-treatments were given from November 1, 15 or 29, 1962. In the whole experiment only one effect was found, viz. an increase of truss length with the period of chilling:

	Period of chilling in weeks				
	0	2	4	6	8
Truss length in cm after 60 d.	11.6 (a)	12.4 (abc)	13.0 (b)	13.9 (cd)	14.9 (d)

Two figures with one letter in common means: no significant difference ($P \geqslant 0.95$).

In experiments 22 and 23 chilling was given to plants, which had gone dormant under natural conditions. In the experiment 24 chilling was given to plants which stopped normal growth under greenhouse conditions.

Experiment 24. In experiment 4, as described on p. 7, 24 treatments of 16 plants each were compared to study the onset of dormancy. On the last date of forcing 8 plants from the cultivars 'Deutsch Evern' and 'Redgauntlet' were taken at random out of each treatment and divided into 2 series for experiment 24, to study the influence of chilling on these plants. The first series was immediately placed at 18°C and LD. The second series was given 6 w. of chilling at 3–5°C (with 16 hours of weak TL), followed by 18°C and LD. The petiole length was measured after 111 days from the end of the chilling-period and the number of runners per plant was counted up to that date. No difference was found due to the temperatures during the pretreatment. According to table 24 the petiole length and number of runners per plant did not increase with 'Deutsch Evern' after chilling. However, with 'Redgauntlet' a remarkable increase was found. Plate 5 illustrates these results.

TABLE 24. *Experiment 24.* Petiole length and number of runners per plant in 2 cultivars, pretreated with SD or LD before – or + chilling during 6 weeks.

Observation	Cultivar	Daylength during pretreatment	Chilling	
			–	+
Petiole length in cm	Deutsch Evern	SD	6.7	5.4
		LD	6.8	6.3
	Redgauntlet	SD	10.8	15.0
		LD	9.2	13.7
Number of runners per plant	Deutsch Evern	SD	0.3	0
		LD	0	0
	Redgauntlet	SD	2.3	10.0
		LD	2.0	4.0

3.3.3. *By gibberellic acid*

In experiment 17, already discussed on p. 17, GA_3 promoted truss elongation immediately after flower initiation in SD. The LD effect of IL could be intensified by sprays with GA_3. Trusses were affected more than petioles. Further effects of GA_3 will be treated in the next chapter.

4. EXPERIMENTS ON FORCING

Forcing-experiments were carried out from 1961–1964. The main effects of and many interactions between the following were studied:

1. Cultivar
2. State of dormancy
3. Period and intensity of chilling
4. Beginning-date of forcing in autumn and winter
5. Temperature
6. Daylength extension or night break by IL
7. GA_3 sprays

The observations refer to the characters:

a. The speed of growth
b. The amount of growth during forcing
c. The harvest
d. The growth after forcing

4.1. IN ARTIFICIAL LIGHT

In a factorial forcing-experiment with the cultivar 'Deutsch Evern', chilling was given from 3 dates at 3 temperatures during 5 periods, followed by forcing under controlled conditions.

Experiment 22. The design of this experiment has already been described on p. 27. The main effects on the speed of the growth and on the harvest are summarized in table 25. The only significant main effect was found in the harvest

TABLE 25. *Experiment 22.* Plant growth as number of days and number of fruits influenced by 3 beginning-dates of chilling, 3 chilling-temperatures and 5 periods of chilling in a factorial forcing-experiment under artificial light with 'Deutsch Evern' in 1961/62. Significant effects are underlined ($P \geqslant 0.95$).

Observation	Beginning-date of chilling in 1961			Chilling-temperature			Period of chilling in weeks				
	Oct.	Nov.									
	30	15	30	8°C	5°C	2°C	0	2	4	6	8
Number of days											
to 1st bud	14	11	11	12	12	12	13	13	11	11	11
to 1st flower	25	22	23	23	25	23	25	25	23	23	23
to 1st fruit	65	62	67	63	66	65	66	64	62	64	66
to 50% harvest	72	67	70	67	71	71	72	72	68	68	68
to last fruit	86	81	84	81	85	85	91	88	82	79	78
of harvest period	21	20	16	19	18	20	25	24	20	15	12
Number of fruits											
after 60 days	1	1	1	1	1	1	1	1	1	1	1
after 90 days	11	12	9	11	10	11	11	11	12	10	9
in total	12	12	9	11	10	12	13	12	12	10	9

period. The interaction between the two main influencing-factors, viz. beginning-date and period of chilling was somewhat irregular and therefore is not described in detail.

Experiment 23. During 1962/63 experiment 22 was repeated under identical conditions. The main effects are summarized in table 26. They do not show any significant difference. A comparison of the tables 25 and 26 reveals that the number of days to 50% harvest and the number of harvested fruits did not differ appreciably in both years.

TABLE 26. *Experiment 23.* Plant growth as number of days, number and weight of fruits influenced by 3 beginning-dates of chilling, 3 chilling-temperatures and 5 periods of chilling in a factorial forcing experiment under artificial light with 'Deutsch Evern' in 1962/63.

Observation	Beginning-date of chilling in 1961			Chilling-temperature			Period of chilling in weeks				
	Oct.	Nov.									
	30	15	30	8°C	5°C	2°C	0	2	4	6	8
Number of days											
to 1st bud	6	3	3	3	4	4	5	3	6	2	4
to 1st flower	18	18	18	16	19	18	15	16	19	19	20
to 1st fruit	61	62	60	62	60	61	56	57	65	65	62
to 50% harvest	70	74	70	72	71	71	67	70	75	74	71
to last fruit	83	81	81	83	81	81	80	76	86	84	82
of harvest period	22	19	21	22	21	19	25	19	21	19	20
Number of fruits											
after 60 days	2	1	2	1	2	2	3	2	0	1	3
after 90 days	10	12	13	12	12	12	12	11	9	11	15
in total	10	13	14	12	12	12	12	11	10	12	15
Weight of fruits in g											
after 60 days	8	4	10	6	8	8	13	7	1	4	11
after 90 days	37	43	48	42	43	43	42	42	38	39	52
in total	37	44	49	43	44	44	42	42	39	41	52

Experiment 21. To describe the state of dormancy, 'Deutsch Evern' plants were forced periodically during 1963/64, as already described on p. 26. To get comparable plants, all were reduced to one crown after 30 days of forcing. From table 27 it follows that:

a. More days were needed to the 1st bud when forcing started before 30/10 than afterwards. This delay also worked on the number of days to the 1st flower, 1st fruit and 50% harvest.

b. A tendency existed for less days to 50% harvest when forcing started on 16/1.

c. An optimal number of trusses per plant was found, when forcing started on 30/10.

d. In general, opposite to expectation, beginning of forcing on a later date did not increase the total weight of fruits nor the average fruit weight.

TABLE 27. *Experiment 21.* Mean number of days to 1st bud, 1st open flower, 1st fruit and 50% harvest, and number of trusses and harvest of fruits per plant, as influenced by beginning-date of forcing. Cultivar 'Deutsch Evern'.

Beginning-date of forcing in 1963–1964	Mean number of days to				Number of trusses after 60 d.	Harvest of fruits		
	1st bud	1st open flower	1st fruit	50 % harvest		Total number	Total weight	Average fruit weight
20/9	32	45	86	95	1.9	7.3	31.4	4.3
30/9	28	42	80	89	1.9	8.4	36.3	4.3
16/10	18	31	71	78	2.3	7.2	37.3	5.2
30/10	9	23	58	70	2.6	10.4	51.4	4.9
16/11	5	17	55	68	2.4	11.6	54.4	4.7
30/11	11	26	65	76	2.4	10.4	40.9	3.9
16/12	7	29	68	74	2.4	10.7	40.8	3.8
30/12	3	22	60	66	2.1	8.4	29.4	3.5
16/1	5	20	54	58	2.1	8.0	31.9	4.0

4.2. IN A GREENHOUSE

Experiment 25. 'Deutsch Evern' as an early cultivar and 'Talisman' as a late one, were compared during 1962/63 in a periodical forcing-experiment in a greenhouse at 18 °C. The daylength was extended to 16 hours by incandescent light from bulbs of 40 Watts at 55–60 cm height above the plants with one lamp per 10 plants. Young runner plants were potted during the first week of August 1962 and grown in the open till the beginning-dates of forcing which ran from 14/9/62 to 17/4/63. On each date 12 plants of each cultivar were used.

TABLE 28. *Experiment 25.* Mean number of days from flower to fruit and to the 1st fruit, and number of fruits after 90 days, as influenced by beginning-date of forcing in the cultivars 'Deutsch Evern' and 'Talisman'.

Beginning-date of forcing in 1962–1963	Mean number of days				Number of fruits after 90 days	
	from flower to fruit		to the 1st fruit			
	D. Evern	Talisman	D. Evern	Talisman	D. Evern	Talisman
14/9	23	29	75	82	2.4	1.0
28/9	28	28	68	70	4.1	0.2
15/10	50	50	77	90	2.1	0.1
30/10	51	> 60	74	> 90	3.2	0
15/11	60	51	75	83	3.8	0.5
30/11	48	54	67	84	6.8	1.3
14/12	44	51	64	86	8.6	0.9
2/1	41	45	64	76	10.3	2.9
15/1	33	43	55	75	8.2	4.6
31/1	35	43	60	75	12.4	7.2
15/2	37	36	59	65	11.3	14.6
1/3	34	37	51	65	13.9	10.3
15/3	30	33	47	55	14.7	15.2
29/3	28	33	42	51	19.4	21.9
17/4	25	31	34	42	16.1	13.7

In table 28 the mean number of days from flower to fruit jumps from 28 to 50 when forcing started on 28/9 and 15/10 respectively and it gradually decreased from 15/11 or 30/11. A somewhat similar pattern is seen for the number of days to the first fruit. On all beginning-dates 'Deutsch Evern' needs fewer days to the 1st fruit than 'Talisman', but as the season advances, the difference tends to decline. The number of fruits, harvested after 90 days of forcing, increases when forcing starts later. Here the difference between the cultivars also disappears.

Experiment 26. During 1961/62 a factorial forcing-experiment was carried out with 'Deutsch Evern' to study the main effects and interactions of beginning-dates, daylength extension and sprays of gibberellic acid. During August, two young runner plants were planted per wooden box of 25 × 25 × 30 cm and kept in the open till the beginning-dates of 15/12, 2/1 or 15/1. These dates were chosen, as growers consider them as 'critical'. Natural short days were not extended or extended with weak or strong incandescent light to a total of 16 hours, with bulbs of 25 or 100 Watts respectively, on 50 cm above the plants and 1 lamp per 6 boxes. Gibberellic acid, 15 or 30 ppm, was sprayed 3 times with intervals of 3 or 4 days, since the first bud became visible. The controls were sprayed with water. All plants were sprayed till dripping. Per treatment 16 plants

TABLE 29. *Experiment 26.* The main effects of beginning-date of forcing, of daylength extension by IL and of GA_3 sprays in a factorial forcing-experiment on fruit trusses, on plant growth as number of days, and on the harvest of fruits. Cultivar 'Deutsch Evern'. Significant effects are underlined ($P \geqslant 0.95$).

Observation	Beginning-date in 1961–1962			Daylength extension by IL			GA_3 in ppm		
	15/12	2/1	15/1	no	weak	strong	0	15	30
Fruit trusses									
Number per plant	2.5	2.4	2.8	2.7	2.3	2.8	2.3	2.4	3.1
Length in cm	19.8	19.4	20.1	16.4	20.8	22.1	15.0	21.3	22.9
Length of stalk in cm	8.8	8.5	7.9	5.1	9.0	11.2	6.5	9.2	9.5
Number of days									
to 1st flower	44	38	33	41	38	37	38	38	39
to 1st fruit	103	91	83	93	93	91	89	93	95
from flower to fruit	58	53	50	52	55	54	51	54	56
to 50% harvest	105	97	91	101	97	94	95	98	99
of the harvest period	7	17	16	17	12	12	17	13	11
Harvest of fruits									
Number in 90 days	0.2	2.7	3.3	1.9	1.7	2.6	3.5	1.8	1.0
Average weight/fruit in 90 days	–	6.1	6.6	7.3	6.2	5.6	6.4	6.8	5.9
Number in 120 days	4.2	10.2	9.7	10.9	6.1	7.2	8.8	8.3	7.0
Average weight/fruit in 120 days	4.3	4.1	4.3	4.4	4.4	3.8	4.7	4.3	3.7

were used. The main effects are summarized in table 29, in which the significant tendencies are underlined.

A later beginning-date does not influence the fruit trusses, diminishes the number of days to flowers and fruits, increases the harvest period and increases the numbers of fruits, with a remarkable difference between plants forced from 15/12 and those from 2/1.

Daylength extension promotes truss elongation, especially the stalk of the truss; the plants flower a few days earlier and the harvest is earlier but smaller than without daylength extension.

Sprays with GA_3 increase the number and length of the trusses, but the harvest is later and smaller and the average weight/fruit in 120 d. is reduced.

Plate 6 illustrates some of these effects.

Four significant interactions were found between daylength extension and gibberellic acid sprays and these are presented in table 30. They are related to the number of days to the 1st flower, and to the harvest period in days, to the average fruit weight after 90 d. and to the fruit number after 120 d. In all these cases the difference between the effects of no and strong daylength extension increase with increasing concentrations of GA_3.

TABLE 30. *Experiment 26.* Significant interactions from table 29 between daylength extension and sprays with gibberellic acid for the number of days to the 1st flower, harvest period in days, average fruit weight in g after 90 days and fruit number after 120 days ($P \geqslant 0.95$).

Daylength extension	Concentrations of gibberellic acid in ppm											
	0	15	30	0	15	30	0	15	30	0	15	30
	Number of days to the 1st flower			Harvest period in days			Average fruit weight in g after 90 days			Fruit number after 120 days		
no	40	41	43	19	15	17	6.5	7.6	7.9	9.8	11.1	11.7
weak	39	37	37	12	12	11	6.8	6.3	5.4	5.9	6.3	6.1
strong	37	36	37	18	12	5	5.9	6.5	4.5	10.8	7.5	3.3
no – strong	3	5	6	1	3	12	0.6	1.1	3.4	–1.0	3.6	8.4

In general, GA_3 works in an opposite direction when we compare its effect combined with no and strong daylength extension. However, it is of interest to note that daylength extension and sprays of GA_3 both promoted truss length, as was shown in table 29, without an interaction. This means that the fruit trusses could reach a maximal length when both factors worked together and this was found indeed, as is also shown in plate 6, which shows a striking difference between the plants upper left and lower right.

Experiment 27. During 1962/63 a factorial forcing-experiment was carried out with all combinations of:

Two cultivars: 'Deutsch Evern' and 'Glasa'.

Three beginning-dates of forcing: 17/12, 31/12 and 14/1.

Two light-treatments: without or with a night break of weak incandescent light from lamps of 25 Watt, giving light between 23.30 and 2.30 h.

Three concentrations of GA_3: 0, 15 or 30 ppm, given as one spray at the moment that the first fruit bud became visible.

Young runner plants were planted on 1/8/62, two plants per box of 25 × 25 × 30 cm, and grown in the open till the date of forcing. Per treatment 8 plants were used. During a frost period in January, the plants of 'Glasa' were partly killed and the remaining plants of the 3rd beginning-date have given very irregular results with this cultivar. Therefore the experiment was mathematically treated as an analysis of variance in 2 ways:

a. For 2 cultivars × 2 beginning-dates × 2 light-treatments × 3 concentrations of GA_3.
b. For 1 cultivar × 3 beginning-dates × 2 light-treatments × 3 concentrations of GA_3.

The main effects of the combination (a) are given in table 31 and will be discussed in the order of the experimental factors.

TABLE 31. *Experiment 27.* The main effects of cultivar, beginning-date of forcing, light-treatment and GA_3 sprays on petiole, fruit truss, plant growth in number of days and on the harvest of fruits. Significant effects are underlined ($P \geqslant 0.95$).

Observation	Cultivar		Beginning-date in 1962		Light-treatment		GA_3 in ppm		
	Deutsch Evern	Glasa	17/12	31/12	—	+	0	15	30
Petiole									
Length in cm after 60 days	7.9	13.3	9.9	11.3	5.4	13.2	10.6	10.6	10.6
Fruit truss									
Length in cm after 60 days	13.4	15.2	13.3	15.2	10.8	16.0	12.5	15.0	15.3
Number/plant after 60 days	3.9	2.1	2.9	3.1	2.8	3.1	3.0	3.0	3.0
Number of days									
to 1st open flower	28.0	28.2	27.2	29.0	29.1	27.6	29.6	27.8	27.0
to 50% harvest	84.9	80.2	83.6	81.5	83.1	82.3	82.3	81.9	83.4
Harvest of fruits									
Number/plant	12.5	9.7	11.1	11.2	10.6	11.7	10.2	11.5	11.7
Average weight/fruit in g	3.5	4.0	3.6	3.8	3.6	3.7	3.9	3.7	3.8
Total weight/plant in g	44	39	40	43	38	43	40	42	44

Cultivar. 'Deutsch Evern' has shorter petioles and shorter but more trusses, is later, and has more but smaller fruits than 'Glasa'.

Beginning-date. When forcing starts later, the petioles and trusses become longer, the plants flower a little bit later, but they ripen quicker.

Light-treatment. With a night break petioles and trusses are much longer than without.

GA_3 sprays. With GA_3 trusses are longer and flower somewhat earlier than without.

Plate 7 illustrates some of these effects.

The main effects of the combination (b) are not given in details, as they are similar to the results, already mentioned. Only a few additions should be added here:

Beginning-date. The total weight of fruits per plant increases significantly with a later date from 41 to 48 to 51 g.

Light-treatment. With a night break the plants flower 2 days earlier.

GA_3 sprays. More but smaller fruits are harvested in the sprayed plants compared with unsprayed controls.

Significant interactions were found between the light-treatment on the one hand, GA_3 sprays and the cultivar in series a, the beginning-date in series b on the other hand. They influence the number of days to 50% harvest and the petiole length in cm, and they can be found in table 32. With a light-treatment the influence of GA_3 sprays on the number of days to 50% harvest is very small, but without a light-treatment GA_3 sprays are retarding the harvest. With a light-treatment the petiole is longer than without for both cultivars, but the influence of the light is greatest on 'Glasa'. The influence of the light-treatment on the petiole of 'Deutsch Evern' is smaller on 17/12 than on both other dates.

TABLE 32. *Experiment 27.* Significant interactions from table 31 between the light-treatment on the one hand, GA_3 sprays and cultivar in series (a), the beginning-date in series (b) on the other hand. They influence the number of days to 50% harvest and the petiole length in cm ($P \geqslant 0.95$).
(a) = For 2 cultivars and 2 beginning-dates.
(b) = For 'Deutsch Evern' and 3 beginning-dates.

	GA_3 sprays in ppm			Cultivar		Beginning-date in 1962–63		
	0	15	30	Deutsch Evern	Glasa	17/12	31/12	14/1
	(a)					(b)		
Light-treatment	Number of days to 50% harvest			Petiole length in cm				
+	82.8	83.0	81.0	9.5	16.9	8.4	10.6	11.2
—	80.0	82.0	87.3	4.7	6.1	4.5	4.9	6.0
(+)-(—)	2.8	1.0	-6.3	4.8	10.8	3.9	5.7	5.2

Experiment 28. During 1963/64 a factorial forcing-experiment was carried out to study the main effects and interactions of cultivar, light-treatment, temperature and beginning-date on petioles, fruit trusses, plant growth in number of days, harvest of fruits, runners during and after forcing and fruit trusses after forcing. Young plants were potted in August 1963 and grown in the open till the beginning-dates of forcing. The experiment was carried out with all combinations of:

TABLE 33. *Experiment 28.* The main effects and significant interactions of cultivar, light-treatment, temperature and beginning-date of forcing in 1963–1964 on: petioles, fruit trusses, plant growth i

Observation	C = Cultivar		L = Light-treatment		
	Deutsch Evern	Glasa	–L	$+L_{16}$	$+L_{24}$
Petioles after 30 d.					
Length in cm	12	17	11	15	18
Fruit trusses after 30 d.	1.7	1.5	1.6	1.6	1.7
Length in cm	11	12	9	11	14
Number of days:					
to 1st bud	5	8	7	7	6
to 1st open flower	22	25	24	23	23
to 1st fruit	70	65	69	69	65
from bud-flower	17	17	17	16	17
from flower-fruit	48	40	45	46	42
Harvest of fruits					
Number	5	8	6	7	7
Weight/plant in g	19	33	24	28	26
Weight/fruit in g	3.5	4.0	3.8	3.8	3.6
Runners during forcing					
Number	0.5	1.0	0.3	0.8	1.2
Length/plant in cm	21	44	12	32	54
Runners after forcing					
Number	9	22	16	15	15
Fruit trusses after forcing					
Number	4.5	1.4	3.4	2.8	2.6

C = 2 cultivars: 'Deutsch Evern' and 'Glasa'.

L = 3 light-treatments: –L = natural daylength
$+L_{16}$ = natural daylength extended to 16 h.
$+L_{24}$ = natural daylength extended to 24 h.

The extension was given with IL of 40 Watt at 50 cm above the plants and 2 lamps per 20 plants.

T = 3 temperatures: 15, 18 or 21°C, during the period of natural daylight and 5°C lower from 17.30–8.00 h.

D = 4 beginning-dates: 20/12/63, 17/1, 14/2 or 13/3/64.

Per treatment 8 plants of 'Deutsch Evern' and 12 plants of 'Glasa' were used. After 30 days of forcing all plants were reduced to one crown. During flowering every 2 days the pollination was carried out with a brush. A routine-spraying programme was applied, but unfortunately the plants of the 4th beginning-date number of days, the harvest of fruits, runners during and after forcing and fruit trusses after forcing. Significant main effects are underlined if P ⩾ 0.95.

T = Temperature			D = Beginning-date of forcing				Factors interacting with (reciprocals in brackets)			
15°C	18°C	21°C	20/12	17/1	14/2	13/3	C	L	T	D
13	15	17	11	13	16	19	L	T (C)	(L)	
1.5	1.6	1.7	0.9	1.4	2.0	2.1				
10	11	14	7	10	13	16				
7	6	6	9	8	5	4	D			(C)
27	24	19	24	26	25	19	D			(C)
77	68	57	81	70	65	53			D	(T)
20	18	13	15	18	20	15			D	(T)
50	44	38	57	44	40	34			D	(T)
6	7	6	3	8	9	7 [1]	D			(C)
25	30	23	11	30	34	27 [1]	D			(C)
3.8	4.0	3.5	3.5	3.8	4.0	3.8[1]				
0.6	1.0	0.7	0.1	0.5	1.5	1.0[1]	L	(C)		
30	43	25	6	19	64	41 [1]	L	(C)		
15	15	15	7	11	17	26	D			(C)
2.8	2.8	3.2	5.6	4.0	1.9	0.1	D			(C)

[1] Spray damage

have got leaf damage, which also reduced the harvest. After the forcing of all groups was finished on 27/5/64 out of each treatment 4 plants were chosen for an aftertreatment and grown for 120 days in the open, to study the formation of new runners and trusses.

The results were subjected to a complete analysis of variance with the aid of a computer, type IBM-1620, at the Mathematical Department of the Agricultural University at Wageningen.

The main effects and the significant interactions are presented in table 33, from which the following conclusions appear:

C = Cultivar. 'Deutsch Evern' compared with 'Glasa':

- has shorter petioles.
- has more trusses/plant.

- shows its buds and flowers earlier, but ripens later, due to a longer period from flower-fruit.
- has given fewer and smaller fruits.
- has given fewer runners and shorter length/plant during forcing and fewer runners after forcing.
- has made more trusses after forcing.

L = Light-treatment. Daylength extension ($+L_{16}$ or $+L_{24}$), compared with no extension (–L):

- promotes the length of petioles and of fruit trusses.
- increases the number of fruits/plant slightly.
- increases the number and length of runners during forcing.

T = Temperature. A higher temperature compared with a lower one:

- increases the length of petioles and of trusses after 30 days which must be due to an accelerated plant growth, as this effect is not found anymore after 60 days (figures not shown).
- increases the number of trusses a little bit.
- results in shorter periods from bud-flower and from flower-fruit, hence hastens flowering and fruiting.
- increases the average weight/fruit if 18 °C is compared with 15 °C, but decreases the average weight/fruit if 21 °C is compared with both other temperatures and this tendency was significant.

D = Beginning-date. A later date, compared with an earlier one:

- gives longer petioles, more and longer trusses.
- reduces the number of days to 1st bud, 1st open flower (with one irregularity) and 1st fruit, which is mainly due to a reduced number of days from flower fruit.
- gives more and bigger fruits (with the last date as an exception, due to the spray damage, mentioned above).
- gives more runners and total length of runners/plant during forcing (again with the 4th date as an exception).
- gives more runners and fewer trusses after forcing.

In all, 13 significant interactions were found. In table 33 only indications and no details are presented. The following summary reviews all the interactions, while 3 will be discussed in more details.

Factors interacting with C. The difference between the cultivars:

- in petiole length increases with an increased duration of the light-treatment.
- in number of days to the 1st bud and to the 1st open flower is greatest on the earliest 2 beginning-dates and smallest on the last 2 beginning-dates, but the pattern is somewhat irregular.
- in number of fruits and the fruit weight/plant increases with a later beginning-date.
- in number and length of runners/plant during forcing increases with increasing duration of the light-treatment.
- in number of runners after forcing (table 34) first increases and later decreases with a later beginning-date of forcing.

TABLE 34. *Experiment 28.* Significant interactions from table 33 between cultivar and beginning-date of forcing for number of runners and trusses/plant, counted during an aftertreatment (P ⩾ 0.95).

Cultivar	Beginning-date of forcing in 1963/64							
	20/12	17/1	14/2	13/3	20/12	17/1	14/2	13/3
	Number of runners/plant				Number of trusses/plant			
Deutsch Evern	2.6	3.6	8.6	21.1	8.3	6.4	3.0	0.1
Glasa	11.1	18.4	25.9	30.8	2.9	1.6	0.9	0.3
Difference	-8.5	-14.8	-17.3	-9.7	5.4	4.8	2.1	-0.2

- in number of trusses after forcing (table 34) decreases with a later beginning-date of forcing.

Factors interacting with L. The differences between the light treatments:

- in length of petiole decrease somewhat with increasing temperatures.

Factors interacting with T. The differences between the temperatures:

- in number of days to the 1st fruit, from bud-flower and from flower-fruit decrease with later beginning-dates of forcing. This is shown in table 35 for the days from flower-fruit.

TABLE 35. *Experiment 28.* The significant interaction from table 33 between forcing temperature and beginning-date of forcing for the number of days from flower to fruit (P ⩾ 0.95).

Forcing temperature during the day	Beginning-date in 1963/64			
	20/12	17/1	14/2	13/3
15°C	65	49	42	36
18°C	57	45	40	32
21°C	41	36	39	36
(15°)-(21°)	24	13	3	0

Several effects are demonstrated on the plates 8 and 9. The results of the forcing-experiments, described in this chapter, are summarized in a schematical way in table 36, which tells its own story. They will be discussed in the next chapter.

TABLE 36. A summary of the main effects and interactions in 4 forcing-experiments.

Legend:

— — = strongly negative	o = no	+ = positive	? = unknown
— = negative	± = variable	++ = strongly positive	

Observation	Cu = Cultivar	Ch = Chilling-effect	D = Beginning-date	L = Daylength -extension	T = Tempera-ture	G = GA$_3$-sprays	Factors interacting with					
		(under artificial light)	(in winter and spring in a greenhouse)		(during forcing)	(of 15 and 30 ppm)	(reciprocals in brackets)					
							Cu	Ch	D	L	T	G
Plant growth in number of days												
to bud	+	o	+	o	o	o	D		(Cu)			
to flower	+	o	+	±	++	±	D		(Cu)	G		(L)
to fruit	++	o	++	±	++	±			T	G	(D)	(L)
from bud-flower	+	o	+	o	++	±			T		(D)	
from flower-fruit	++	o	++	±	++	±			T		(D)	
of harvest period	+	±	+	—	+	—				G		(L)
Growth in cm												
Length of leaf petioles	++	+	++	++	++	+	L		L	(Cu) (D) T	(L)	
Length of trusses	+	+	++	++	++	++						
Number of trusses	++	—	+	o	+	±						
Number of runners	++	+	+	+	±	+	L			(Cu)		
Harvest of fruits												
Number	+	o	++	±	o	+	D		(Cu)	G		(L)
Total weight/plant	+	o	++	±	—	o	D		(Cu)			
Weight/fruit	+	o	++	±	—	—				G		(L)
After forcing, influenced by the forcing-treatments												
Number of runners	++	+	++	o	o	?	D		(Cu)			
Number of trusses	+	—	— —	o	o	?	D		(Cu)			

5. DISCUSSION

The questions put forward in chapter 1 will be discussed, using the data from the experiments 1 to 28 and the literature. They are dealing with:

1. Characteristics of an early cultivar.
2. Backgrounds of flower initiation, in relation to temperature and daylength and studied in mother and daughter series.
3. The relative dormancy of some cultivars, especially of 'Deutsch Evern', as influenced by LD, chilling and GA_3.
4. The usefulness of forcing when starting before the 15th of January.

5.1. CHARACTERISTICS OF AN EARLY CULTIVAR

Bud initiation. Though SIRONVAL (156) expected an early initiation of early cultivars, no strong correlation could be detected between the date of initiation and the season of ripening in the experiments 1 and 2, during 2 seasons. However, the start of the initiation was not late, as has been shown before (30, 175).

Bud development and flowering. During periodical forcing in experiment 25, the early cv. 'Deutsch Evern' has always shown its fruit bud sooner and flowered earlier than the late cv. 'Talisman' and its stage of bud realization was more advanced.

Period from flower to fruit. This period is shorter for an early cultivar than for a late one. In a relatively low light intensity, an early cultivar ripens more quickly than a later one (experiment 21). The difference between the early 'Deutsch Evern' and the still earlier 'Glasa' was due to a shorter period from flower to fruit for 'Glasa' without an interaction with the beginning-date of forcing, the daylength or the temperature in the forcing-experiment 28. According to BLACKMAN (11) it has been established that the net assimilation rate of some cultivars can be significantly higher than that of other cultivars, be it with other crops than the strawberry. If it holds true for the latter also, it can explain why, besides tradition, in different countries different cultivars are used for forcing (12, 86, 100, 127).

In France a cv. with a short period from flower to fruit is called 'hâtif' (79), but it should be realized that a cv. which is 'hâtif', is not necessarily an early one (31, 151).

Chilling-requirement and daylength. Experiment 24 has indicated that an early cultivar as 'Deutsch Evern' does not react to chilling as a later one does. This makes it comparable to everbearers (156) which probably do not need a chilling-period (9), the more so, as 'Deutsch Evern' belongs to the cultivars which often flower twice a year (110, 146). Also the strong reaction of 'Glasa' to daylength extension or a night break by IL suggests that this may be typical for an early cultivar.

Formation of stamens. In winter sometimes the first flowers of the trusses are missing stamens (9, 110). Especially in 'Deutsch Evern' this has been observed during the experiments 27 and 28. Though DARROW (34) has ascribed this to the autumn conditions during bud formation, it appeared that the production of stamens and pollen is dependable on the light energy available during forcing (79, 107). After sunny days the pollen production often increases. According to CHRISTOFF (30), pollen formation in nature takes place late in spring.

5.2. BACKGROUNDS OF FLOWER INITIATION

After mentioning several data from the experiments and the literature, some hypotheses will be discussed.

Leaf area. Young vegetative runner plants need a minimal leaf area, before flower initiation can take place (experiment 5). Also, this holds true for seedlings, see JONKERS (83). On the contrary, defoliation in summer of older plants, which have already flowered before, promotes renewed flower initiation, especially if very young leaves are left behind (64, 71 d–i, 72, 110, 146, 168).

Effect of a low temperature. A cold treatment of germinated seeds does not accelerate the flower initiation (experiment 14).

When runner plants are given 4–6 w. of cold, they can initiate fruit buds at all daylengths, both in IL and TL (experiments 12 and 13), but longer periods of cold lead to more irregular flowering-results at a higher temperature and LD afterwards than shorter periods of cold (experiments 11 and 13). This is also described in 49.

After relatively long periods of natural chilling-temperatures, plants return from a generative to a vegetative state (experiments 15 and 28, reference numbers 8, 43, 60, 110, 118, 174).

In recent years it has been found that generative runner plants, which have been in cold storage for many months, have to be planted out in summer 2–3 weeks before the normal date. Otherwise the initiation of fruit buds for the next season can be lacking in spite of vigorous growth (65, 66, 71h, 77, 150, 183).

From these facts it is clear that rather short periods of cold are influencing the flower initiation in another way than long periods of cold are doing.

Effect of medium temperatures and light. At temperatures between 15 and 25°C the daylength, the light quality and the light intensity become important. Flower initiation can still take place in a LD of TL, but only after short days if sunlight, IL, or both are given above a minimal level (experiments 6, 7, 8, 9, 10).

The flower initiation is more rapid at medium temperatures and SD than at 3–5°C (experiments 3 and 13). As a period of 3–5°C is not necessary for, neither accelerates the flower initiation, the effect of 3–5°C is not considered as vernalization. In this respect the strawberry behaves as the SDP *Pharbitis nil*, which is also dayneutral at 3–5°C (144).

After a relatively short period of cold the flower initiation can be promoted in SD at a medium temperature (experiment 16). What will happen when longer periods of cold are followed by SD at a medium temperature, has not been tried extensively. But plants with a pretreatment in cold of different durations, followed by LD at a medium temperature, can be reinduced by SD to the same degree (experiment 15).

When the plants in mother-daughter series were given differential SD and LD treatments, a weak retarding or even inhibiting effect was found, originating from plants in LD and affecting the flower initiation of the connected plants in SD (experiments 18 and 19). This confirms comparable results of GUTTRIDGE (59, 62, 63, 64). No transport of a flower stimulus was found, which opposes the results of HARTMANN (74).

Incidental observations. Unexpected flower initiation in vegetative plants has been observed after transplanting (110, p. 48) and an inhibitory effect on the initiation has been shown from an extra gift of water just before the natural time of the flower initiation (116).

It seems of interest to note that a plant which flowers continuously, originally was found probably as a mutant in a field of a cultivar that flowers once a year (35).

Hypotheses on flower initiation. Three hypotheses will be discussed viz.:

H 1. The initiation of fruit buds always follows after an inhibitor has disappeared or dropped below a certain threshold level.

H 2. Initiation only can take place after the production of a flower stimulus, which is produced under special conditions of plant size, temperature and daylength.

H 3. After the disappearance of an inhibitor, a stimulus is produced which promotes the flower initiation.

Facts and hypotheses. Many arguments for the existence of an inhibitor have been put forward by GUTTRIDGE and THOMPSON, who think that its nature might be gibberellin-like (59, 62, 63, 64, 71, 165, 167, 168). The occurrence of gibberellins in the strawberry has definitely been proved by PORLINGIS and BOYNTON (120) and LESHEM (personal communication). Indeed many effects of gibberellic acid are similar to those of LD or a prolonged chilling-period. Sprays with gibberellic acid can promote the elongation of petioles (experiments 26–27 and reference numbers 68, 70, 102, 152, 167), the elongation of fruit trusses (experiments 17, 26–27 and reference numbers 71e, 71h, 71i, 95, 102, 121, 153, 157, 159, 186) and the formation of runners (experiments 17 and reference numbers 55, 70, 121, 149, 153, 167). However, no inhibitory effect of GA_3 on the flower initiation was observed in experiment 17; others have shown such an effect, but only under 'threshold conditions' (70, 71f, 119, 121, 167), which probably have not been reached in experiment 17.

Till now nothing is known exactly about the synthesis of GA inside the plant. With the strawberry it is speculated that the synthesis always takes place in the full grown leaves. At rather high temperatures and LD more is produced than is used by the young leaves or trusses. At rather low temperatures it is still produced but slowly and it is not used, which leads to an accumulation. In SD or TL the production is rather small. With the hypothesis that the flower initiation is inhibited when a certain level of GA is maintained, many of the facts on flower initiation, mentioned above, could be explained. Further research about the different types of gibberellins and the connection between daylength, light intensity and light quality on the one hand, the synthesis of gibberellins in the strawberry on the other, seems promising.

For the existence of a transportable flower stimulus only few indications exist. HARTMANN's results with the cv. 'Missionary' (74) and some observations with *Fragaria vesca* (71h, 155) are pointing into this direction. Whether the need of a minimal leaf area for flower initiation in young vegetative plants in particular deals with the production of a stimulus or with a general lack of carbohydrates, is difficult to answer.

It is also possible that both H 1 and H 2 can culminate in H 3. To test this hypothesis, more experimental data must be gathered and promising techniques seem the use of mother and daughter plants in combination with sprays of gibberellins, anti-gibberellins or both, and leaf or runner grafts between June- and everbearing cultivars.

5.3. THE RELATIVE DORMANCY OF 'DEUTSCH EVERN'
EFFECT OF LD, CHILLING AND GA$_3$

Entrance and characteristics of dormancy. When the elongation of fruit trusses is taken as a criterion for dormancy, 'Deutsch Evern' becomes more and more dormant from the last weeks of September till the beginning of November. This is followed by a period during which the trusses gradually can elongate better. Under LD, elongation can be perfect from January 15. Without daylength extension, this elongation is not optimal before the end of February or March 15. The decrease and increase of truss elongation was shown in a greenhouse by forcing periodically (experiment 20), but also under constant artificial light (figure 5). Always there is some elongation and the production of fruits under constant light is not affected by the degree of truss elongation

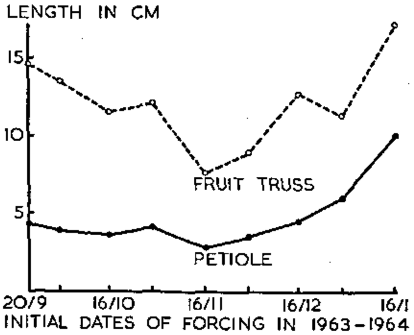


FIGURE 5.
Experiment 21. Average length in cm from varying initial dates of forcing in 1963–64 of petiole and fruit truss after 60 and 90 d. respectively, under artificial light. A minimum was found when forcing started on 16/11/63.

(experiment 23). Therefore, the term 'relative dormancy' is preferred. The entrance of this relative dormancy is influenced more by the shortening natural daylength than by the temperature in the range from 15–18–21 °C (experiments 4 and 10). Others have found the same for the strawberry (6, 40, 42, 139) and also for the raspberry (182). Daylength extension by IL can check this entrance of dormancy, even in low intensities (experiments 6 and 7), though the amount of growth depends on the total light energy and hence increases in spring. Root growth was stronger without than with daylength extension (experiment 4). This does not fit in with the results of ROODENBURG (134), but BOSSE (22) and GUTTRIDGE (60) have suggested that it could take place. In spite of decreasing average day temperatures, we can assume that the same will be found in nature, as BROUWER (27) has proven that even at 5 °C the strawberry had relatively the greatest root activity out of 7 crops.

In nature, flower initiation has taken place before the entrance of dormancy. This is obvious from experiment 7, as fruit buds were formed at intensities high enough for elongation, while plants forced from September 15, 1960 could flower and elongate nicely (experiment 20). It seems likely that fruit buds are already induced during longer daylengths than are needed for inducing dormancy, as e.g. is also known in *Begonia* (138, 139). For the raspberry, WILLIAMS (182 in 1960, p. 219) has concluded that flower- and dormancy induction are not necessarily connected causally. For cultivars, adapted to southern countries, natural daylength may be short enough for flower induction but too long for the entrance of dormancy.

Up to now dormant plants as such cannot be recognized. Respiration was not influenced from October 15 to April 1 according to BRIERLEY and LANDON (24, 25). An accumulation of 'pipecolic acid' has been shown (184) but this was also found after maleic hydrazide sprays (23) and with potassium deficiency (93). Therefore, STEWARD (161, p. 210) wonders whether this accumulation in hibernating organs may be considered as a reaction to unfavourable conditions. Also the starch level has been studied (26, 97, 98) and an increase was found in autumn and a decrease in spring, as could be expected, but chilling has shown a greater influence on growth vigour than differences in reserves of starch (26).

The truss elongation during dormancy.

Daylength. During permanent SD no elongation was seen in experiment 14. Nearly always LD promotes the elongation, but not sufficiently when forcing starts during the period from October to December (experiment 21). LD must consist of natural sunlight eventually extended by IL. TL has no effect (experiments 6 and 15). From the experiments 20, 21, 25–28 the conclusion can be drawn that long day was effective when forcing started on December 17 in one year or on January 2 in another year. This LD increased the truss elongation without influencing fruit production.

For daylength extension already weak intensities of IL are sufficient when used to 16 hours, but extension to 24 hours is better (experiments 26 and 28). Also night interruption during 3 hours can be used (experiment 27). In practice, cyclic lighting given as 15 minutes of light per hour during 8 hours has proven to be effective too (4, 5). Below a certain level, the intensity and the duration are important. STOLWIJK (163), using the cv. 'Madame Moutot', could undo the effect of infrared by giving red together with or after infrared. This points to a role of the phytochrome system, as put forward by BORTHWICK and HENDRICKS (19, 20).

Beginning-date of forcing. The daylength being equal, truss elongation is promoted when forcing starts later, after December 21. This must be ascribed to a longer chilling-period and a higher amount of total light (experiments 22, 27 and 28).

Chilling. During the experiments 22–23 the truss elongation was promoted very gradually with increasing periods of chilling.

Gibberellic acid. Sprays of GA_3 of 15 or 30 ppm have promoted the truss elongation and no interaction was found with extension of the day (experiments 17, 26 and 27).

Interactions. As in many other plants the factors LD, chilling and GA_3 are working in the same direction (29, 71f, 71h, 104, 117, 121, 167, 178). The effect of GA_3 sprays is not identical with a LD effect. They are working additively (experiment 26), as e.g. was also shown by MOHR and APPUHN (104) in the hypocotyl elongation of *Sinapis alba L.* According to GOSSELINK (56) infrared promotes cell elongation, while GUTTRIDGE and THOMPSON (68, 69) have shown that GA_3 and LD both are affecting the number and the length of cells, when the light energy has reached a minimal level. Besides GA_3 other gibberellins can promote the elongation of petioles (70) and further research on their specificity can be important to see whether chilling during October to December can be replaced.

Fulfilment of the chilling-requirement. With VEGIS (171, p. 243), the 'chilling-requirement' is defined as the number of hours that a cultivar needs during winter at or below a certain temperature (e.g. 7°C) to assure an adequate leafing and a regular flowering. In the strawberry the reported results of cold treatments are conflicting: no effect (81, 82 in 1959, p. 229 and 1960, p. 258), or questionable (110, p. 129) or favourable (60, 107, 125, 126, 174). In seedlings MOULTON and JOHNSTON (107) applied 4 w. of 0°C. In somewhat comparable perennials as rhubarb, all hours under 9.4°C were cumulative (1), while raspberry did not need more than 8 w. of 3°C (182) and for the black currant 15 w. of 3°C were sufficient (78).

The relatively small effects of 0, 2, ..., 8 w. at 2, 5 or 8°C during the experiments 22 and 23 are pointing to a slow accumulation of the chilling-effect, without a significant difference between the temperatures. Probably the duration of the chilling-period was too short for a maximal effect when we compare with facts from the literature mentioned above.

During experiment 24 the cv. 'Redgauntlet' did react much better than 'Deutsch Evern'. Somewhat vaguely it is mentioned by GUTTRIDGE (60) that

'Royal Sovereign' probably needs less chilling than 'Climax'. Especially from the U.S.A., differences in reaction to chilling between cultivars are known (9, 36, 37, 39, 40, 43, 118, 151). Cultivars adapted to southern states have no or a small chilling-requirement and this characteristic is inherited from *Fragaria chiloensis*, though nothing is known about its genetical backgrounds (10).

The 'chilling-requirement' of 'Deutsch Evern' was not shown in a convincing way. This is partly due to the interaction with the daylength and to a duration of the chilling-treatment which probably was too short. For a final answer, the chilling-effect should be studied by forcing under controlled conditions of temperature and light, using two daylengths. As soon as the elongation becomes the same in SD and LD, the chilling-requirements are fulfilled. When studied in this way, the early cultivars 'Deutsch Evern' and 'Glasa' probably will appear to need long cold periods, as even in February the elongation is promoted by daylength extension according to experiment 28. This is also known from practice (142).

5.4. THE START OF FORCING BEFORE THE 15TH OF JANUARY

For useful forcing, 2 factors are important viz. the earliness and the production.

5.4.1. The earliness

This is determined by the main factors cultivar, light energy and temperature and depends upon the beginning-date of forcing in a greenhouse and on the speed of plant development, which are closely related.

An early cultivar has a greater speed of plant development than a later one. The adaptation of the cultivar to the available light energy may be the main reason for the use of different cultivars for forcing in different countries (75, 86, 94, 100, 127, 154). The available light energy in a greenhouse during winter and spring is of major importance for the earliness and it should be kept in mind that the light energy in a greenhouse on the average is 30% less than in nature. The later one starts with forcing in a greenhouse during January to April at a given temperature, the shorter the period will be to the 1st fruit (experiments 21, 25–28) and this is exactly as is found in the culture of early tomatoes (173, p. 205).

The experiments 21–23 under artificial light have shown that the earliness was not connected with any degree of dormancy or any degree of truss elongation. A higher forcing-temperature, however, has accelerated the plant development and hence the earliness, as could be expected (experiment 28).

Sprays of GA_3 can accelerate the fruit development more or less (95, 166), but its effect on fruit size often is disadvantageous.

There are other factors which have a modifying influence on the earliness but practically all reduce plant vigour and hence also the production, as e.g.: a light soil and a low level of ground water, nitrogen deficiency and the presence of virus (58, 92, 130), the use of younger plants instead of older ones (79) and a later date of planting before the beginning of forcing (82, in 1958).

5.4.2. The production

Besides early, the production should be as big as possible, while the fruit size is more important than the number of fruits (162), because forced strawberries are marketed and paid per fruit and not per unit of weight.

When forcing starts later in spring, the production increases (experiments 25–28). For a culture under continuous artificial light KLESCHNIN (87) considers that at least 10^5 erg/cm^2/sec of light will be necessary, with 400–800 Watt/m^2 of installed power. Even at that level, as was used during the experiments 21–23, the production per plant remained low.

Sprays with sugar solutions have given a few more, but small fruits (90).

A normal production in early forcing is 100 g per plant and an excellent one is 150–200 g per plant (87). This production was never reached in the experiments described in chapter 4, which might be due to the use of clay-pots.

The elongation of the petioles and the trusses is of minor importance for the direct production, but the amount of marketable product may be higher with a better elongation due to a more open habit of the plant which decreases the damage by *Botrytis.*

When the temperature is too high during forcing at a rather low light intensity, the fruit size is reduced, e.g. at 21 °C during experiment 28. The temperature of forcing must be adjusted to the available amount of light energy, but experiment 28 has also shown that a temperature of 18 °C during the day and 13 °C during the night, given early in the season, can be applied without disadvantages instead of the temperatures of 15 °C and 10 °C respectively, as has been advised in practice up to now.

Sprays of GA_3 can easily reduce the fruit size (experiments 26 and 27, reference numbers 95, 102, 153, 157, 159, 169, 186) and they do not seem advisable for the practice.

In conclusion, the beginning-date of forcing in January is related strongly to the amount of light energy in the greenhouse. Without extra strong light for assimilation, the chances for useful forcing before the 15th of January are small. The perspectives for the early forcing depend on measures, which promote the assimilation in an economical way as e.g.: the breeding of cultivars which are using the light more efficiently and distribute it over the fruits appropriately (as in the cultivar 'Glasa'); a small increase in concentrations of CO_2 in the greenhouse (73, 89, 125, 126); the use of greenhouses with a high input of light and the use of strong extra light, as soon as the application becomes cheaper than at the present. Especially the last factor will determine the economical possibilities.

SUMMARY

During the last decade the very early forcing of strawberries became attractive for growers in the Netherlands and has good prospects. The most important centre is found near Zaltbommel.

A research was carried out to study whether successful forcing can start before the 15th of January. Therefore the following subjects were studied: the backgrounds of the flower initiation, the characteristics of an early cultivar, treatments influencing the dormancy, the results of forcing after varying beginning-dates.

The background of the flower initiation. In nature, the flower initiation in many June-bearing cultivars starts between August 20 and September 20. The microscopical stages of development are shown in plate 1.

Early cultivars start their flower initiation before late cultivars. Between early and mid-season cultivars there may not be much difference in this respect. In 2 successive years the differences between the cultivars were not the same and probably this was caused by other differences in plant size.

After a minimal leaf area has been reached, 14–18 SD cycles of 8 hours of light and 16 hours of darkness are needed for 'Deutsch Evern' in 18°C.

For keeping plants vegetative, the natural short day has to be extended by incandescent light and at 21°C at least 2.400 erg/cm^2/sec should be given at plant height. Fluorescent light is ineffective.

At rather high temperatures the initiation takes place in SD, but at 5°C the plant is almost dayneutral though even then the realization can be promoted by 16 or 24 hours of IL per day. Long periods in 5°C can lead to irregular flowering at relatively high temperatures afterwards. The action of low temperatures on the flower initiation is supposed to be twofold: a short period removes the light inhibition, but during a longer period a substance accumulates which can stimulate the elongation and inhibits the flower initiation. After a short period in 5°C, SD (in 20°C) can intensify the degree of initiation somewhat. After varying amounts of cold, followed by LD (at a rather high temperature), the plants can be reinduced by SD to the same degree. After long periods of chilling the generative plant reverts to a vegetative condition. No effect of seed vernalization has been found.

No inhibition was found by 3 sprays of GA$_3$ of 15 ppm before or during a SD treatment; when given afterwards, the truss elongation was promoted and the number of open flowers was increased.

In runner series with mother and daughter plants receiving differential SD or LD treatments, no transport was found of a flower stimulus from the plants in SD. On the contrary, a slight inhibitory action was noted, coming from mother plants in LD. In one experiment this factor has promoted the runner formation. The theory of GUTTRIDGE on the absence or presence of an inhibitor which determines whether initiation can take place or not, may be right.

The characteristics of an early cultivar. An early cultivar is characterized by a rather early start of the flower initiation, by an advanced state of realization early in spring, by an early time of flowering and by a short period from flower to fruit. It seems likely that early cultivars can use the light more efficiently than late ones.

Production of pollen in the first flowers is important.

Treatments influencing the dormancy. To keep plants growing above ground in 15–21 °C during September, the extension of the natural daylength by IL is more important than a high temperature. Already weak intensities of about 900 erg/cm^2/sec can be used even though these are too low for keeping the plants vegetative. Root growth, however, is stronger in SD than in LD and decreases in a relatively higher temperature.

No absolute dormancy has been observed. When plants were forced periodically, the elongation of the petioles and the fruit trusses of 'Deutsch Evern' was at a minimum between October 15 and November 15. The term 'relative dormancy' is preferred above others.

Rather long periods of chilling are necessary for promoting the truss elongation; no difference was found between the treatments in 2, 5 or 8 °C. For a better elongation of the fruit trusses in autumn, rather short periods of cold can be supplemented by LD and GA_3 sprays, which are working additively. To determine the chilling-requirement of a cultivar, forcing should be carried out periodically and with 2 daylengths at least. The cv. 'Redgauntlet' has been influenced more by 6 w. in 5 °C than 'Deutsch Evern'.

The elongation of petioles and trusses is influenced by:

a. The cultivar. 'Glasa' elongates better than 'Deutsch Evern'.
b. The beginning-date of forcing. With a later date in winter a better elongation is obtained.
c. A long day of IL, given as daylength extension or as a night break.
d. Sprays with GA_3, of 15 or 30 ppm. They influence especially the fruit trusses.
e. A relatively high temperature. This accelerates the elongation, but does not influence the final length.

The results of forcing with varying beginning-dates. The speed of plant development is influenced by the cultivar, a later beginning-date of forcing and a relatively high temperature, as main factors. An extended chilling-period, daylength extension and sprays with GA_3 have no accelerating action.

Size of the yield is influenced by the cultivar and the beginning-date of forcing, the latter being primarily related to the amount of light energy. The forcing-temperatures of 15 °C during the day and 10 °C during the night, which are advised in practice, can be raised without difficulties to 18 and 13 °C respectively but a rise to 21 and 15 °C respectively reduces the fruit size. A long chilling-period and daylength extension can have an indirect influence by reducing the losses caused by *Botrytis*. Sprays with GA_3 easily reduce the fruit size.

The perspectives for the early forcing, especially before January 15, are determined by all measures which promote the efficient use of the assimilatory light.

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SAMENVATTING

OVER DE BLOEMAANLEG, DE WINTERRUST EN HET VROEGE FORCEREN VAN AARDBEIEN

Het zeer vroege forceren van aardbeien is de laatste decade voor telers in Nederland aantrekkelijk geworden en heeft goede vooruitzichten. Het belangrijkste centrum ligt nabij Zaltbommel.

Een onderzoek werd uitgevoerd om na te gaan of men met succes eerder dan ongeveer 15 januari met het forceren kan beginnen. Daartoe zijn bestudeerd: de achtergronden van de bloemaanleg, de kenmerken van een vroeg ras, de beinvloeding van de rustperiode, de forceerresultaten bij verschillende begindata.

De achtergronden van de bloemaanleg. In de natuur begint de bloemaanleg bij veel éénmaaldragende rassen ongeveer tussen 20 augustus en 20 september. De microscopische ontwikkelingsstadia zijn op plaat 1 afgebeeld.

Vroegrijpende rassen beginnen eerder met de bloemaanleg dan late rassen, maar tussen de vroege en middentijdse rassen is soms weinig verschil. Met betrekking tot het begintijdstip van bloemaanleg waren de rasverschillen in 2 opeenvolgende jaren niet dezelfde, wellicht door andere verschillen in plantgrootte.

Nadat een minimaal bladoppervlak bereikt is, zijn bij 18°C tenminste 14–18 KD cycli van 8 uur licht en 16 uur donker nodig.

Om bloemaanleg tegen te gaan is verlenging van de natuurlijke korte dag nodig met gloeilicht, dat bij 21° tenminste 2.400 erg/cm^2/sec op planthoogte moet zijn. TL werkt niet.

Bij vrij hoge temperaturen heeft de bloemaanleg plaats in korte dag, maar bij 5°C is de plant vrijwel dagneutraal, hoewel de realisatie dan nog wel bevorderd wordt door 16 of 24 uur gloeilicht per etmaal. Lange kouperioden kunnen leiden tot onregelmatige bloei bij hoge temperaturen daarna. Aangenomen wordt dat bij een korte kouperiode de remming van het licht is opgeheven, maar dat er zich bij een lange duur van de kou een strekkingsbevorderende doch tevens bloeiremmende stof ophoopt. Na een korte kouperiode kan KD (bij 20°C) de bloemaanleg enigszins versterken. Na verschillende hoeveelheden voorafgaande kou, gevolgd door LD in de warmte, kan KD de planten opnieuw en in dezelfde mate tot bloei induceren. Na lange kouperioden slaat een generatieve plant op de duur om naar een vegetatieve toestand. Zaadvernalisatie werkt niet bloeibevorderend.

Een drietal bespuitingen met GA_3 van 15 dpm, gegeven vóór of tijdens de KD periode, remt de bloemaanleg niet; indien gegeven aan het eind of na afloop van de KD, dan werkt het bevorderend op de trosstrekking en het aantal open bloemen wordt vergroot.

In proeven met uitloperseries van moeder- en dochterplanten in LD of KD werd geen transport gevonden van een bloeistimulerende factor uit de KD, maar wel van een zwak bloeiremmende, komende van de moederplanten in LD. In één proef bevorderde deze factor de uitlopervorming. De theorie van GUTT-

RIDGE, die de af- of aanwezigheid van een remmende factor bepalend acht voor al of geen bloemaanleg, kan niet verworpen worden.

De kenmerken van een vroeg ras. Een vroeg ras wordt gekenmerkt door een vrij vroeg begin van de aanleg, door een ver voortgeschreden aanleg in het voorjaar, door een vroege bloei en door een korte periode van bloem tot vrucht. Het lijkt waarschijnlijk dat vroege rassen het zonlicht efficiënter benutten dan late rassen.

Produktie van stuifmeel in de eerste bloemen is belangrijk.

De beïnvloeding van de rustperiode. Om planten in september bovengronds aan de groei te houden, is in het traject 15–21 °C dagverlenging belangrijker dan een hoge temperatuur en dit effect wordt al bereikt met zwak gloeilicht van ongeveer 900 erg/cm^2/sec op planthoogte; dit is een intensiteit waarbij de bloemaanleg niet meer wordt tegengehouden. De wortelgroei is echter sterker in KD dan in LD, maar neemt af bij toenemende temperatuur.

Een absolute rust werd niet gevonden. Bij periodiek forceren bleek de strekking van bladstelen en bloemtrossen bij 'Deutsch Evern' minimaal tussen 15 oktober en 15 november. Aan de term 'relatieve rust' wordt de voorkeur gegeven boven een andere.

Onder invloed van voorafgaande perioden kou nam de strekking geleidelijk iets toe; er werd geen verschil gevonden tussen de behandelingen bij 2, 5 of 8 °C. Voor strekking van de bloemtros in de herfst kan een betrekkelijk korte kouperiode aangevuld worden door een LD behandeling of door GA$_3$ bespuitingen, die additief werken. Om de koubehoefte van een ras te bepalen, kan men het beste periodiek forceren bij tenminste 2 daglengten. Bij 'Redgauntlet' werkte 6 w. 5 °C beter dan bij 'Deutsch Evern'.

De strekking van bladstelen en bloemtrossen wordt beïnvloed door:

a. Het ras. 'Glasa' strekt beter dan 'Deutsch Evern'.
b. De begindatum van het forceren. Hoe later men in de winter begint, hoe beter de strekking is.
c. Een lange dag van gloeilicht, gegeven als aanvulling van het daglicht of als nachtonderbreking.
d. Bespuitingen met GA$_3$ in 15 of 30 dpm. Zij beïnvloeden vooral de trosstrekking.
e. Een hogere temperatuur. Deze versnelt, maar de uiteindelijke lengte wordt er niet door bevorderd.

De forceerresultaten bij verschillende begindata. Op de ontwikkelingssnelheid hebben vooral het ras, de begindatum van het forceren en de temperatuur invloed. Een langere voorafgaande kouperiode, dagverlenging of GA$_3$ bespuitingen hebben geen belangrijke versnelling tot gevolg.

De oogstgrootte wordt bepaald door het ras en de begindatum van het forceren en bij deze laatste factor is de hoeveelheid licht doorslaggevend. De forceertemperaturen van 15 °C overdag en 10 °C 's nachts, zoals die in de praktijk worden aanbevolen, kunnen zonder bezwaar verhoogd worden tot 18 °C respectievelijk 13°C; bij een verdere verhoging tot 21°C respectievelijk 15°C wordt de vruchtgrootte nadelig beïnvloed. Een langere kouperiode en dagverlenging kunnen indirect een gunstig effect hebben door minder vruchtrot bij een 'meer open' gewas. Bespuitingen met GA_3 leiden snel tot kleine vruchten en kunnen niet algemeen aanbevolen worden.

De perspectieven van de vroege forceerteelt, vooral vóór 15 januari, worden bepaald door alle maatregelen die het efficiënt gebruik van het assimilatorische licht bevorderen.

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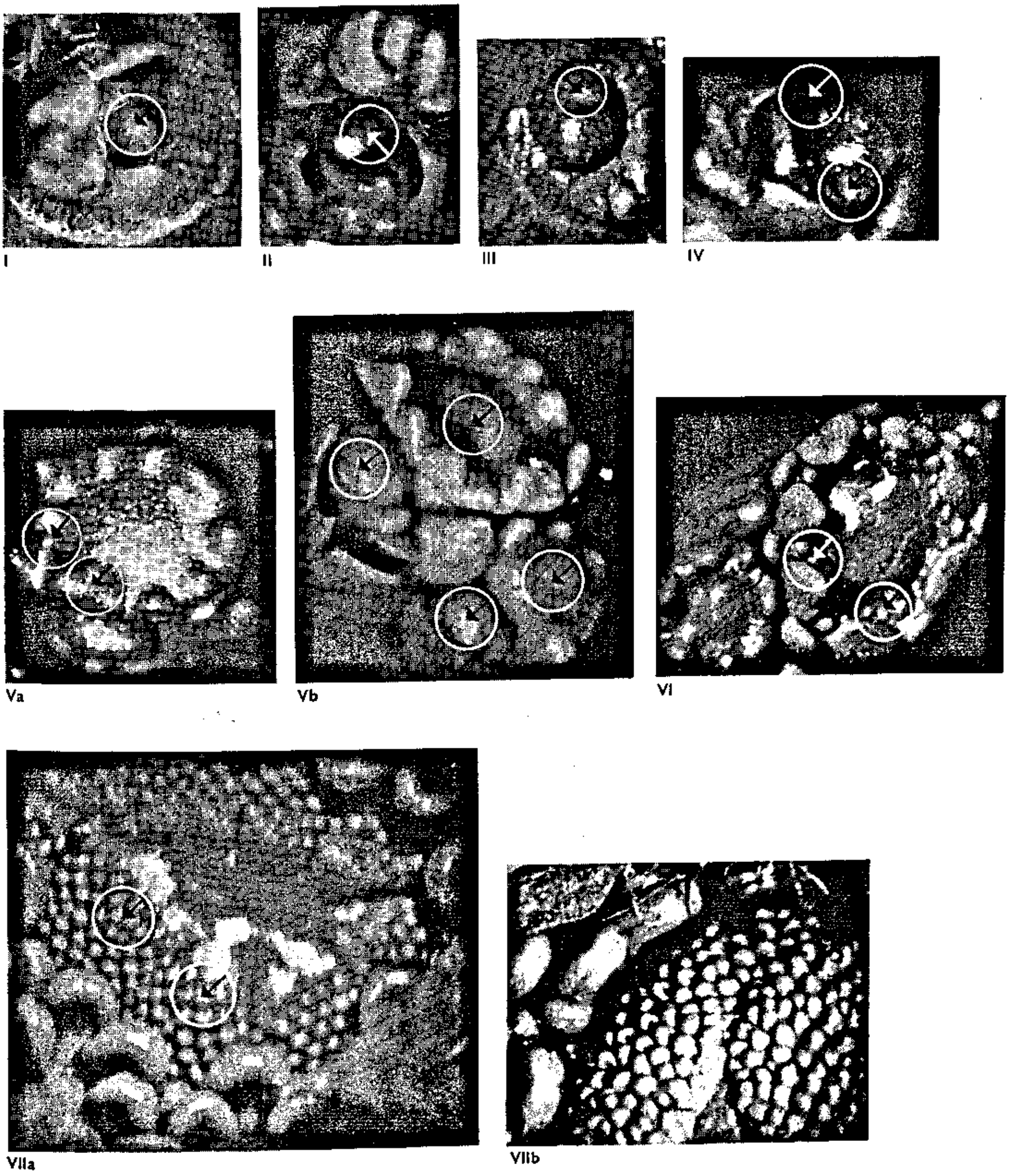


Plate 1. Stages of flower development in 'Deutsch Evern'. Magnification 50 ×.

I. Flat vegetative growing point
II. Round generative growing point
III. The first bract
IV. Primordia of the calyx
Va. Primordia of the corolla
Vb. Flowers of one truss in different stages of development
VI. Primordia of the stamens
VIIa. Primordia of the carpels, but the receptacle is not complete
VIIb. Advanced stage of VIIa

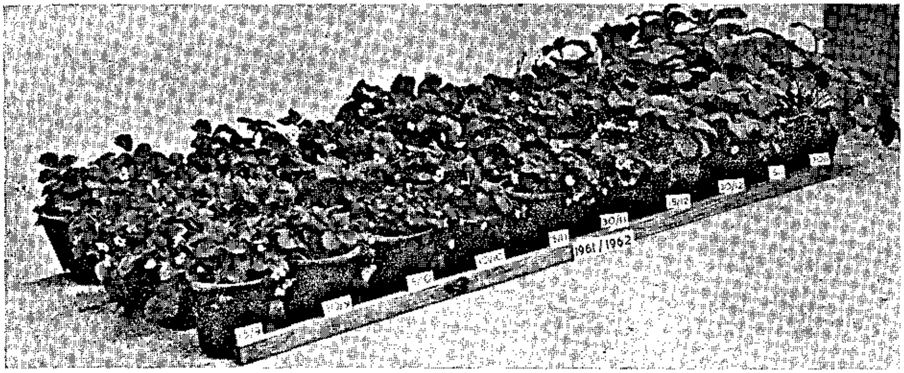


PLATE 2. *Experiment 15.* Ten groups of 'Deutsch Evern' plants were grown in the open till the initial date of forcing, as indicated from 15/9/61, ..., 30/1/62, in a greenhouse at 18°C and natural daylength. From 15/12/61 leaves and petioles were growing better and the number of trusses was reduced. Date of photo: 12/4/62.

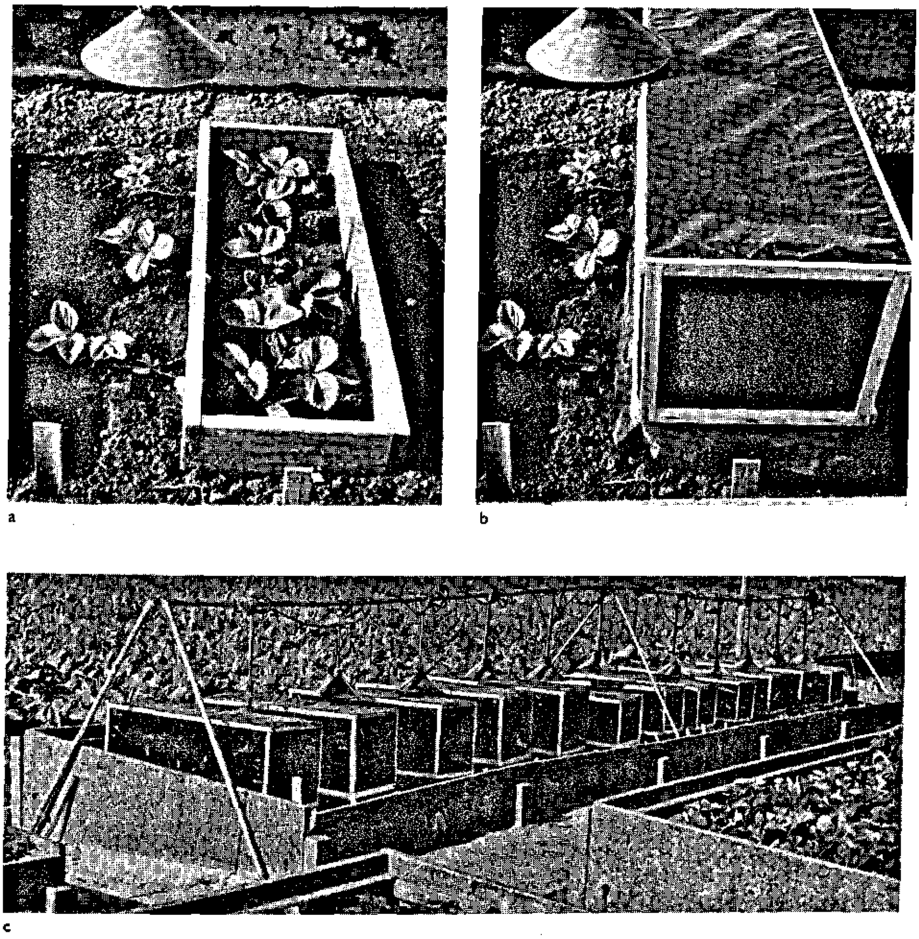


PLATE 3. *Experiment 19.* Three pairs of mother and daughter plants, differentially treated with LD or SD.

a. The runners are directed through cotton-wool filled grooves in wooden frames. The mothers (left) are partially defoliated and receive a LD treatment. In the second series the runner is cut off.

b. The daughters are given a SD treatment by putting a black plastic cover upon the frame.

c. General view of the LD and SD treatments.

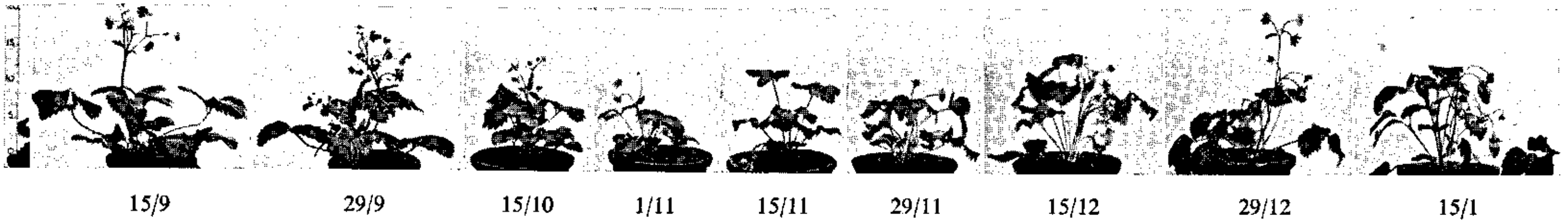


Plate 4. *Experiment 20.* 'Deutsch Evern' plants were forced from varying beginning-dates in 1960–61, for 60 days at 18 °C and LD. The elongation of the fruit trusses was minimal when forcing started on 15/11. Note the advanced stages of fruit growth when forcing started on 15/1/61.

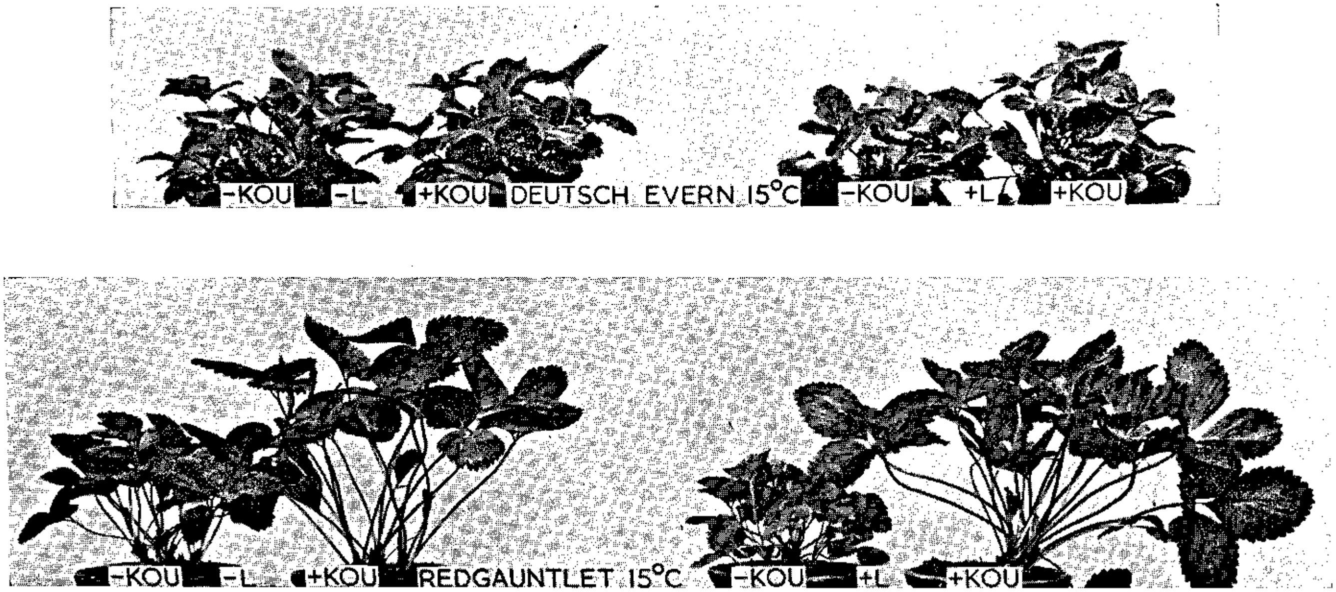


Plate 5. *Experiment 24.* The 2 cultivars 'Deutsch Evern' and 'Redgauntlet' were pretreated with SD (= –L) or LD (= +L) before – chilling (= – Kou) or + chilling (= + Kou) was given during 6 weeks. 'Redgauntlet' showed an increased vigour after chilling, but 'Deutsch Evern' did not react.

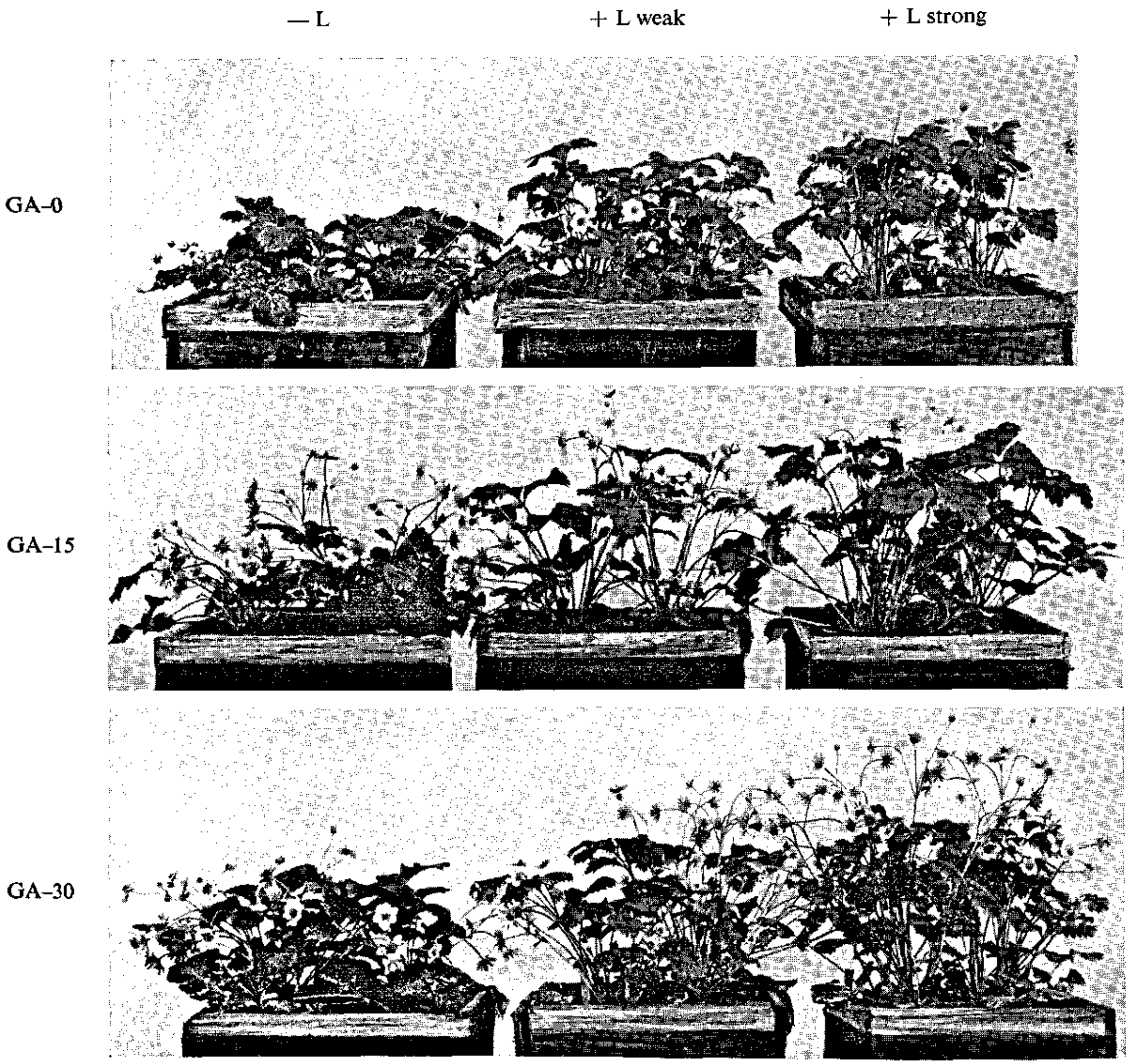


PLATE 6. *Experiment 26.* 'Deutsch Evern' plants were forced from 15/1/62 in all combinations of 3 light-treatments and 3 concentrations of GA_3 sprays. The photos were made after 7 w. of forcing.
The elongation of the petioles is promoted more by the light-treatments than by the GA_3 sprays.
The length of the fruit trusses was enhanced by the light and the GA_3 sprays, which did not interact.
The difference in elongation between the plants upper left and lower right is striking.
– L = without daylength extension
+ L weak = daylength extension to 16 hours by weak incandescent light
+ L strong = daylength extension to 16 hours by strong incandescent light
GA–0, –15, –30 = gibberellic acid, 0, 15 or 30 ppm.

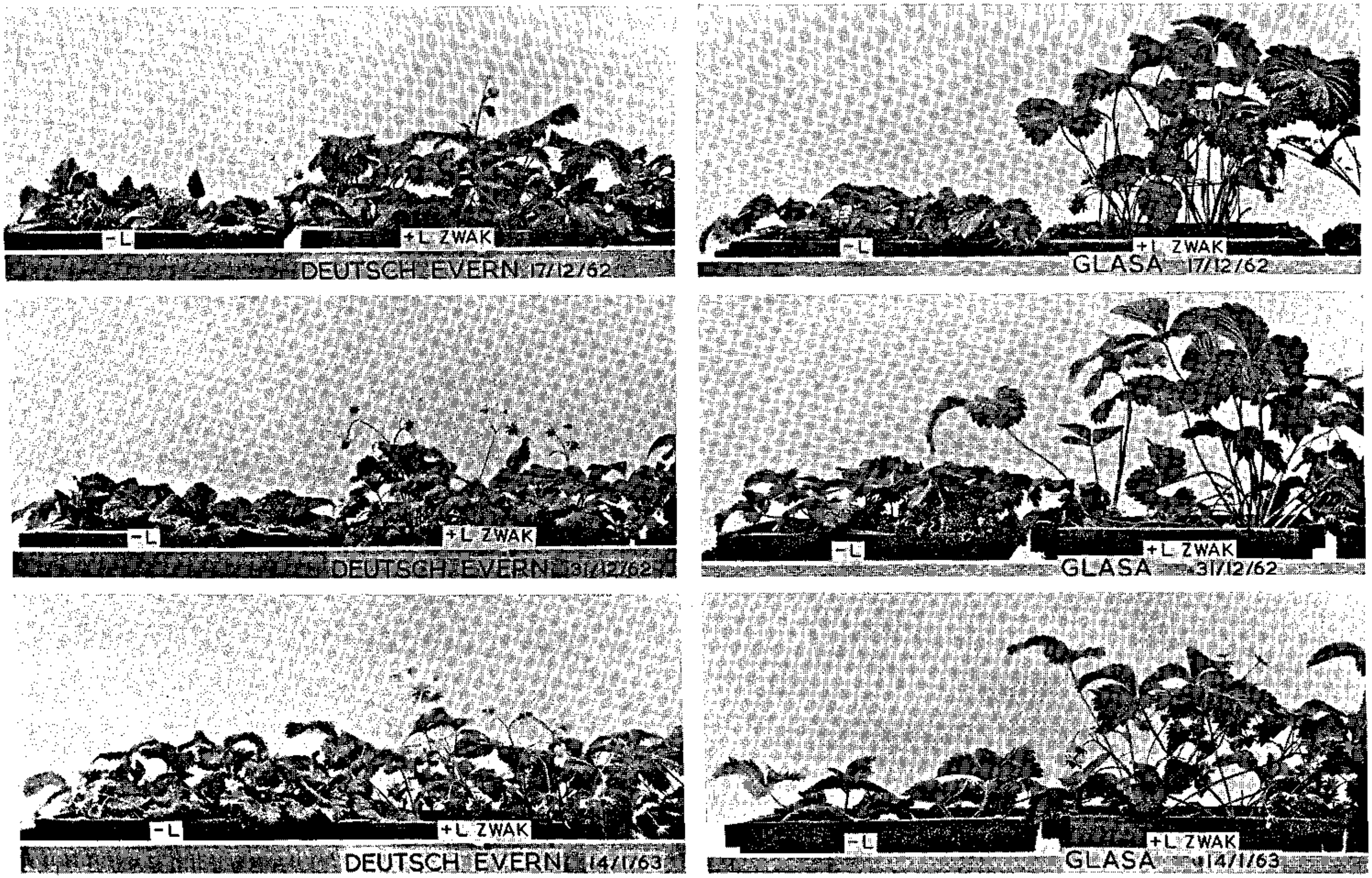


Plate 7. *Experiment 27.* The cultivars 'Deutsch Evern' and 'Glasa' were forced in a greenhouse, without (—L) or with a night break of 3 hours by weak incandescent light (+ L zwak), from 3 beginning-dates of forcing in 1962–63, as indicated. The photos were made after 9 w. of forcing, from the 3rd date.

Without a night break (— L) the elongation of petioles and fruit trusses was bad in both cultivars and on all dates, but much better with a night break, especially in 'Glasa'. Unfortunately the plants of 'Glasa', —L, 14/1/63, were damaged by severe winter frost, before the forcing started.

Deutsch Evern Beginning-dates of forcing

20/12/63

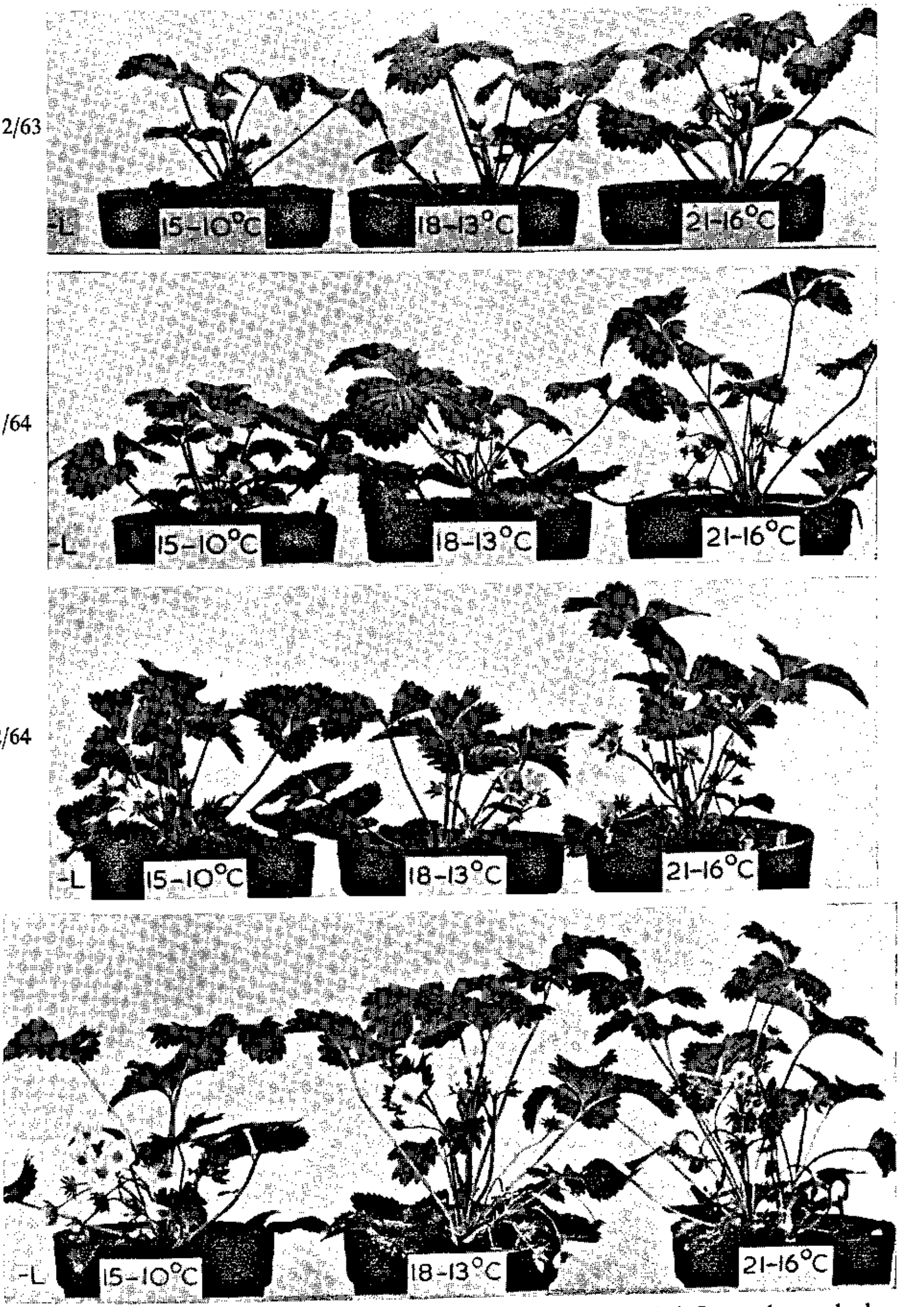
17/1/64

14/2/64

13/3/64

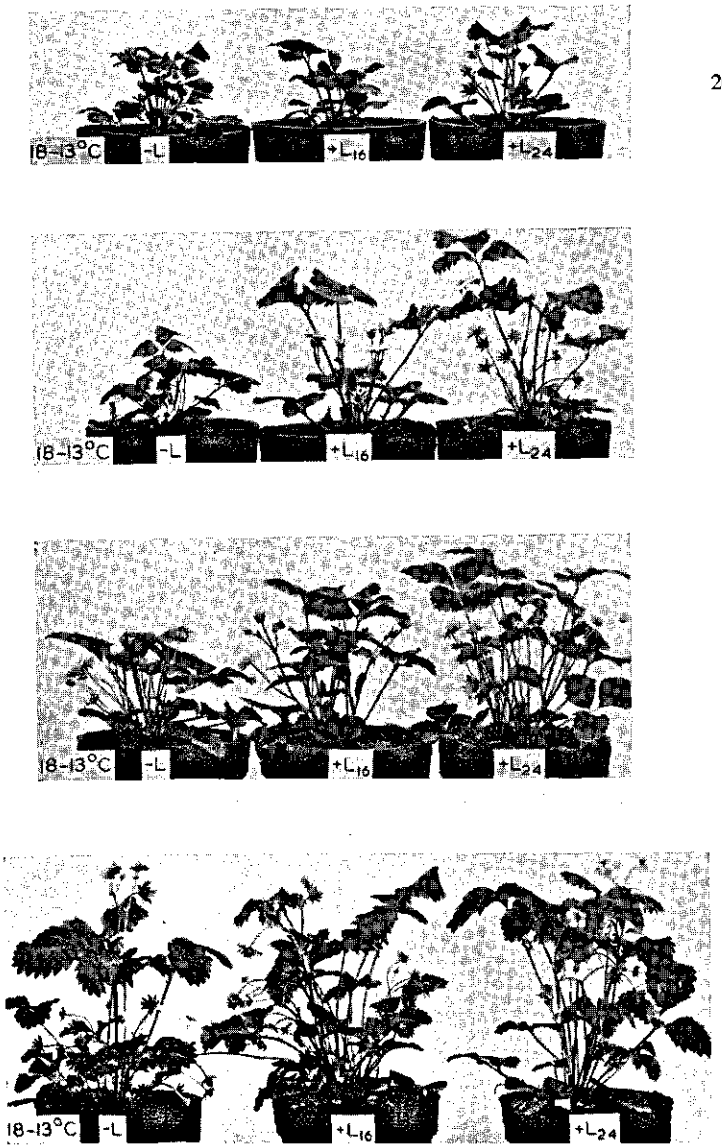
Plate 8. *Experiment 28.* The cultivars 'Deutsch Evern' (left) and 'Glasa' (right) were forced from 4 beginning-dates in 1963–64 at 3 temperatures as indicated. The temperature during the night was 5°C lower than during the day. The photos were made after 4 w. of forcing in a greenhouse.

Beginning-dates of forcing *Glasa*



The elongation of petioles and especially of fruit trusses is influenced more by beginning-date than by the temperature. Compare plate 9.
— L = natural daylength

Deutsch Evern Beginning-dates of forcing



20/12/63

17/1/64

14/2/64

13/3/64

Plate 9. *Experiment 28.* The cultivars 'Deutsch Evern' (left) and 'Glasa' (right) were forced from 4 beginning-dates in 1963–64 and 3 light-treatments, at 18°C during the day and 13°C during the night. The photos were made after 4 w. of forcing in a greenhouse. Daylength extension promotes the elongation of petioles and fruit trusses, but its influence decreases with a later beginning-date. Compare plate 8.

$-L$ = natural daylength

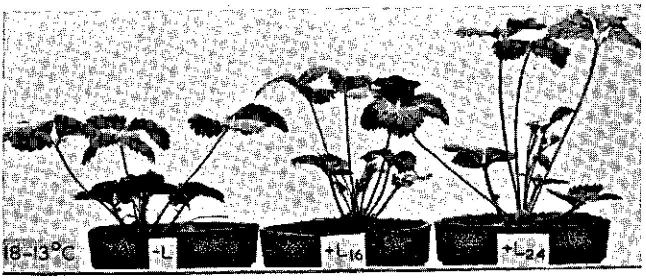
$+L_{16}$ = natural daylength extended to 16 hours by incandescent light

$+L_{24}$ = natural daylength extended to 24 hours by incandescent light

Beginning-dates of forcing

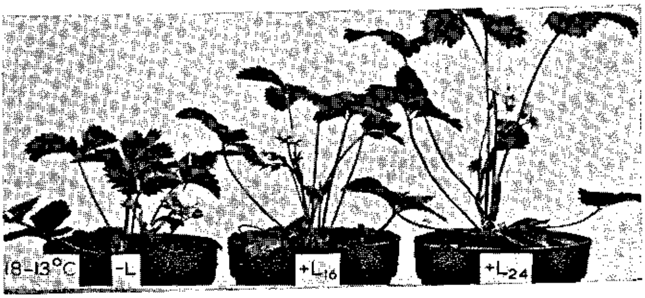
Glasa

20/12/62



17/1/64

14/2/64



13/3/64