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FLOWER DEVELOPMENT OF ASTER DURING WINTER

PBG/DIARP project 93/09

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PREFACE

This research was carried out on the Research Station for Floriculture and Glasshouse Vegetables in Aalsmeer, and was partly subsidized by DIARP (Dutch-Israeli Agricultural Research Program). This research was carried out in cooperation with Dr. Israela Wallerstein, at the department of Floriculture of the Volcani Center in Bet Dagan.
About the research two annual reports have been compiled by both counterparts. This report includes the contents of these two reports, and covers the entire research of the three years (only the Dutch part). Together with the final report of Israela Wallerstein this report concludes the project DIARP 93/09.

Acknowledgements

We thank Klaas van Dam and Marcel van Haalem for the cultivation of the plants, Tanja Rozendal for the dissection of aborted flower meristems, and Herman Stephan for making some photographs. We thank the members of the VGB group 'Aster-stek' for their continuous interest in our research, and for supplying cuttings of 'Monte Cassino'.

Ing. Adri Durieux
Dr. Tjeerd Blacquière

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ABSTRACT

The quality of *Aster* is determined for a large part by the number of flowers that develops on a shoot. This number of flowers is particularly controlled by the quantity of light that is available. With a lack of light the plants cannot assimilate enough to support the development of flowers, leading to abortion of many meristems. Therefore the quality of *Aster* grown in the Netherlands during winter is poor. In Israel the same problem exists to a certain instance, despite the higher level of light (three times that in the Netherlands). A poor flower load therefore may be not due to a lack of light only.
In this research the influence of photoperiod on the development of flowers was studied. It was found that with low light levels and very short days a lot of abortion occurred. The number of flowers could be increased by extending the short-day to 13.5 hours with a low light flux. The developmental rate of the meristems was slowed down by day extensions, resulting in a retardation of flowering by five to eleven days, and a considerable decrease in the number of aborted meristems. The susceptibility to abortion was maximal in the first weeks of the short-day period. During the first four to five weeks of the short-day period the most important improvement was achieved. In this same period a lack of light did readily cause flower bud abortion.
In this research the cultivars 'Dark Pink Star' and 'Monte Cassino' were used. There exist differences between these cultivars in the rate of flower development, despite the fact that they almost flower simultaneously. In 'Monte Cassino' the development of the flowers is during the first three to four weeks slower than in 'Dark Pink Star'. The day extension in order to get more flowers therefore also needed to continue for a slightly longer period in 'Monte Cassino'.
The day extensions were carried out with incandescent lamps and 'Energy saving' lamps (compact discharge lamps, SL-Agro). Incandescent have a part of their output in the far-red wavebands, the SL has no far-red. In the research it was found that a day extension with a small quantity of only far-red light caused a decrease in the number of flowers. However it could not be concluded that a mixture of red and far-red (incandescent lamp) was negative for flower development.
The most clear cut conclusion from this research is that the short-day photoperiod of 11 hours, applied by the growers, is far from ideal. Improvement of the number of flowers can easily be achieved by extending the short-day to 13.5 hours during the first five weeks of the short-day period.

1. INTRODUCTION

1.1 GENERAL

Aster is a rather new cut flower crop, gaining interest in both Israel and the Netherlands the last few years. *Aster* is a short-day plant for flowering (Kadman-Zahavi & Yahel, 1985; Schwabe, 1985). The critical daylength, i.e. the daylength that must be exceeded to inhibit the short-day response (flowering) is between twelve and thirteen hours (Blacquière & de Koster, 1991). During long-days *Aster* grows vegetatively and elongation of the future inflorescent shoot occurs. During the subsequent short-day period flowering is induced and flower development takes place. Simultaneously new juvenile shoots develop at the stem base. Photoperiods slightly longer than the critical daylength result in a significant delay of flowering (photoperiod longer than 13 hours) or even prevent flowering (above 14 hours; Blacquière & de Koster, 1991). Probably these slightly longer photoperiods also retard the development of new basal shoots.
During winter it is not possible to produce a good quality flowering shoots in the Netherlands, since the flower occupancy of the shoots is too low. Many of the potential flower buds abort or wither in early stages. The direct cause of this poor flower occupancy of *Aster* shoots is the low irradiance during winter. However, in Israel, with plenty irradiance during winter, the problem of a decreased number of flower heads per branch also occurs. This suggests that the low light level during winter cannot be the only cause of the reduction of the number of flowers. Previous research, both in the Netherlands and Israel, suggests in addition to irradiance, an important role for photoperiod in the control of development of flowers in *Aster* (Blacquière & de Koster 1991; Wallerstein *et al.*, 1992). Asters growing under short-days slightly longer than the critical daylength produced more flowers per shoot, and flowered a few days later than plants that experienced photoperiods of twelve or less hours. This suggests that the decreased rate of flower development leads to a reduced withering of flower buds, i.e. leads to a higher number of fully developed flowers per shoot.

1.2 BACKGROUND INFORMATION

Aster (Compositae or Asteraceae) is a herbaceous perennial plant. Its growth and development are strongly regulated by photoperiod (Schwabe, 1985). After flowering, when growing in shortdays (and not too high temperatures) Aster remains vegetative and in a rosette stage. The rosette shoots are not able to produce flowers. They need long-days to de-juvenilize and elongate. After elongation the shoots can develop flowers upon induction by short-days. Each apical and axillary position has the potency to produce a flower head. However, the number of fully developed flowers that is actually produced differs between seasons, and is also dependent on the density of the canopy of the crop. During winter there are only few flowers per shoot, whilst in summer many axillary meristems produce a flower. Therefore a shoot can bear easily ten times more flowers during summer than during winter. The position of a meristem on the shoot strongly determines its susceptibility for withering. Axillary meristems are more susceptible for a failure of development than the apical meristems. Axillary meristems on side branches which are severely shaded are very susceptible for abortion.
The possible rate of development of a meristem to a flower depends on temperature, the amount of available light for photosynthesis, and on the photoperiod. Low temperatures slow down the development or even cause complete failure of it. The quantity of light determines how much sugars/carbohydrates the plant is able to produce in benefit of the development of flowers. A lack of sugars as a result of scarce sun light may disturb the development of the meristem.
Plants are able to measure daylength (Vince-Prue, 1975), and many plant species,

including *Aster*, have adapted to seasonally associated fluctuations in the environment. In spring and summer the aster plant will develop vegetatively under the influence of long-days, in late summer and autumn the shorter days induce flower development. In nature the days slowly become shorter towards the winter, giving the plant after approaching its critical daylength enough time to develop many flowers. Very short days are a signal that there is very little time left to fulfill the development of flowers. The rate of development will be very high under very short photoperiods.
The development of flowers is not the only process under the control of photoperiod in *Aster*. In addition to the development of flowers the plants will also start to develop new basal shoots for the next year. That the process develops at a higher rate at shorter daylengths also holds for basal shoot development.
One hypothesis to explain the failure of development of axillary meristems is that the release of apical dominance proceeds too fast (Wallerstein, 1993). Apical meristems release auxins that prevent or retard the development of axillary meristems. These meristems remain devoid of assimilates. Through the secretion of auxins meristems are able to attract assimilates (Salisbury & Ross, 1992). The apical dominance exists as long as the apical meristem is vegetative, or has not reached a certain stage of flower development. After release of apical dominance (probably after flower evocation in the apical meristem) the axillary meristems can built up an auxin gradient and as a consequence import assimilates to support their growth and development.
Under dark circumstances, with a low rate of photosynthesis, little assimilates are available for the meristems. A fast cancellation of apical dominance will cause many axillary meristems to demand for assimilates simultaneously, leading to a failure of development of many of them. Retardation of this cancellation of apical dominance leads according to this hypothesis to a more gradual demand for assimilates by the axillary meristems, during a longer time (the development of the axillary meristems proceeds at a lower rate). Per unit time less assimilates are thus needed for the same number of developing axillary meristems. According to this hypothesis the flower load of aster branches can be improved by extending the shortday photoperiod, since this reduces the number of axillary meristems that aborts as a consequence of a lack of assimilates.

1.3 OBJECTIVES OF THE RESEARCH

The primary aim of this research was to improve the flower load of shoots of *Aster* by means of extension of the shortday photoperiod with artificial lighting. In addition the influence of the amount of natural irradiation on the flower load was studied, and we tried to detect in which phase of the shortday period and which stage of meristem development the chance of abortion was maximal.

1.4 COOPERATIVE RESEARCH

As part of the Dutch-Israeli Agricultural Research Program (DIARP) a cooperative research was carried out by the Research Station for Floriculture and Glasshouse Vegetables (PBG) in Aalsmeer and the Volcani Center in Bet Dagan. The aim was to improve the quality of winter produced *Aster* shoots by increasing the flower load. The following hypotheses were proposed and tested during the research:

1. The failure of flower development occurs after floral evocation upon flower induction by shortdays.
2. The photoperiod controls the rate of flower development through the rate of cancellation of apical dominance.
3. The rate of release from apical dominance influences the success of flower development of axillary meristems.
4. The direct effect of the amount of irradiance on the success of flower development is mediated by the amount of assimilates available for flower development.
5. The rate of release from apical dominance and the rate of flower initiation and development influence the chances on success or failure by their effect on the sink activity of the axillary meristems.

The hypotheses mentioned above are more or less fundamental. The fundamental research has predominantly taken place at Bet Dagan, and therewith it is beyond the scope of this report. However, keeping these hypotheses and backgrounds in mind may help the reader to interpret the more practical experiments and results described in this report.

2. MATERIALS and METHODS

2.1 GREENHOUSE COMPARTMENTS

The experiments were carried out in the "Phototron" of PBG Aalsmeer. The phototron consists of four identical greenhouse compartments of 60 m^2 each. In each compartment there are four trolleys (2 m^2) that can be moved at any time to a dark compartment, controlled by a computer. In the dark compartments it is possible to reduce the photoperiod or to extend it by using artificial lighting. Using this equipment enabled us to provide the plants with any possible photoperiod. Both the dark and the daylight compartment were climate controlled by a computer.

2.2 PLANT MATERIAL AND LONG-DAY PERIOD

Because of previous research with the same variety it was decided to use *Aster* 'Dark Pink Star' for the experiments. In later experiments 'Monte Cassino' was added. Stock plants were cultivated in the Phototron with a photoperiod of 11 hours. The stock plants were replaced regularly in order to keep the quality of the cuttings on a good standard. The cuttings were rooted in fine perlite (provided by Pull ltd. Rhenen, Netherlands) and planted in a peat mixture in pots with a diameter of 12 cm. The plants for the experiments were cultivated as unpinched one-stem plants, and grown at a day temperature set point of 18°C and a night temperature of 14°C. During the long-day period the daylength was 18 hours, realized by lighting with HPS lamps at a PPF of 35 μmol m^{-2} s^{-1}. The relative humidity of the greenhouse air was tried to be kept above 40% throughout by fogging. The pots were placed on irrigation mats, and water and nutrient solutions were provided by an ebb-flow system. When the plants reached a length of 50 to 60 cm they were sorted on length and extent of branching, as a measure for maturity, and placed in the phototron where the actual experiments took place. During periods without ventilation the CO_2 concentration in the greenhouse approached 800 ppm. When ventilation was necessary the CO_2 concentration was kept about 360 ppm.

2.3 SHORT-DAY PERIOD

In the phototron the different photoperiod treatments were realized. From April 1994 till June 1996 more than 20 experiments were conducted, providing a good impression of the effects of photoperiod during the course of the seasons.
Most experiments were conducted using the following procedure:

- photoperiods of 11, 13 and 13.5 hours. In the earlier experiments also 12 and 12.5 hour photoperiods.
- The daily photoperiod in which the plants received sufficient light for photosynthesis was kept at 11 hours. In this way different photoperiods did receive the same daily number of photosynthetic photons. The differences between the treatments were realized by day extensions of different durations, provided by incandescent lamps at a PPF of 3 to 4 μmol m^{-2} s^{-1}. In a few experiments also compact discharge lamps were used (Philips SL-R-Agro 18 W).
- When the natural photoperiod was longer than 11 hours the plants were darkened. For practical reasons the darkening was applied in the morning: for the plants the photoperiod started 11 hours before sunset.
- When the natural photoperiod was shorter than 11 hours the day was extended with supplementary light till 11 hours (HQI-T, daylight spectrum, Osram, 20 to 25 μmol m^{-2} s^{-1} PPF). This additional light was also needed to compensate for the poor light transmission of the Phototron (about 35%). This lighting was used from October through March.

2.4 LIGHT MEASUREMENTS

During the whole experimental period continuously the PPF was measured in each greenhouse compartment, using cosine corrected quantum sensors (Bottemanne Weather Instruments, Amsterdam). Cumulative values for PPF are expressed as mol m^{-2} per unit of time (day, week, experimental period etc.)

2.5 OBSERVATIONS

When all top inflorescences of main shoot and side branches were open from each treatment a number of plants was harvested. Of these plants the number of flower heads, the number of 'blind' positions (meristems that had not produced a flower head or bud), the length and weight were determined. In many cases the number of flowers at the 30 upper positions were separately recorded, as well as the number of flowers at position 20, 25, 30, 35, 40, 45. Positions were numbered from the top (= position 0). In most experiments also the day of opening of the top flower head of each plant was recorded.

2.6 ANATOMY

In some of the experiments the development of the apical and the adjacent meristems was followed anatomically. Each week samples were taken, starting at the begin of the short-day period until the apical meristems had reached stage 11 (see p. 35), generally after 4 weeks. The samples were fixed in FPA 70% (Formaldehyde, propionic acid and ethanol). The fixed tissue samples were dehydrated in an ethanol series, embedded in a cold curing resin based on 2-hydroxy ethyl methacrylate (Technovit 7100, Kulzer & Co. Wehrheim, Germany), and sliced on a rotary microtome (Jung 2055 Autocut) 3 or 5 μm thick. The dissections were stained with Astra blue and safranin or in some cases with toluidin blue. After enclosure with Euparal the preparations were studied with a light microscope (Leica DM RB). Photographs were made using a Leica MPS 48/52 micro photography equipment.

3. RESULTS

3.1 EXPERIMENT 1: EXPLORATORY EXPERIMENT

- start 21 June 1994 (day 172)
- number of plants per m^2: 70
- length at start short-day: ± 65 cm
- number of sampled plants per treatment: 6

Table 1- Results experiment 1. Number of days in short-day until opening of apical flower, number of flowers on the 30 upper positions (top), total number of flowers per shoot, shoot weight (g) and shoot length (cm). values ±SEM.

treatment	days to flower	N flowers top	N flowers total	length cm	weight g
11	28	77.2 ± 5.9	173.7 ± 20.2	108 ± 3.6	47.7 ± 2.2
12	29	72.8 ± 6.4	232.5 ± 32.9	116 ± 3.7	60.7 ± 5.2
12 SL	30	78.3 ± 5.7	184.7 ± 27.4	110 ± 6.8	51.3 ± 4.8
13	37	149.8 ± 7.9	361.5 ± 39.9	111 ± 3.7	59.8 ± 5.7
13.5	x	x	x	x	x

The treatment with a photoperiod of 13.5 hours did not flower since the plants continued to grow vegetatively, and each meristem continued to branch off. Flower primordia were formed, but generally did not reach anthesis. The treatment of 13 h. produced considerably more flowers than the other treatments (Table 1). This increased flower number was accompanied by a retardation of flowering of about eight days. The 13 h. plants remained vegetative for a longer time. This was concluded since the side branches had developed a higher number of nodes (Figure 1, right). In later experiments this continuation of vegetative growth did not occur, and the retardation of flowering was always much less (see for instance the Figures 2, 3 and 4). Possibly something in this experiment went wrong, or the application of a longer short-day during the summer months may be risky. Also the dense canopy of the crop (70 plants per m^2) may have had a negative influence. The 12 h. treatment seemed to produce slightly more flowers than the 11 h. and the 12 SL (photoperiod 12 hours, 11 hours day + one hour lighting with SL-R-agro). All treatments with photoperiods longer than 11 h. produced slightly heavier shoots.

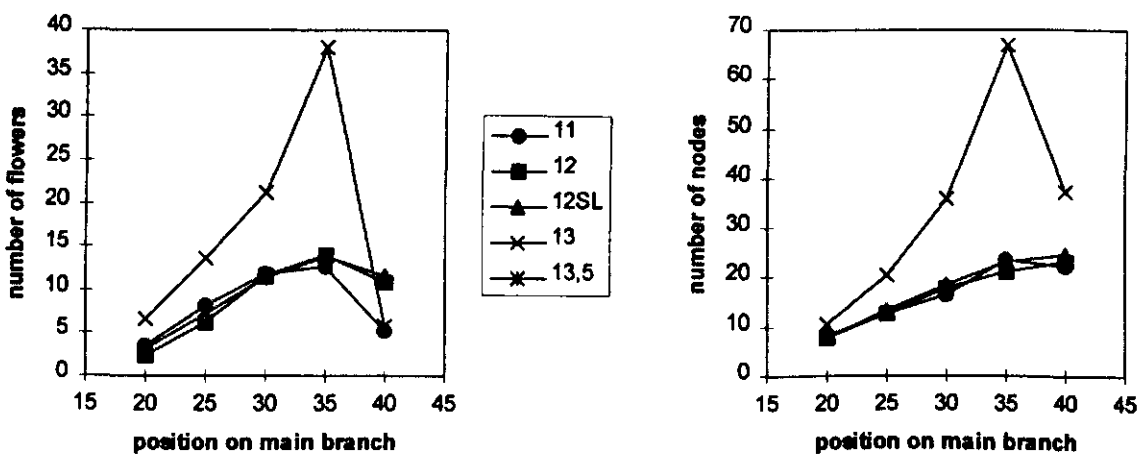


Figure 1- The effect of different photoperiods on the development of flowers and nodes on axillary branches on different positions. Positions are counted from the top (the top flower is position 1). Left: number of flowers; Right: number of nodes.

3.2 EXPERIMENT 2: EXPLORATORY EXPERIMENT

- start experiment: 19 July 1994 (day 200)
- number of plants per m^2: 70
- length of the shoots at start of short-day: ±65 cm
- number of sampled plants per treatment: 6

Table 2- Results experiment 2. Number of days in short-day until opening of apical flower, number of flowers on the 30 upper positions (top), total number of flowers per shoot, shoot weight (g) and shoot length (cm). values ±SEM.

treatment	days to flower	N flowers top	N flowers total	weight g	length cm
11	29	134.2±11.2	169.7±22.8	51.0±3.8	97.7±1.0
12	29	147.5±10.5	234.2±27.6	57.3±4.4	101.2±1.0
12 SL	30	204.7±8.7	222.2±36.1	59.7±3.1	98.7±1.4
13	37	178.5±11.2	230.5±68.6	54.8±3.0	101.0±1.3
13.5	55	201.3±11.8	271.0±36.6	73.2±5.8	106.3±1.9

In this experiment for the treatment 13.5 h. the photoperiod was reduced to 11 hours after six weeks, in order to prevent full inhibition of flowering, as occurring in experiment 1. In this experiment all treatments did produce more flowers than the 11 h. control. It was accompanied however by a tremendous retardation of flowering. Flowering was retarded by 26 days in the 13.5 h. treatment! There was only a very slight increase in flower number of the 13 and 13.5 h. treatments in comparison with the 12 h. treatments. Maybe the high planting density and the high temperatures during the experiment have caused this. Outwardly there were more buds visible than in the other treatments, but especially the buds on the lower side branches of the shoots did not fully develop. From Figure 2 it can be concluded that in contrast with experiment 1 no extra nodes were developed with longer photoperiods. Each node has the possibility to produce one flower.

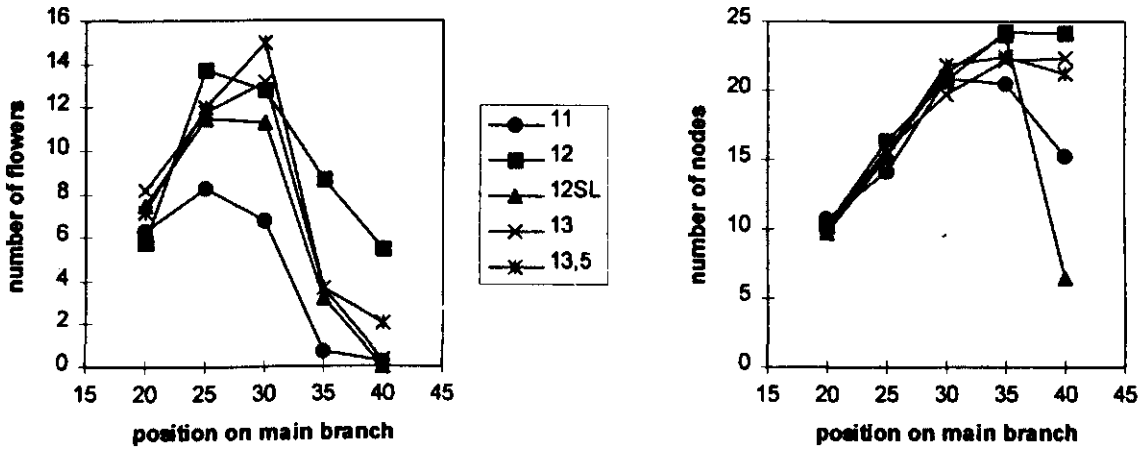


Figure 2- The effect of different photoperiods on the development of flowers and nodes on axillary branches on different positions. Positions are counted from the top (top flower is position 1). Left: number of flowers; Right: number of nodes.

3.3 EXPERIMENT 3: EXPLORATORY EXPERIMENT

- start experiment 18 August 1994 (day 230)
- number of plants per m^2: 60
- length of the shoots at the start of the short-day period: ±70 cm
- number of sampled plants per treatment: 8

Table 3- Results experiment 3. Number of days in short-day until opening of the apical flower, number of flowers on the 30 upper positions (top), total number of flowers per shoot, shoot weight (g) and shoot length (cm). values ±SEM.

treatment	days to flower	N flowers top	N flowers total	weight g	length cm
11	40	63.8±4.4	131.3±11.1	44.8±2.1	87.0±1.1
12	42	60.8±2.9	149.7±13.8	46.1±2.7	89.1±1.1
12 SL	46	62.1±5.2	132.0±8.8	41.1±2.0	87.4±1.1
12.5	46	74.8±5.2	149.3±7.4	42.4±1.4	90.6±0.8
13	46	63.3±3.9	172.4±11.2	47.8±1.8	91.7±0.7
13.5	49	77.3±3.1	140±9.3	43.8±1.6	92.2±1.2

In this preparatory experiment the 13.5 h. photoperiod was reduced to 11 h. already after two weeks. None of the treatments resulted in a considerably higher number of flowers than the control treatment of 11 h. (Table 3).

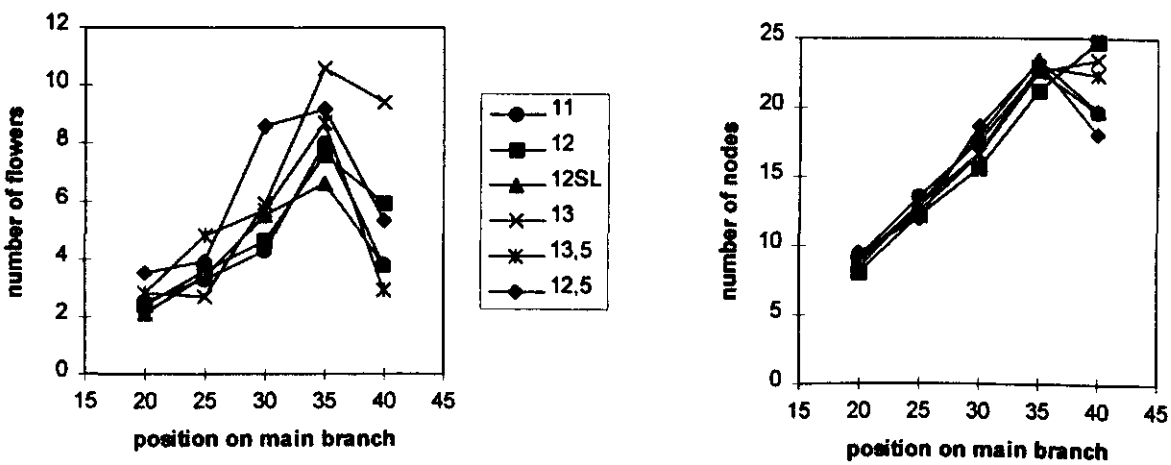


Figure 3- The effect of different photoperiods on the development of flowers and nodes on axillary branches on different positions. Positions are counted from the top (top flower is position 1). Left: number of flowers; Right: number of nodes.

3.4 EXPERIMENT 4: AUTUMN EXPERIMENT

- start experiment 5 September 1994 (day 248)
- number of plants per m^2: 60
- length of the shoots at the start of the short-day period: ±65 cm
- number of sampled plants per treatment: 6

Table 4- Results experiment 4. Number of days in short-day until opening of the apical flower, number of flowers and blind axils on the 30 upper positions (top), total number of flowers per shoot, shoot weight (g) and shoot length (cm). values ± SEM.

treatment	days to flower	N flowers top	N blind axils top	N flowers total	weight g	length cm
11	41	41.8±4.8	2.2±09	71.5±8.6	42.2±1.4	95.5±0.8
12	42	49.8±4.4	3.2±1.3	93.3±8.4	45.7±4.1	95.2±1.8
12 SL	41	45.0±7.4	0.0±0.0	101.0±7.2	41.3±1.4	91.3±1.4
12.5	41	56.0±3.1	2.7±1.1	97.3±10.5	41.3±2.8	93.7±1.4
13	43	57.8±6.7	0.2±0.1	118.8±12.8	42.2±2.7	93.5±1.6
13.5	44	53.0±5.6	1.0±0.4	73.7±9.0	38.7±1.5	96.5±1.1

In this experiment the photoperiod of the 13.5 h. treatment was reduced to 11 h. after four weeks. In the 12, 12 SL , 12.5 and 13 h. there was a small improvement of the number of flowers per shoot. The 13.5 h. treatment showed no improvement in comparison with the 11 h. control. There was hardly any retardation of flowering. Figure 4 (right) shows that there were no differences in the number of nodes per branch, regardless the position of the branch on the main shoot.

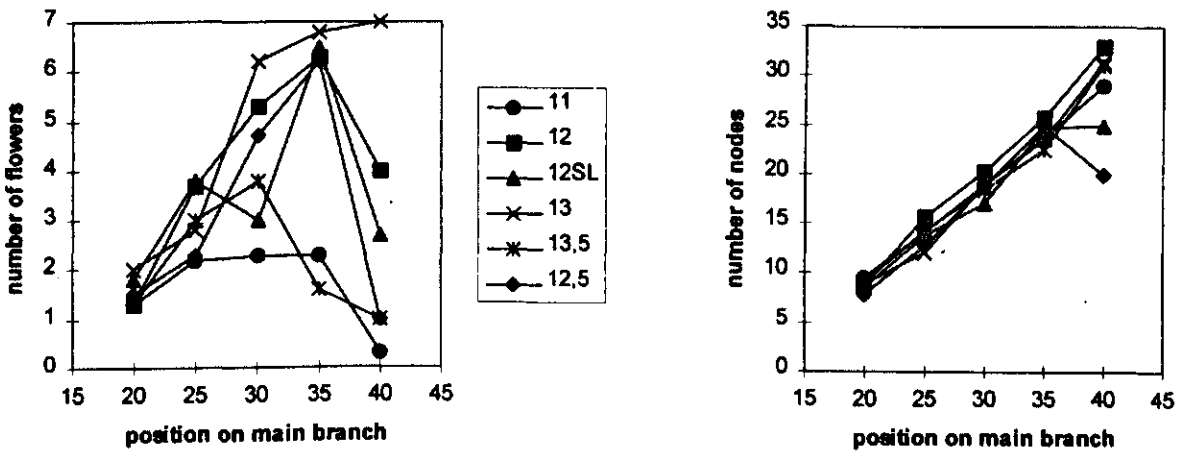


Figure 4- The effect of different photoperiods on the development of flowers and nodes on axillary branches on different positions. Positions are counted from the top (top flower is position 1). Left: number of flowers; Right: number of nodes.

3.5 EXPERIMENT 5: AUTUMN - WINTER

- start experiment 26 October 1994 (day 299)
- number of plants per m^2: 60
- length of the shoots at the start of the short-day period: ±65 cm
- number of sampled plants per treatment: 8

Table 5- Results experiment 5. Number of days in short-day until opening of the apical flower, number of flowers and blind axils on the 30 upper positions (top), total number of flowers per shoot, shoot weight (g) and shoot length (cm). values ± SEM.

treatment	days to flower	N flowers top	N blind axils top	N flowers total	weight g	length cm
11	53	16.4 ± 1.0	14.0 ± 1.1	21.4 ± 1.8	31.8 ± 1.2	97.0 ± 1.0
12	54	17.0 ± 1.2	13.3 ± 1.1	23.1 ± 1.9	33.4 ± 2.4	100.4 ± 1.2
12.5	56	14.4 ± 0.4	15.6 ± 0.4	22.5 ± 2.1	31.6 ± 1.7	100.1 ± 1.3
13	57	36.0 ± 4.2	5.4 ± .6	52.5 ± 6.8	33.8 ± 1.2	97.1 ± 1.3
13.5	62	37.4 ± 2.9	2.3 ± 07	61.4 ± 8.4	35.8 ± 2.1	105.3 ± 1.8

Table 5 and Figure 5 will be explained in paragraph 3.6, together with Table 6 and Figure 6.

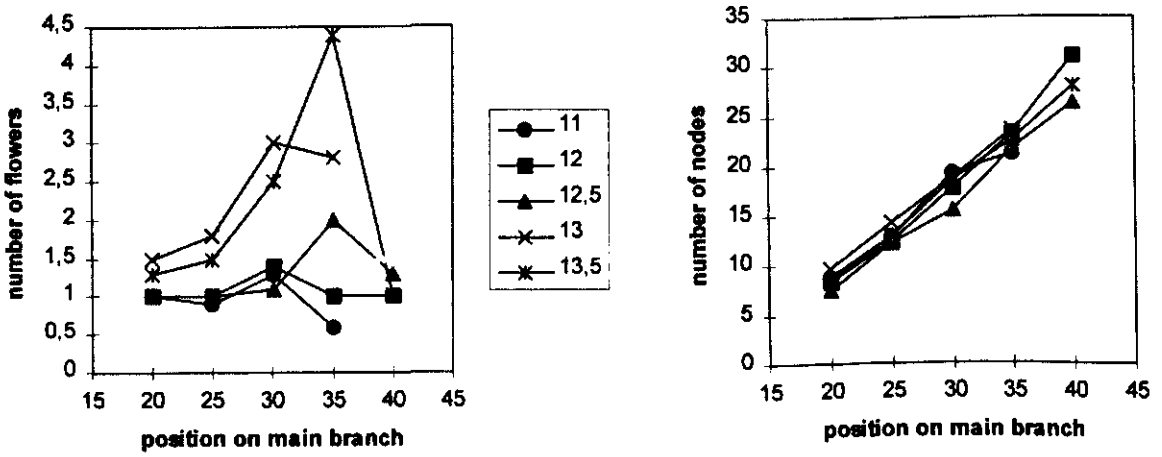


Figure 5- The effect of different photoperiods on the development of flowers and nodes on axillary branches on different positions. Positions are counted from the top (top flower is position 1). Left: number of flowers; Right: number of nodes.

3.6 EXPERIMENT 6: WINTER

- start experiment 7 November 1994 (day 311)
- number of plants per m^2: 60
- length of the shoots at the start of the short-day period: ±65 cm
- number of sampled plants per treatment: 8

Table 6- Results experiment 6. Number of days in short-day until opening of the apical flower, number of flowers and blind axils on the 30 upper positions (top), total number of flowers per shoot, shoot weight (g) and shoot length (cm). values ± SEM.

treatment	days to flower	N flowers top	N blind axils top	N flowers total	weight g	length cm
11	46	12.6±1.0	17.4	16.1±1.4	27.5±1.2	87.5±1.2
12	49	13.4±1.1	16.6	18.4±1.3	28.0±1.0	93.6±1.2
13	52	16.1±0.6	13.9	20.5±1.3	25.4±1.2	91.8±1.2
13.5	56	26.5±1.4	8.6	42.3±5.9	35.5±1.6	101.9±0.8

In experiments 5 and 6 the improvement of flower load by day extension was considerable (Tables 5 and 6). The number of flowers produced per shoot was very low for all treatments and in both experiments, since the harvests fell in the darkest period of the year (Tables and Figures 5 and 6). The retardation of flowering was 9 - 10 days for the 13.5 h. treatment, 1 - 3 days for 12 h. and 6 days for the 13 h. treatment. A photoperiod of 12 and 12.5 h. did not result in an improvement of the flower load, whilst 13 h. was only effective in experiment 5. A photoperiod of 13.5 h. resulted in a considerable increase of flower number and a decrease of the number of blind axils, accompanied by an increased time needed to reach flowering. Weight and length of the shoots at harvest was also increased by a photoperiod of 13.5 hours.

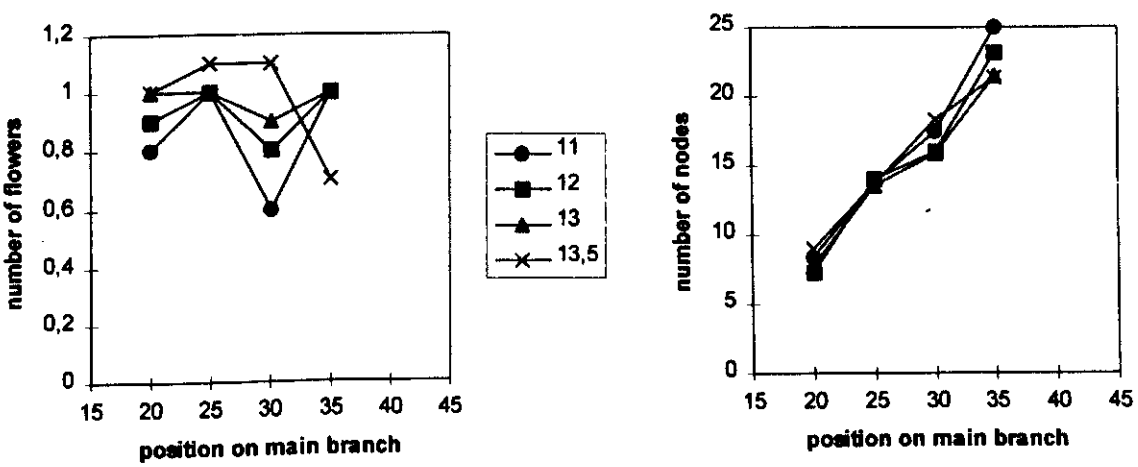


Figure 6- The effect of different photoperiods on the development of flowers and nodes on axillary branches on different positions. Positions are counted from the top (top flower is position 1). Left: number of flowers; Right: number of nodes.

3.7 EXPERIMENT 7: WINTER

- start experiment 4 January 1995 (day 4)
- number of plants per m^2: 60
- length of the shoots at the start of the short-day period: ±60 cm
- number of sampled plants per treatment: 20

Table 7- Results experiment 7. Number of days in short-day until opening of the apical flower, number of flowers and blind axils on the 30 upper positions (top), total number of flowers per shoot, shoot weight (g) and shoot length (cm). values ± SEM.

treatment	days to flower	N flowers top	N blind axils top	N flowers total	weight g	length cm
11	x	17.3+1.1	15.2	30.7±2.6	29.9±1.4	81.6±1.4
13	x	19.3±1.1	13.5	32.8±2.2	28.3±0.8	84.5±1.0
13.5	x	33.6±2.7	7.4	69.9±5.7	34.2±1.3	92.5±1.1

In experiment 7 again the 13.5 h. treatment has more flowers than the other treatments (Table 7; Figure 7 left). The number of blind axils in the top 30 nodes was about 50% of that in the 11 and 13 h. treatments. Moreover, the shoots of the 13.5 h. treatment were longer and heavier (and stronger).

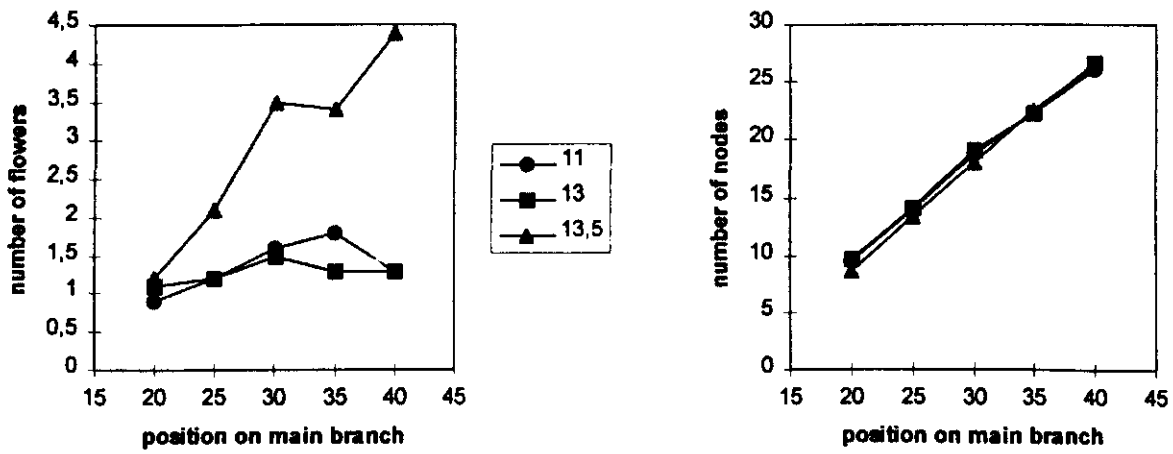


Figure 7- The effect of different photoperiods on the development of flowers and nodes on axillary branches on different positions. Positions are counted from the top (top flower is position 1). Left: number of flowers; Right: number of nodes.

3.8 EXPERIMENT 8: WINTER

- start experiment 21 January 1995 (day 21)
- number of plants per m^2: 60
- length of the shoots at the start of the short-day period: ±60 cm
- number of sampled plants per treatment: 20

Table 8- Results experiment 8. Number of days in short-day until opening of the apical flower, number of flowers and blind axils on the 30 upper positions (top), total number of flowers per shoot, shoot weight (g) and shoot length (cm). values ± SEM.

treatment	days to flower	N flowers top	N blind axils top	N flowers total	weight g	length cm
11	50	13.7±0.8	16.5±0.7	21.5±1.1	26.3±0.8	83.6±1.0
13	51	20.2±1.3	13.3±0.7	40.4±3.3	33.0±1.3	87.7±1.2
13.5	55	27.3±1.5	8.2±0.8	77.2±5.7	35.2±1.1	88.3±1.2

3.9 EXPERIMENT 9: WINTER

- start experiment 1 February 1995 (day 32)
- number of plants per m^2: 60
- length of the shoots at the start of the short-day period: ±65 cm
- number of sampled plants per treatment: 20

Table 9- Results experiment 9. Number of days in short-day until opening of the apical flower, number of flowers and blind axils on the 30 upper positions (top), total number of flowers per shoot, shoot weight (g) and shoot length (cm). values ± SEM.

treatment	days to flower	N flowers top	N blind axils top	N flowers total	weight g	length cm
11	47	14.8±1.2	x	40.6±3.5	28.6±1.1	82.5±1.2
12.5	48	16.8±1.1	x	42.3±4.0	29.8±1.3	84.0±1.4
13	49	26.9±1.7	x	60.2±4.2	33.3±0.9	87.1±0.9
13.5	51	38.6±2.2	x	84.9±7.9	33.3±1.4	87.8±1.1

3.10 EXPERIMENT 10: WINTER - SPRING

- start experiment 15 February 1995 (day 46)
- number of plants per m^2: 60
- length of the shoots at the start of the short-day period: ±65 cm
- number of sampled plants per treatment: 20

Table 10- Results experiment 10. Number of days in short-day until opening of the apical flower, number of flowers and blind axils on the 30 upper positions (top), total number of flowers per shoot, shoot weight (g) and shoot length (cm). values ± SEM.

treatment	days to flower	N flowers top	N blind axils top	N flowers total	weight g	length cm
11	45	31.2 ± 2.7	8.9 ± 0.9	76.7 ± 6.2	38.2 ± 1.3	90.8 ± 1.0
13	46	36.8 ± 3.0	6.0 ± 0.8	84.7 ± 6.7	35.7 ± 1.3	91.7 ± 1.1
13.5	49	48.6 ± 3.6	2.3 ± 0.5	137.4 ± 12.2	39.5 ± 1.5	98.5 ± 1.0

3.11 EXPERIMENT 11: EARLY SPRING

- start experiment 28 February 1995 (day 59)
- number of plants per m^2: 60
- length of the shoots at the start of the short-day period: ± 60 cm
- number of sampled plants per treatment: 20

Table 11- Results experiment 11. Number of days in short-day until opening of the apical flower, number of flowers and blind axils on the 30 upper positions (top), total number of flowers per shoot, shoot weight (g) and shoot length (cm). values ± SEM.

treatment	days to flower	N flowers top	N blind axils top	N flowers total	weight g	length cm
11	43	50.6 ± 3.9	3.5 ± 0.9	108.9 ± 8.7	45.4 ± 1.5	96.9 ± 0.9
13	45	80.1 ± 4.7	0.4 ± 0.1	167.8 ± 9.9	48.1 ± 1.7	100.1 ± 1.0
13.5	50	70.4 ± 3.2	0.7 ± 0.1	136.7 ± 10.9	46.3 ± 2.1	100.4 ± 1.3

Experiments 8, 9, 10 and 11 again clearly show that an extension of the photoperiod to 13.5 hours improves the flower load of shoots of *Aster* 'Dark Pink Star'. The number of meristems just below the apex that aborts is considerably reduced in the 13.5 h. treatment. The retardation of flowering remains restricted to 4 to 5 days in these experiments. An improvement of flower load by a day extension to 13 h. was not accomplished in all experiments.
These experiments were carried out during the winter months, and although there was an improvement the quality of the shoots was still poor.

3.12 EXPERIMENT 12: SPRING

- start experiment 9 March 1995 (day 68)
- number of plants per m^2: 60
- length of the shoots at the start of the short-day period: ± 70 cm
- number of sampled plants per treatment: 10

Table 12- Results experiment 12. Number of days in short-day until opening of the apical flower, number of flowers and blind axils on the 30 upper positions (top), total number of flowers per shoot, shoot weight (g) and shoot length (cm). values ± SEM.

treatment	days to flower	N flowers top	N blind axils top	N flowers total	weight g	length cm
13.5	49	x	0.0 ± 0.0	272.5 ± 18.2	64.0 ± 0.9	105.3 ± 3.0
14	53	x	0.1 ± 0.1	279.7 ± 17.9	64.9 ± 1.2	105.8 ± 2.7
14.5	58	x	1.6 ± 0.5	287.8 ± 20.2	64.1 ± 1.5	110.3 ± 2.9

In this experiment it was checked whether photoperiods longer than 13.5 hours could contribute to a better flower load. This was clearly not the case (Table 12). Flowering is however further delayed.

3.13 EXPERIMENT 13: SPRING

- start experiment 21 April 1995 (day 111)
- number of plants per m^2: 60
- length of the shoots at the start of the short-day period: ± 65 cm
- number of sampled plants per treatment: 15

In this experiment the number of flowers per position was counted. On every position the number of flowers, directly in the axil, or on the first and second order branches, was counted (Figure 8). The increase in flower number in the treatments 13 and 13.5 hours was evident at all positions. In this experiment there were no blind axillary meristems beneath the apical flower anymore. The main increase in flower number was found at positions 20 through 40. On these positions many flowers can be present.

3.14 EXPERIMENT 14: SPRING - SUMMER

- start experiment 13 May 1995 (day 133)
- number of plants per m^2: 60
- length of the shoots at the start of the short-day period: ± 60 cm
- number of sampled plants per treatment: 10

For practical reasons the 13.5 hours treatment did receive 13.5 hours only during the first week of the short-day period. Thereafter 11 hours was the daylength. Obviously the application of one week 13.5 hours has no effects on flower numbers and time to flowering (Table 13). A treatment of 13 hours throughout the short-day period did increase the number of flowers.

Table 13 - Results experiment 14. The total number of flowers per shoot, weight (g) and length (cm) and the flowering date (top flower). Different characters in a line means a significant difference ($p < 0.05$).

	11 hour	13 hour	13.5 / 11 hour
number of flowers	221.3 a	281.1 b	219.7 a
weight g	62.9 a	69.5 a	72.1 a
length cm	108.7 a	111.4 a	111.5 a
flowering date top flower	27 June	30 June	28 June

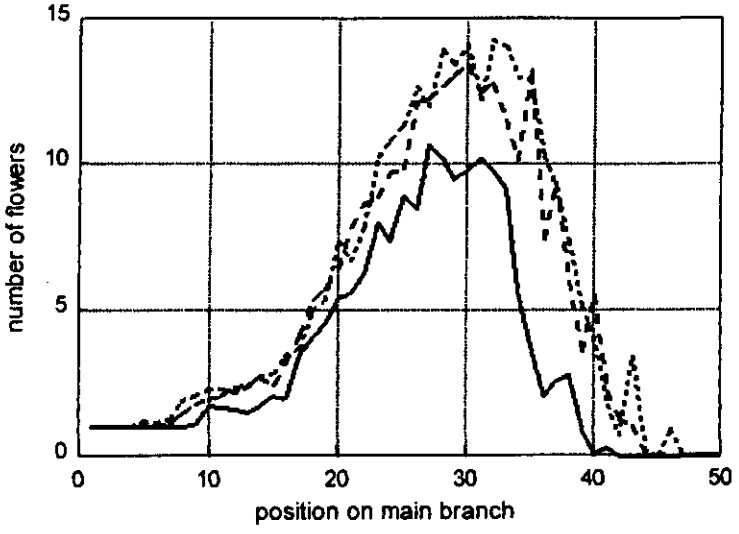


Figure 8 - The number of flowers per position, counted from the apical flower. The total number of flowers per shoot was: 11 hours: 170±6.9; 13 hours: 254±13.0; 13.5 hours: 273±17.2

3.15 EXPERIMENT 15: AUTUMN. 'DARK PINK STAR' & 'MONTE CASSINO'

- start experiment 29 October 1995 (day 302)
- number of plants per m^2: 60
- cultivars: 'Dark Pink Star' and 'Monte Cassino'
- length of the shoots at the start of the short-day period: ±60 cm ('Dark Pink Star'); 55 cm ('Monte Cassino')
- number of sampled plants per treatment: 10

In experiment 15 the cultivar 'Monte Cassino' was used in addition to 'Dark Pink Star', since this is the most grown variety in the Netherlands. As in the former experiments after 4 weeks of 13.5 hours the daylength was reduced to 11 hours.

Table 14 - The total number of flowers per shoot at three photoperiods.

photoperiod	Dark Pink Star	Monte Cassino
11	41.2	52.8
13	57.8	86.0
13.5	69.1	58.4

From Table 14 it is learned that 13.5 hours did not improve the number of flowers in 'Monte Cassino'. 'Dark Pink Star' however did respond positively to the photoperiod of 13.5 hours. A photoperiod of 13 hours was better than 11 hours for both cultivars. From anatomical observations it appeared that the development of meristems of 'Monte Cassino' in the first three weeks of the short-day period proceeded at a lower rate than that of 'Dark Pink Star' (see 3.22). The return to a daylength of 11 hours after four weeks at 13.5 hours may have been too soon for 'Monte Cassino'.

3.16 EXPERIMENT 16: AUTUMN 'MONTE CASSINO'

Experiment 16 was started on 3 January 1996. Because of the disappointing results with 'Monte Cassino' in experiment 15 it was decided not to reduce the photoperiod from 13.5 hours to 11 hours after four weeks, but to continue with 13.5 hours till flowering. The way of development of 'Monte Cassino' differs from that of 'Dark Pink Star'. It has a lower rate of development in the first phase of the short-day period (see 3.22). Only after about four weeks the meristems began to develop quickly. The plant density was similar as in previous experiments, but due to a lack of plants the beds were narrower.

Table 15 - Results of experiment 16. 'Monte Cassino'. Date of flowering (top flower), length (cm), number of nodes on the main stem, total number of flowers per shoot and the number of degenerated axillary meristems beneath the apex (thirty upper axils).

photoperiod	11	13	13.5
date of flowering (top meristem)	9 February	12 February	21 February
length cm	84.3	91.0	94.4
number of nodes on main stem	65.6	69.8	71.4
number of flowers total	23.0	79.4	207.0
N nodes on upper part of stem without branches	37.2	40.7	39.8
number of blind axillary positions	31.4	20.7	6.8
% blind axils in top	84.8	50.4	16.9

Table 15 shows that if the photoperiod is kept at 13.5 hours during the whole short-day period the improvement of flower number is tremendous. The very strong increase in flower number was accompanied by a retardation of flowering of 11 days. The improvement of flower load can predominantly be attributed to the increase in flower number in the lower part of the shoot, on side branches. However, a significant improvement of the quality of the shoots was attained by the lower number of aborting meristems in the top of the shoots. This resulted in a more flower filled upper part of the shoots. From Table 15 it appears that with 13.5 hours photoperiod there was far less abortion of axillary meristems in the top of the stems (85% with 11 hours, contrasting with 17% with 13.5). In this experiment the light penetration in the canopy has been better due to less shading (narrower beds). The improvement of flower load by day extension is stronger when plants are less shaded, by which on the lower branches the flowers could actually develop.

3.17 CORRELATION BETWEEN LIGHT AND NUMBER OF FLOWERS

Analysis of the data from experiments 3 through 13, conducted from 18 August 1994 till 25 April 1995, suggested that in 'Dark Pink Star' the amount of natural irradiation received in the first four weeks of the short-day period was of paramount importance (Table 16). For all treatments the correlation between the amount of light and flower number decreases after week four. From Figure 9 it can also be concluded that the number of developed flowers strongly depends on the amount of irradiation. From Table 16 it also seems that the sensitive phase for flower abortion is shifted to a later part of the short-day period with 13 or 13.5 hours photoperiod. This seems to confirm that by a slower development also the sensitive phase for flower bud abortion shifts. From the Israelian contribution of the research it was known that especially phase 2 and 7 are sensitive for abortion (see also the Anatomical research, 3.22). Under the conditions found in the Netherlands it lasts about four weeks for induced meristems to reach stage 7.

Table 16 - Correlation coefficients of the linear regression between the accumulated number of Photosynthetic Active Photons per fortnight (mol m^{-2} (14 days)$^{-1}$) and the number of developed flowers on the 30 upper nodes of a shoot of aster 'Dark Pink Star'.

treatment	week 1-2	week 2-3	week 3-4	week 4-5	week 5-6
11	0.94	0.95	0.88	0.72	0.58
13	0.80	0.95	0.90	0.75	0.63
13.5	0.85	0.96	0.93	0.79	0.70

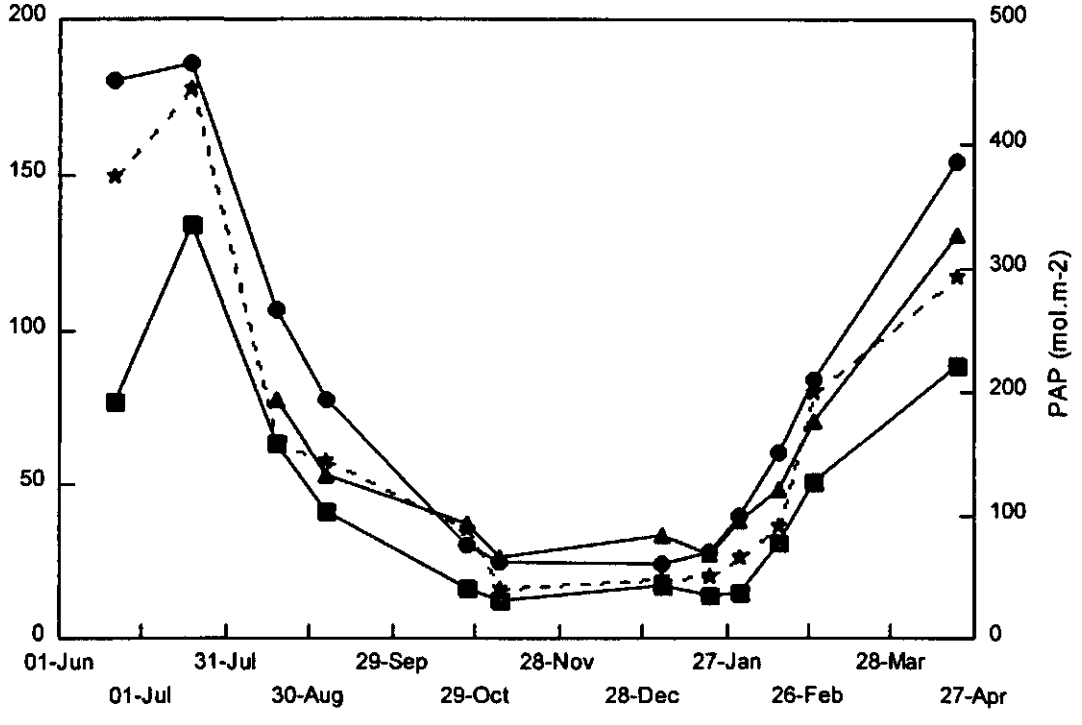


Figure 9 - Seasonal course of the number of flowers on the upper part (30 nodes) of shoots of *Aster* 'Dark Pink Star' in 12 experiments conducted f.om 21 June 1994 till 21 April 1995 (■ : 11 hours; ✱ : 13 hours; ▲ : 13.5 hours), and the seasonal course of the amount of light (PPF per four weeks: ●) in the first four weeks of the short-day periods of each experiment.

3.18 EXPERIMENT 17: INFLUENCE OF IRRADIANCE DURING THE SHORT-DAY PERIOD ON FLOWER NUMBER

In experiment 17 (started on 6 February 1996) the influence of the amount of photosynthetic light was further investigated in three photoperiod treatments: 11 hours, 13 hours and 13.5 hours. Every two weeks six individual plants were taken and changed from an unscreened greenhouse to a screened one (light transmission of the screen 50%) and the other way round. In this way it was possible to investigate in which part of the short-day period a reduction of light had the most severe influence on the eventual number of flowers produced per shoot. In this experiment we used both 'Dark Pink Star' and 'Monte Cassino'. Plant density was only about 30 plants per m^2. This with the objective to study the effect of the day extension on the number of flowers as detailed as possible.

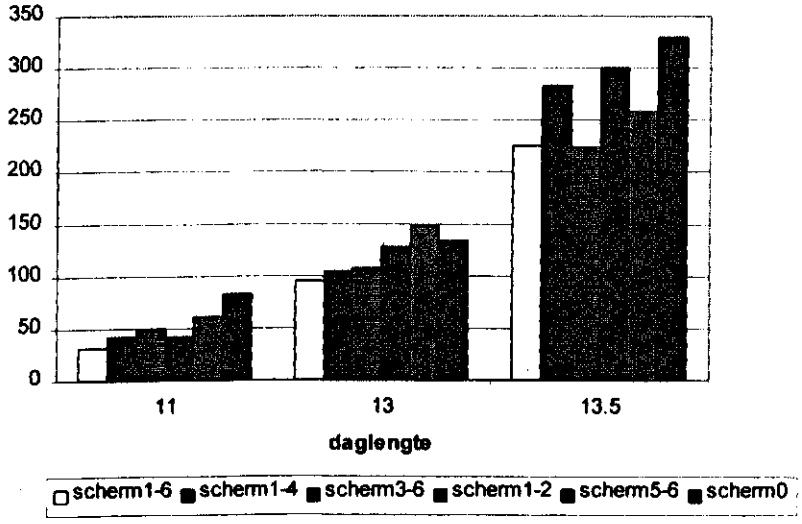


Figure 10 - The effect of 50% screening of the light during different parts of the short-day period on the number of flowers per shoot of 'Dark Pink Star'. Screen 1-6 indicates screened during weeks 1 to 6, screen 0 means unscreened.

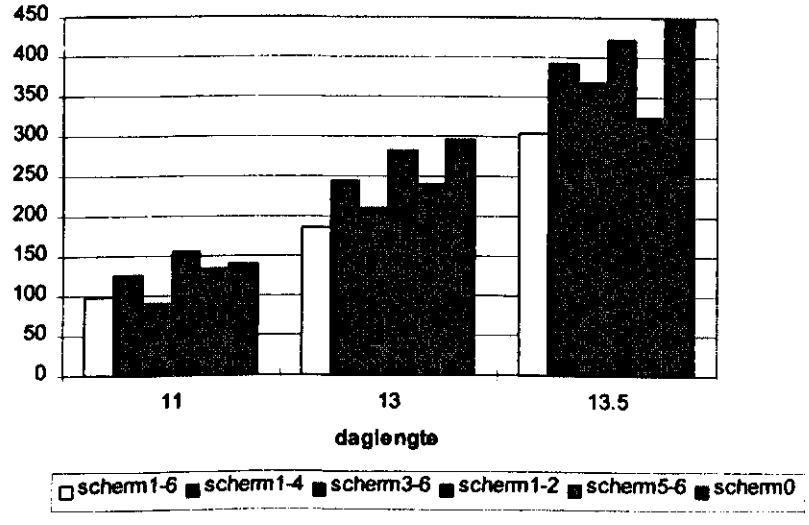


Figure 11 - The effect of 50% screening of the light during different parts of the short-day period on the number of flowers per shoot of 'Monte Cassino'. legend see Figure 10.

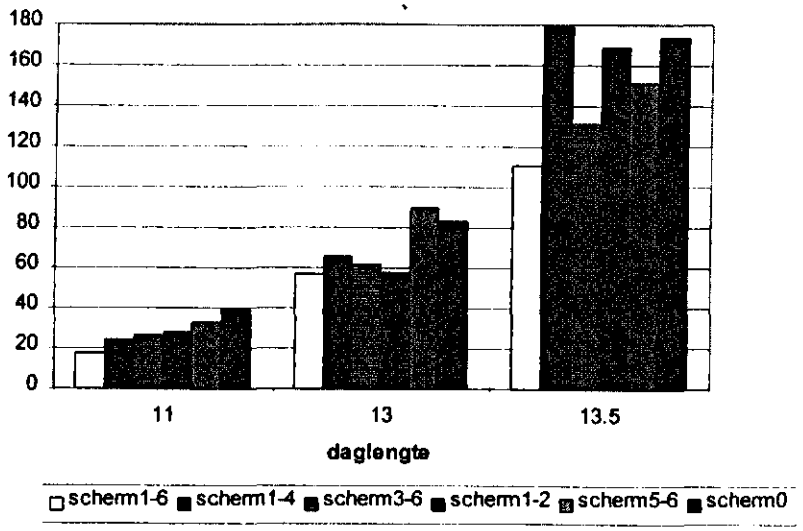


Figure 12 - The influence of 50% screening of the light during different parts of the short-day period on the number of flowers on the thirty upper nodes of 'Dark Pink Star'. For legend see Figure 10.

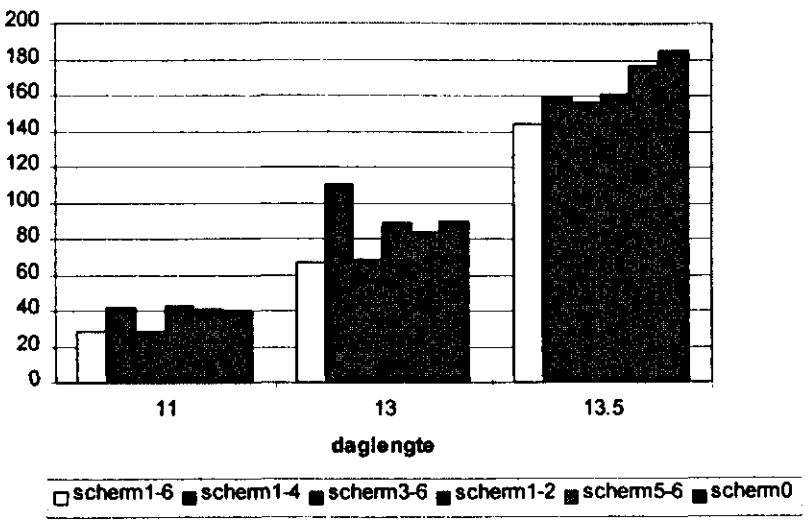


Figure 13 - The influence of 50% screening of the light during different parts of the short-day period on the number of flowers on the thirty upper nodes of 'Monte Cassino'. For legend see Figure 10.

Figures 10, 11, 12 and 13 show the effect of screening 50% of the light during the day, in different parts of the short-day period. For both cultivars it is clear again that the number of flowers increases from 11 to 13 hours, and from 13 to 13.5 hours. The four graphs all show the same pattern: the outermost left column was screened during the whole period, and consequently had the lowest number of flowers; the outermost right column was not screened at all, and generally had the highest number of flowers. This pattern holds for all photoperiodic treatments, 11, 13 and 13.5 hours. A striking observation is that the effect

of the photoperiod convincingly overrules the effect of the light quantity: even the most screened treatment under a photoperiod of 13 hours bears more flowers than the unscreened treatment under a photoperiod of 11 hours. The same holds for the comparison between 13.5 and 13 hours.
Figures 14 and 15 show, in a similar way as the figures above, the effect of screening on the number of degenerated meristems on the upper part of the stem. Degeneration was lowest in 13.5 hours, higher in 13 hours and the highest in 11 hours, and it was generally the highest when screening was for six weeks, and the lowest without screening. In 'Dark Pink Star' the degeneration was the lowest if there was no screening or screening in only the last two weeks (Figure 14). In 'Monte Cassino' the degeneration was on the contrary higher if the light was screened during the last four weeks. Screening during the first two or last two weeks hardly caused extra degeneration (Figure 15).

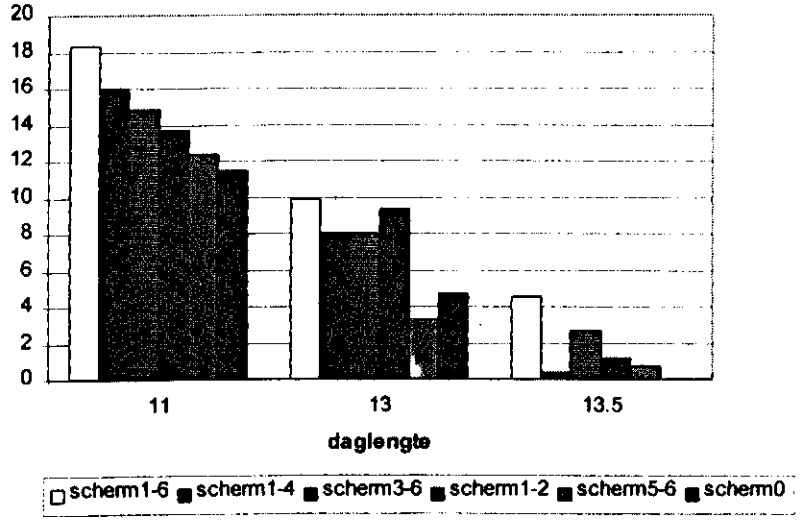


Figure 14 - The influence of screening of 50% of the light during different parts of the short-day period on the number of degenerated meristems on the thirty upper nodes of 'Dark Pink Star' stems. For an explanation of the legend see Figure 10.

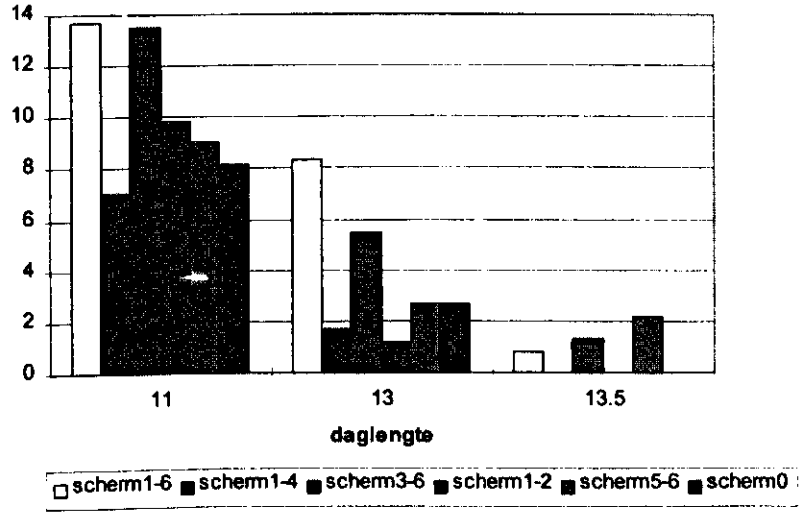


Figure 15 - The influence of screening of 50% of the light during different parts of the short-day period on the number of degenerated meristems on the thirty upper nodes of 'Monte Cassino' stems. For an explanation of the legend see Figure 10.

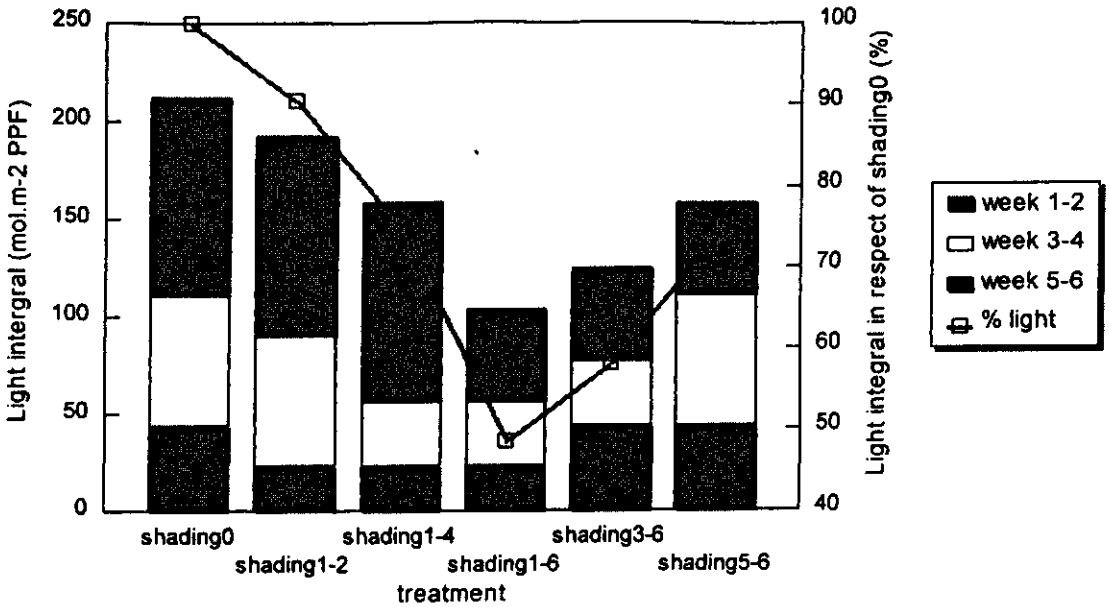
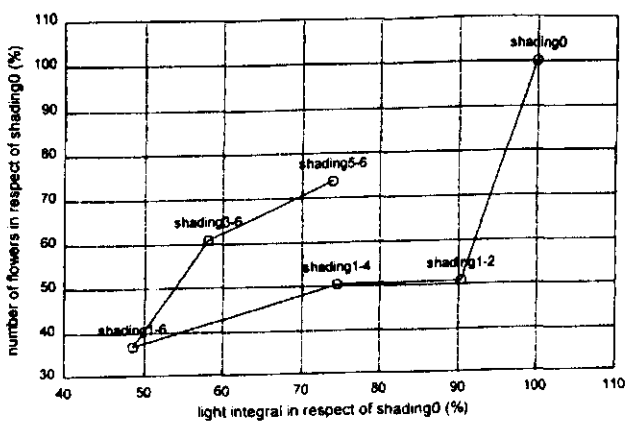


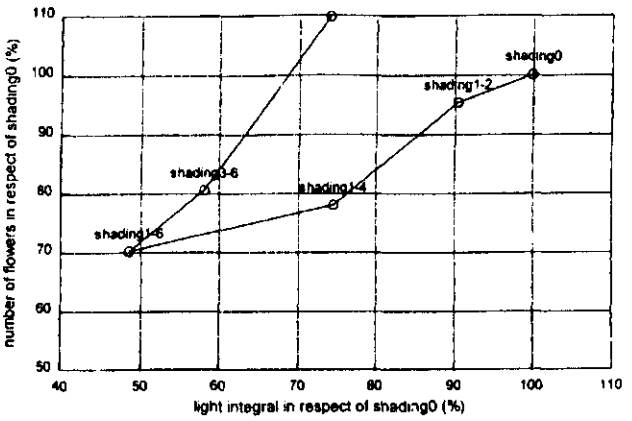
Figure 16 - The number of accumulated photosynthetic active photons (mol m^{-2} PAP) during different parts of the short-day period in different shading regimes: shading 0 = unscreened, shading 1-2 = shaded during week 1 and 2 of the short-day period, shading 1-6 = screened during the whole short-day period. The line represents the amount of light received as a percentage of the un screened treatment. Screening during weeks 5 and 6 reduced the total light received during the experiment more than screening during weeks 1 and 2.

From Figure 16 it is clear that the amount of photosynthetic light was not equally distributed during the experiment. In the first two weeks the amount was 43.6 unscreened and 23.3 mol m^{-2} PAP in the screened treatments, in week 3 and 4 it was 67.3 and 33.6 mol m^{-2} PAP respectively, and in week 5 and 6 it was 101.5 and 46.5 mol m^{-2} PAP, respectively. Screening during the later part of the experiment thus reduced the total amount of light received more than screening during the first weeks (Figure 16).
In Figure 17 therefore the number of developed flowers and the quantity of photosynthetic light were expressed as relative units. From this Figure it can be concluded that screening during the first two weeks of the short-day period already caused a reduction in the number of flowers of 50% in 'Dark Pink Star' in the 11 hour photoperiod treatment. Screening during the last two weeks only reduced the number by 25%. The 11 hours treatment of 'Dark Pink Star' appeared to be very sensitive for screening of light: screening during the whole period reduced the number by 30-35% in the 13 and 13.5 hour treatments, in the 11 hour treatment by 60%. In 'Monte Cassino' screening during the whole period resulted in about 30% reduction in all photoperiod treatments. In 'Dark Pink Star' the period in which the plants are very sensitive for a reduced light level seems to shift to a later moment by a 13 and 13.5 hours photoperiod. Was there a strong reduction in the number of flowers by screening in the first two weeks in the 11 hour treatment, in the 13 hour treatment this strong reduction only appeared in weeks 3-4, and with 13.5 hours in weeks 3, 4, 5 and 6. In 'Monte Cassino' there was hardly any dependence on the moment of screening during the short-day period. Although screening has a strong negative effect on flower numbers, it can not be concluded when the plants are most sensitive for a reduced amount of light. In the 13.5 hour treatment the reduction of light during the last two weeks seems to have a serious negative effect.

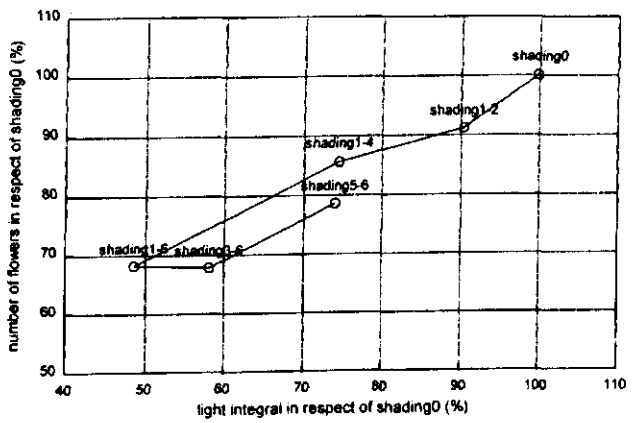
A: Dark Pink Star 11 hours



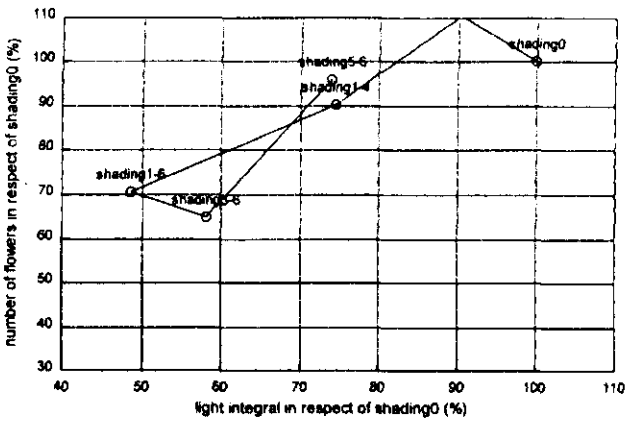
B: Dark Pink Star 13 hours



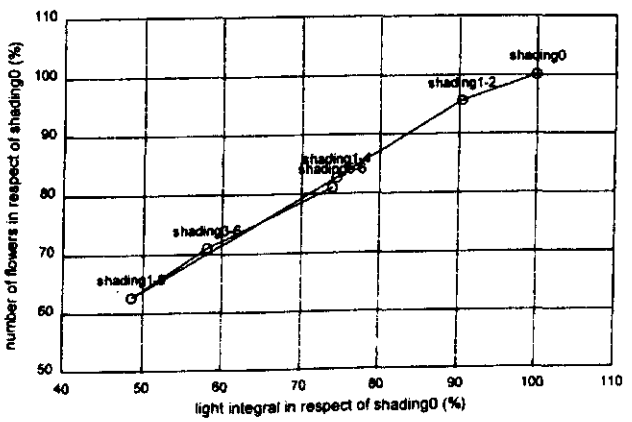
C: Dark Pink Star 13.5 hours



D: Monte Cassino 11 hours



E: Monte Cassino 13 hours



F: Monte Cassino 13.5 hours

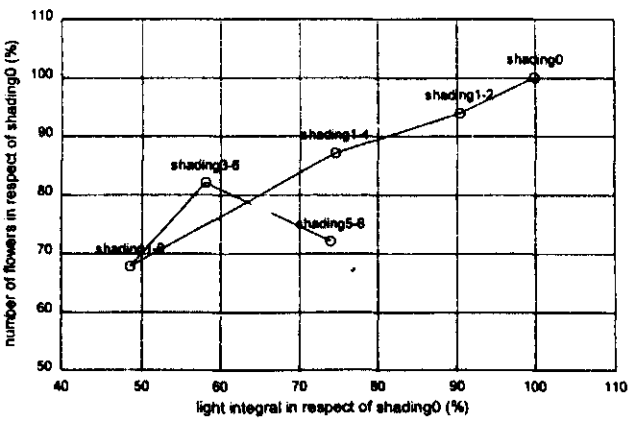


Figure 17 - The relative number of flowers per shoot, as a percentage of the unshaded treatment, plotted against the relative number of photosynthetic photons, as a percentage of the unshaded treatment. 'Dark Pink Star': A = 11, B = 13, C = 13.5 hours. 'Monte Cassino': D = 11, E = 13, F = 13.5 hours.

3.19 EXPERIMENT 18 & 19: THE EFFECT OF DAY EXTENSIONS DURING DIFFERENT PARTS OF THE SHORT-DAY PERIOD

In experiment 18 ('Monte Cassino'; start 23 April 1996) and experiment 19 ('Dark Pink Star'; start 30 April 1996) the effect of a day extension during different parts of the short-day period was studied. The set-up of the experiment was quite similar to that of experiment 17, with the exception that this time the extreme treatments were photoperiods of 11 and 13.5 hours throughout, and plants from intermediate treatments were changed every two weeks from 11 to 13.5 hours and the other way round. The objective was to determine the influence of the photoperiod during the different stages of flower development on the eventual number of fully developed flowers per shoot. Also in this experiment the number of plants per m^2 was only 30.

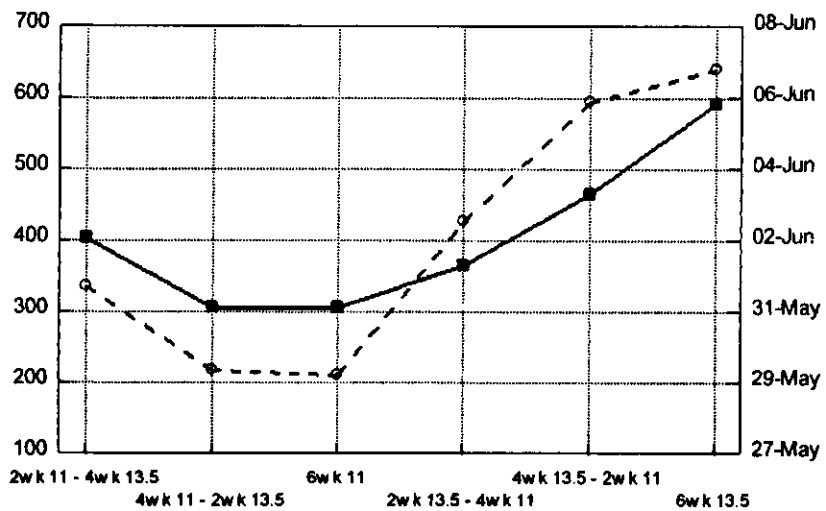


Figure 18 - The effect of a day extension during different parts of the short-day period on the number of flowers (closed line) and on the flowering date of the apical flower (open line) of 'Dark Pink Star'. Explanation: 2 wk 11 - 4 wk 13.5 indicates that the plants had a photoperiod of 1 hours the first 2 weeks and were then changed to 13.5 hours for the remainder 4 weeks. The experiment lasted for about 6 weeks.

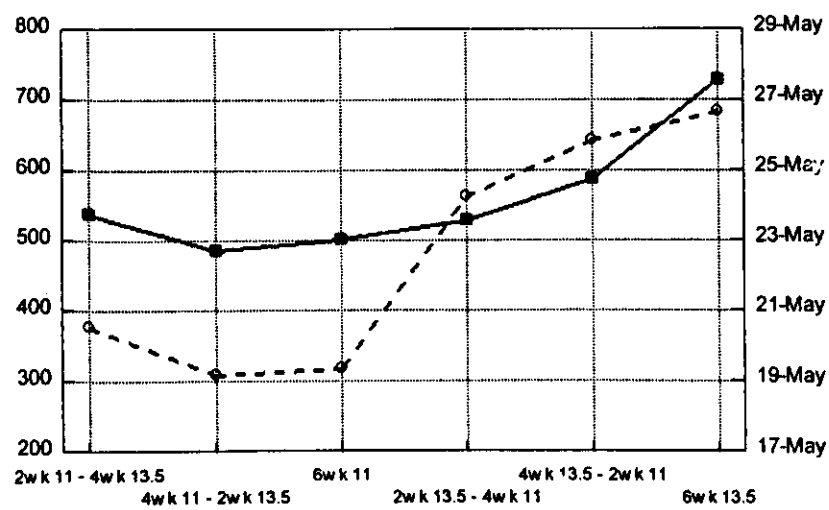


Figure 19 - The effect of a day extension during different parts of the short-day period on the number of flowers (closed line) and on the flowering date of the apical flower (open line) of 'Monte Cassino'. Explanation: see Figure 18.

From Figures 18 and 19 it appears that for 'Dark Pink star' as well as 'Monte Cassino' the retardation of flowering is stronger when the day extension is applied during the first weeks of the short-day period, and that the effect increases if the day extension is continued for a prolonged period. The effect of photoperiod on the increase in flower number becomes only large if the day extension is continued for at least four weeks. Extension of the photoperiod during the first two weeks resulted in a strong retardation of flowering, but did hardly improve the number of flowers. However, if the first two weeks were not included in the day extension period, hardly any improvement of flower number could be achieved.
From this it can be concluded that a day extension is only useful if applied from the beginning, and during a great part of the short-day period. As mentioned before, flower bud abortion occurs predominantly in stage 2 and stage 7 (see 3.22). Stage 7 is reached in axillary positions after 3 to 5 weeks. This can change somewhat by day extension, and can be affected by the amount of light received during the short-day period, but it appears that the day extension needs to be continued until almost all meristems have passed stage 7. For growers this seems to recommend a day extension for at least 4 to 5 weeks. Since 'Monte Cassino' develops a little slower, five weeks should be applied for this cultivar at least.

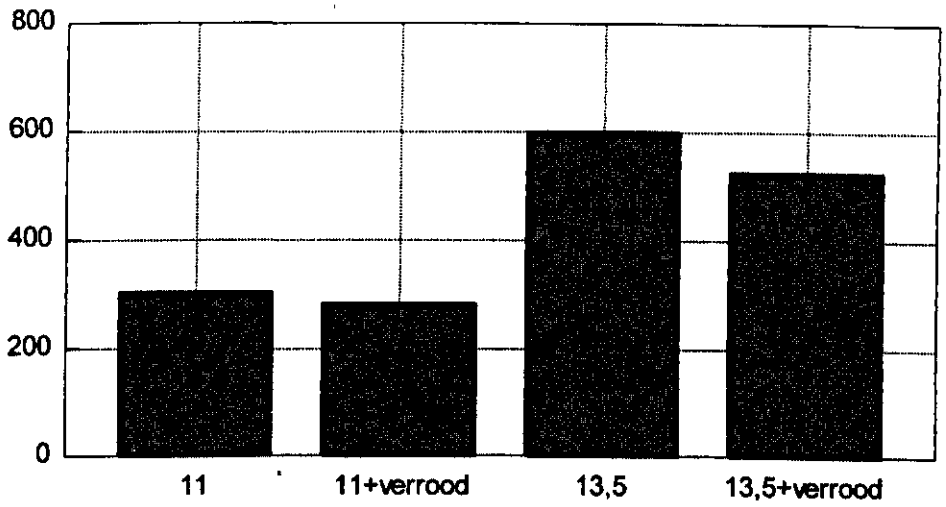


Figure 20 - The effect of a day extension and end-of-day far-red on the number of flowers per shoot in 'Dark Pink Star'.

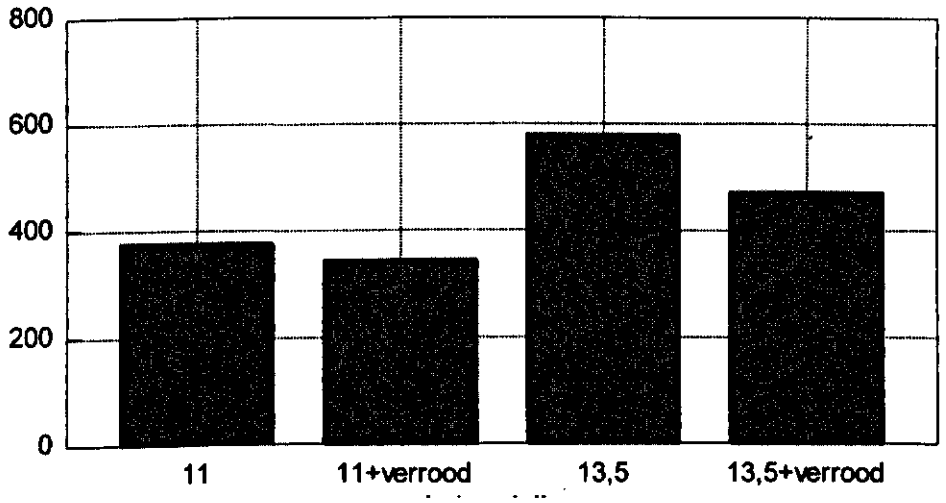


Figure 21 - The effect of a day extension and end-of-day far-red on the number of flowers per shoot in 'Monte Cassino'.

3.20 EXPERIMENT 20: THE EFFECT OF FAR-RED ON THE NUMBER OF FLOWERS

In experiment 20 the effect of far-red irradiation on the number of flowers per shoot was investigated (start of the experiment 7 May 1996). From previous experiments it appeared that with a photoperiod of 12 hours, the use of whether incandescent or compact discharge lamps did not make any difference. Incandescent lamps provide relatively much far-red, whilst compact discharge lamps do not produce far-red. The far-red day extension consisted of half an hour lighting (0.4 μmol m^{-2} s^{-1} , λ = 700 - 800 nm, provided by incandescent lamps and filters Lee 105 and 120, LEE Filters, Andover, England), immediately following the day. In this experiment the plants did receive natural day light as the means to give different photoperiods (thus 13.5 hours did receive 2.5 hours daylight - for photosynthesis - more than the 11 hours treatment!)[1]. It can be expected that the effects of a day extension will be bigger than in the former experiments, since the plants will have more assimilates available for the development of flowers. Alike in the former two experiments plant density was 30 plants per m^2 . The photoperiod treatments were continued till harvest.
From Figures 20 and 21 it becomes clear that a far-red end of day treatment had a negative effect on the number of flowers per shoot. In both cultivars the number of flowers was higher with a photoperiod of 13.5 hours than with 11 hours. Although the 13.5 hour treatment was continued during the whole experiment, there was no continuation of vegetative growth like there was in experiment 1.

3.21 EXPERIMENT 21

In this experiment the effect of day extensions with incandescent lamps, compact discharge lamps, and with supplementary light (HQI-T) on the flower numbers of 'Dark Pink Star' was studied. The experiment started on October 15, 1996. Flowering occurred about mid December. The retardation of flowering in the treatments with a 13.5 hours photoperiod was about 11 days. Of all side branches of a shoot the following parameters were determined (nodes 1 to 10 were pooled together as position "1"):
- the number of fully developed flowers and flower buds (Figure 22)
- the number of nodes (Figure 23)
- the percentage of meristems that had degenerated (Figure 24)
- the number of meristems that aborted before stage 3 had been reached (Figure 25)
- the number of meristems that aborted later than in stage 3 (Figure 26)

From Figure 22 it can be seen that with a photoperiod of 13.5 hours the number of fully developed flowers was on all positions higher than with a photoperiod of 11 hours. This is especially true for the treatments with supplementary lighting (20-25 μmol m^{-2} s^{-1} PPF) until a photoperiod of 11 hours was reached, followed by 2.5 hours day extension either by incandescent or compact discharge lamps. Between these two lamp types there was no difference, despite the fact that incandescent emits far-red. Extension of the natural daylength to 13.5 hours with incandescent light only, did result in an improvement of the number of flowers, but this was less than the improvement by day extension treatments that included supplementary lighting till 11 hours. In the treatments 13.5 SL (=compact discharge) and 13.5 GL (= incandescent) there was far less abortion before stage 3 than in the other treatments (Figure 25). Considering the abortion in later stages the differences between the treatments were smaller, but still very significant. The improvement of flower load thus was predominantly caused by a decreased abortion in early stages of meristem development. The number of nodes on each branch, in all positions, was not affected by the treatments (Figure 23).
The integrated amount of light available during the short-day period was for the treatments 11, 13.5 SL and 13.5 GL about 130 mol m^{-2} PAP, whilst for the treatments nat and nat-13.5 it was about 122-127 mol m^{-2}. The extra amount of light for photosynthesis by supplementary lighting the natural day till 11 hours was approximately 3-7%. The

[1] In all former experiments the photoperiods were assembled from 11 hours natural light and an x hours photoperiodic lighting (level 3 - 4 μmol m^{-2} s^{-1} PPF)

treatment with natural daylength, varying from 10.5 hours in the beginning to 7.5 hours in the end of the experiment, hardly gave less flowers than the 11 hour treatment (3-7% extra light). The treatment with a natural daylength extended with incandescent lamps (nat-13.5) had higher flower numbers than the nat and 11 hour treatments, although it received the same amount of light or even less, but the numbers were lower than those of the 13.5 GL and SL treatments.

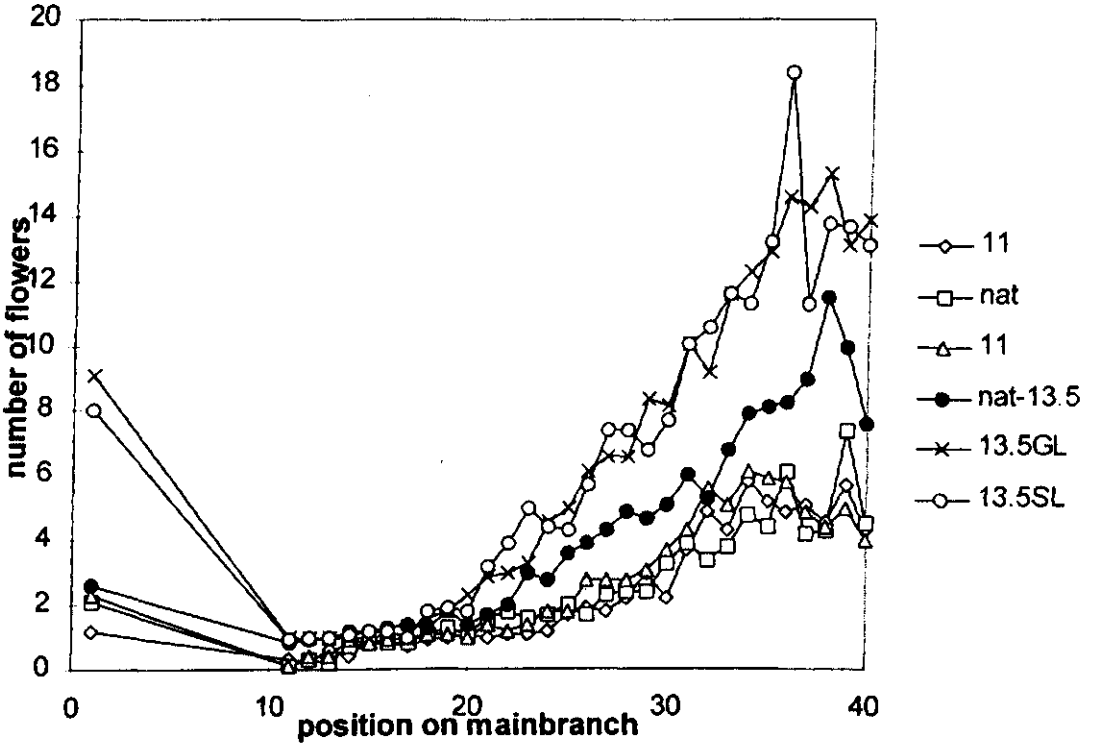


Figure 22 - The number of flowers per position. Position "1" is the sum of the pooled positions 1-10. From 11 downward to 40 each position was counted. 11: natural day + HQI-T till 11 hours; nat: natural daylength; nat-13.5: natural daylength extended with incandescent lamps to 13.5 hours; 13.5-gl: natural day extended to 11 hours with HQI-T, and further to 13.5 hours with incandescent; 13.5-SL: natural day extended to 11 hours with HQI-T, and further to 13.5 hours with compact discharge (SL).

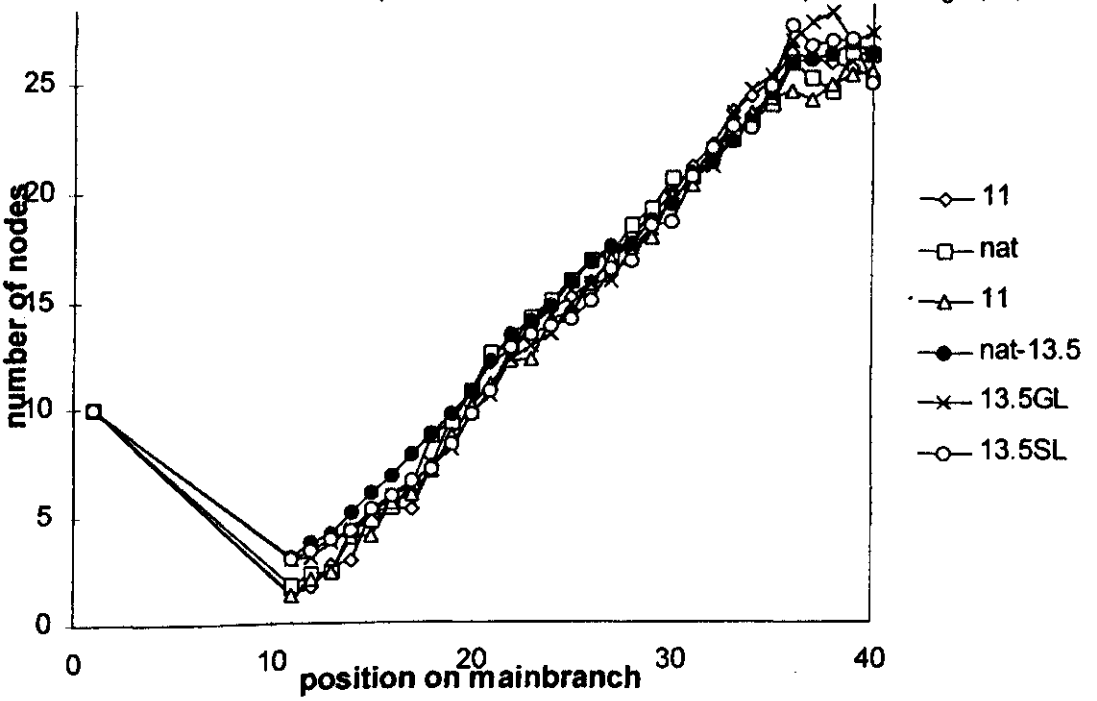


Figure 23 - The number of nodes per position. see legend of Figure 22 for treatments.

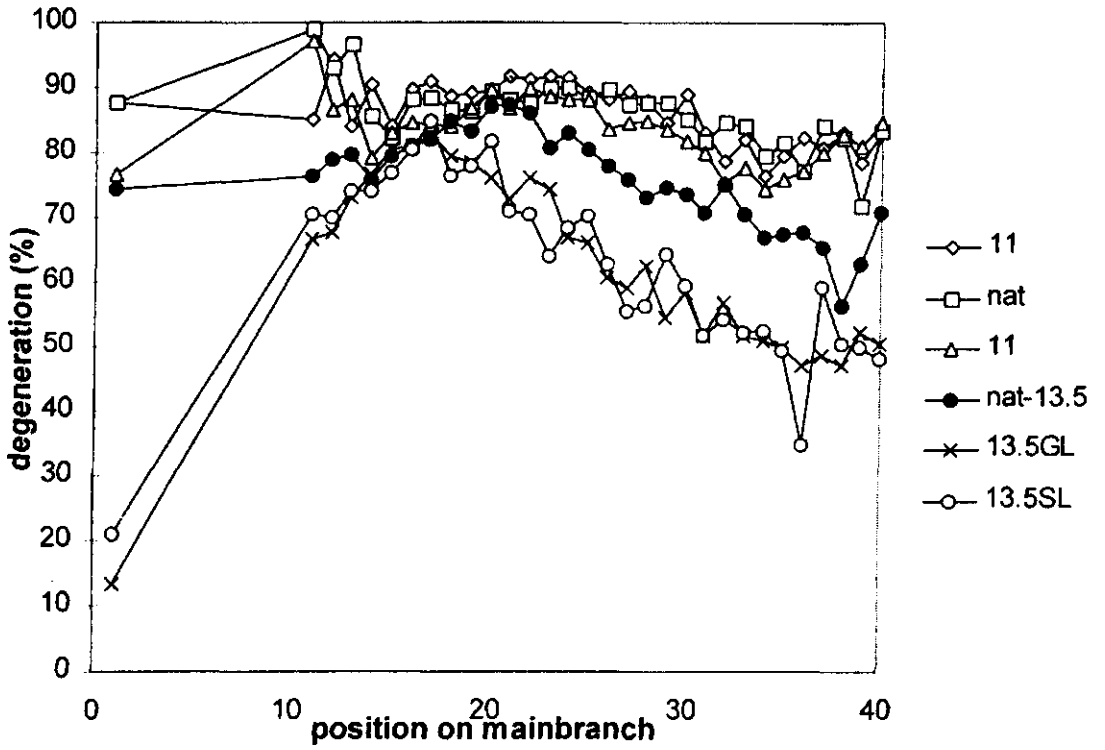


Figure 24 - The percentage aborted meristems per position. See legend of Figure 22.

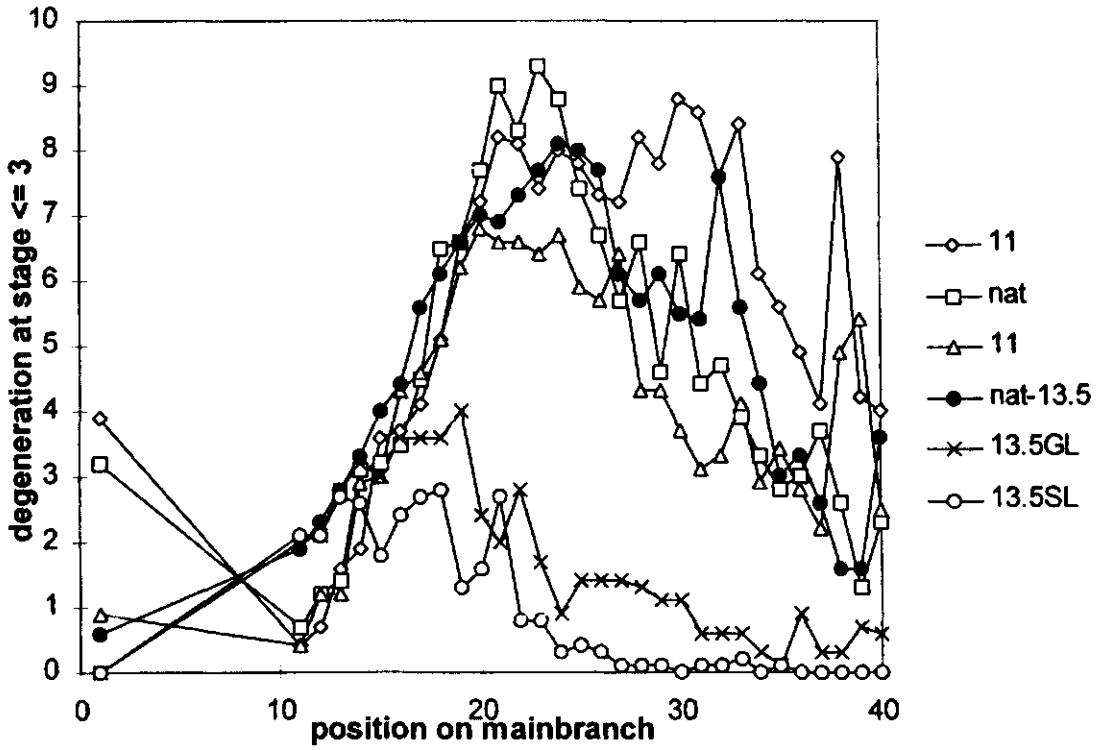


Figure 25 - The number of meristems per position aborted before reaching stage 3. See legend of Figure 22.

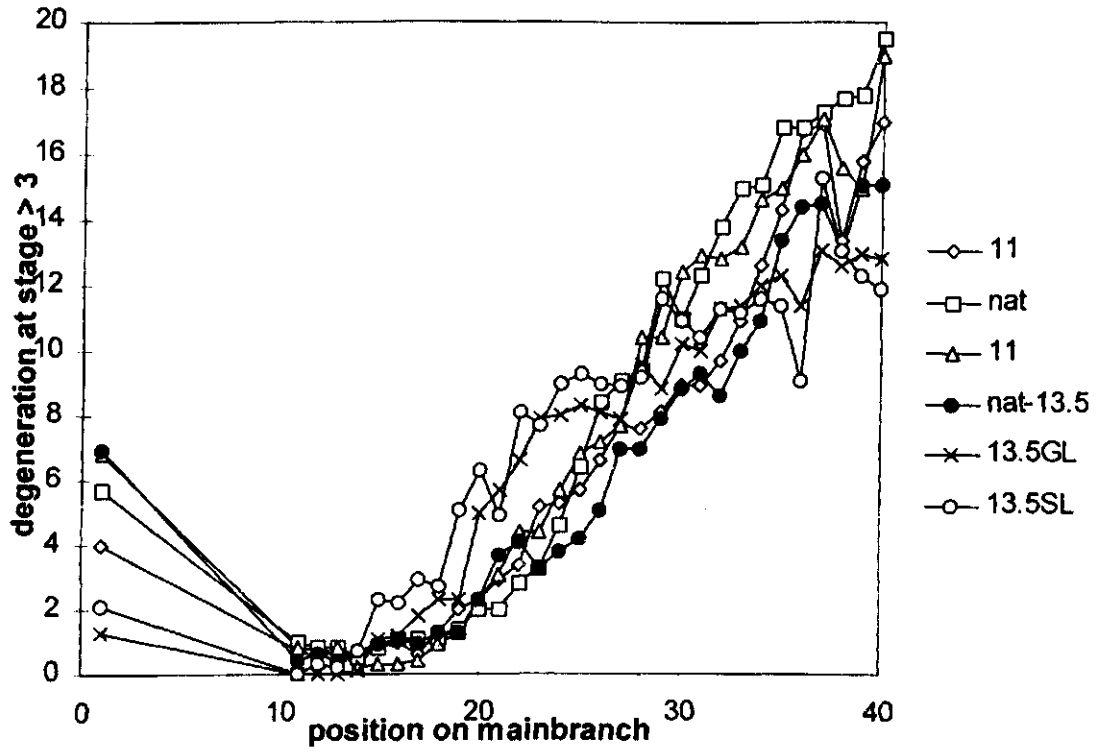


Figure 26 - The number of meristems per position that aborted after stage 3 had been reached. See Figure 22.

3.22 ANATOMICAL RESEARCH

From a number of experiments (experiments 6, 7, 8 and 17) plants were weekly sampled for anatomical research of the meristems, in order to follow the development of these meristems under the influence of different photoperiods. The development of the meristems from vegetative to the stage in which all flower parts have been formed has been divided into eleven stages (Wallerstein, 1993):

1. Vegetative meristem, the apex is rather flat, and is enclosed by leaf primordia.
2. Enlarged meristem, the apical meristem has become a little bigger and developed into a more spherical shape.
3. Around the spherical meristem (the future capitulum) bracts develop.
4. One third of the capitulum is covered with (round) flower primordia. Rings of flower primordia arise at the edge of the meristem.
5. Two third of the capitulum is now covered with flower primordia.
6. The capitulum is now totally covered with flower primordia. The flower primordia start to flatten.
7. The flower primordia are flattened, and due to the initiation of the corolla they become cup shaped.
8. Development of the corolla lobes and initiation of stamens.
9. Stamen differentiation and initiation of the ovary.
10. The corolla covers the flower organs. The ovary starts to develop and differentiate.
11. All flower organs are present.

In appendix II photographs of light microscopic views of longitudinal dissections of the above mentioned stages are presented.

The time needed for an apical meristem to proceed from stage 1 through stage 11 is, depending on the season and on the photoperiod, about three to five weeks. The

development of the apical and axillary meristems, according to the weekly samples, is shown in Figure 27. The developmental rate of 'Monte Cassino', Figure 27D, is in the first weeks of the short-day period slower than that of 'Dark Pink Star', Figure 27C. This arrears was almost made up after three weeks, but still stage 11 was reached a little later. Nevertheless the two cultivars flower simultaneously. This indicates that, because the development to stage 11 (and especially to stage 7) is slower, during the later part of the short-day the rate of development of 'Monte Cassino' has to be higher. As mentioned before this has some consequences for how long to proceed with the day extension.
From Figure 27 it can be seen that the axillary meristems adjacent to the apical meristem hardly show any visible development during the first weeks. This is probably caused by the correlative inhibition that the dominant apical meristem exercises on the lateral meristems Between week 2 and 3 the rate of development of the axillary meristems increases, but hardly in the 13.5 hour treatment. Possibly the release from apical dominance is a little slower in the 13.5 hours treatment.
The rate of development was during winter a little slower than in summer (a few days).

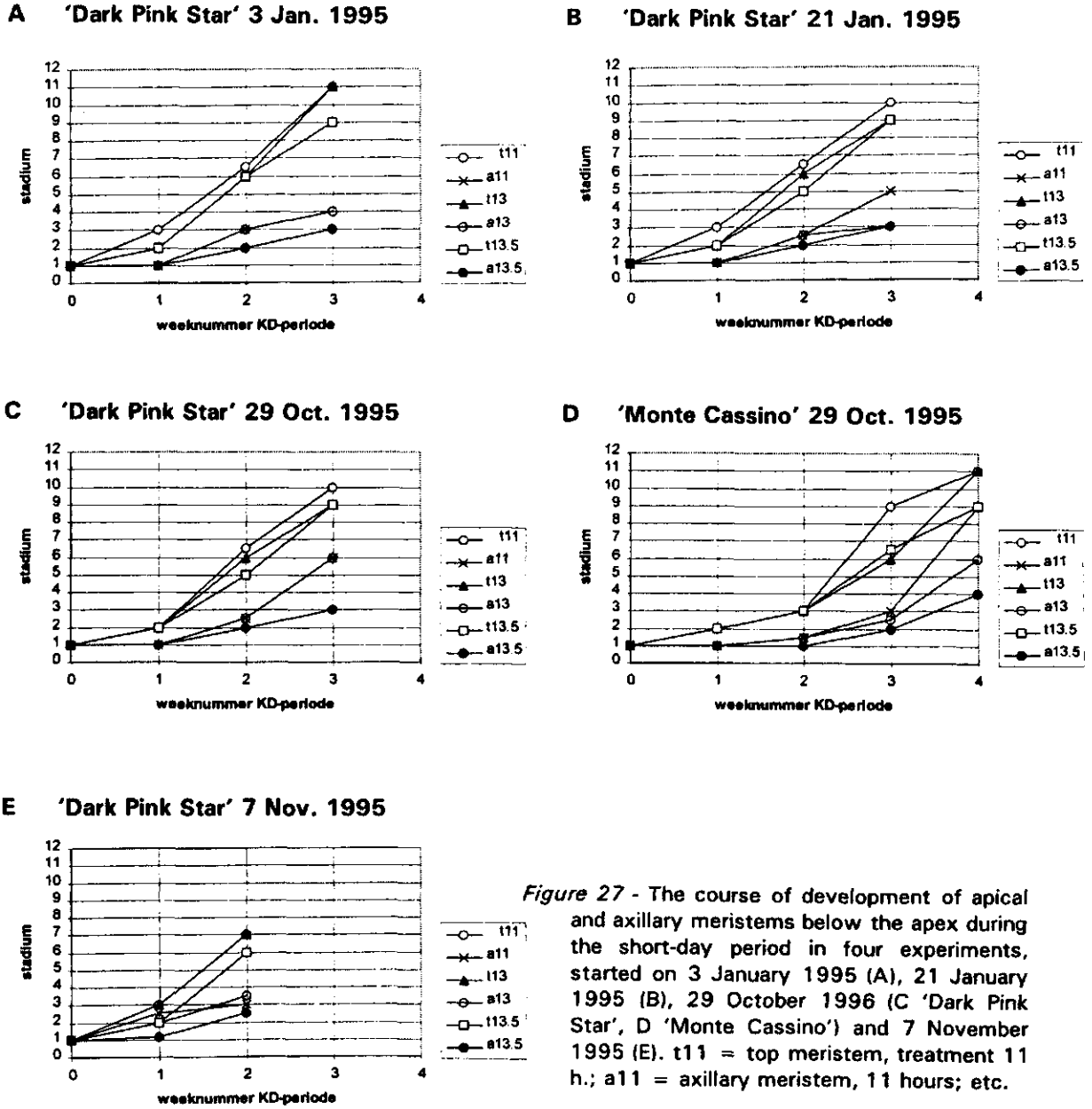


Figure 27 - The course of development of apical and axillary meristems below the apex during the short-day period in four experiments, started on 3 January 1995 (A), 21 January 1995 (B), 29 October 1996 (C 'Dark Pink Star', D 'Monte Cassino') and 7 November 1995 (E). t11 = top meristem, treatment 11 h.; a11 = axillary meristem, 11 hours; etc.

First week
During the first week not so much development is visible. The apical meristems enlarge (stage 2), and only in treatment 11 hours the apical meristems reach stage 3. The axillary meristems show little changes (stage 1). For all meristems the development slows down when they are shaded (lower side branches).

Second week
In the second week of the short-day period many changes occur. The apical meristems in the treatments 13 and 13.5 hours are almost covered with flower primordia (stage 5), and in treatment 11 hours the meristem is even fully covered with flower primordia (stage 6), and sometimes stage 7 is reached (or partially). The diameter of the meristem is now about twice as large as it was a week ago. The axillary meristems are clearly less far developed: stage 2 to 4. Meristems very close to the apical meristem are even less far developed due to the apical dominance (stage 2). With the method of research used here it appeared not possible to discriminate between yet aborted and still vital meristems. It is likely that in this stage, especially in the winter experiments, many of these axillary meristems had already aborted. From research in Israel it has become clear that meristems in stage 2 tend to be susceptible for abortion, and from the observations at harvest in our experiments it appeared that the first positions in which no flowers developed were those close to the apical meristem.

Third week
In treatment 11 hours the development was almost finished (stage 11). All flower organs, including stamens and the pistil with style were visibly present. The apical meristems from treatments 13 and 13.5 had made less progress (stage 10, 10-11). The axillary meristems now develop faster than in the first two weeks of the short-day period (stage 4-6).

Fourth week
In all treatments the apical meristems have now passed stage 11. The size of the meristem of treatment 11 hours is bigger than that of the other treatments, indicating that it is still ahead of the others. Most of the axillary meristems have now passed stage 7, some are even in stage 10.

Some considerations
Abortion of meristems only occurs on axillary positions. A loss of quality by a limited number of flowers is always caused by a massive abortion of axillary meristems. Considering that stages 2 and 7 are crucial stages for successful development of a meristem, it is evident that for 'Dark Pink Star' the first four weeks are very important in determining whether a shoot with many or few flowers will result. After week four almost all meristems have passed this last crucial stage, stage 7. The majority of abortion takes place in the first three to four weeks of the short-day period.

4. DISCUSSION

4.1 GENERAL

This research shows that with little effort and little resources the quality of *Aster* can strongly be improved. *Aster* is a short-day plan, which implies that the plant flowers under short-day conditions. The critical photoperiod is somewhere between 12 and 13 hours. Longer photoperiods cause retardation of flowering. For unknown vague reasons in the Netherlands growers generally use short-days as short as 11 hours. In the Netherlands and Israel the photoperiod varies from respectively 7.5 and 10 hours in winter to 16 and 14 hours in summer (see appendix III). Although in Israel the natural sun irradiance during winter is about three times that in the Netherlands, also there the problem of a reduced flower load exists. In earlier research in the Netherlands and Israel indications arose that the photoperiod plays some role in the eventual number of flowers on shoots of *Aster* (Blacquière & De Koster, 1991; Wallerstein *et al.* 1992).
In the earlier experiments the improvement of flower number was not always that big. In our opinion this may have been caused by the high plant density. Striking was that seemingly in the 13 and 13.5 hours treatments many meristems did develop further than in the 11 hours control, but that these meristems did whither as yet in a later stage. Moreover there was overgrowth and an extra retardation of flowering with 13 and 13.5 hours photoperiod. This later abortion was especially severe in meristems on lower positions. This suggests that the abortion that still occurred was caused by a lack of assimilates, but maybe also (partially) may be explained by the low red/far-red ratio in the dense canopy. As a consequence of the absorption of red light by the leaves of plants the light spectrum in a canopy is characterized by a low red and a high far-red share (Smith 1982). Far-red may stimulate abortion of axillary meristems. In later experiments therefore a lower plant density was used, and in these experiments the longer photoperiods did improve the flower numbers. The improvement of flower numbers cannot be separated fully from the amount of light and plant density.

4.2 THE INFLUENCE OF NATURAL IRRADIANCE

The availability of photosynthetically active photons has a big influence on the number of flowers, i.e. on the abortion of axillary meristems (see 3.17). During winter in the Netherlands the amount of PAP is very low, due to the short days (8-10 hours) and the low level of irradiance. Therefore many axillary meristems cannot develop, due to a lack of assimilates. Growers cannot produce a good quality aster shoots in this period without the use of supplementary light. Although it was demonstrated in this research that through a day extension the flower load could be improved, it still can be doubted whether in the Netherlands Aster can be produced all the year round without the aid of supplementary light. Nevertheless one may assume that, during spring and autumn especially, the quality can strongly be improved. Possibly the production can start earlier in spring and proceed longer in autumn.
The influence of irradiation on the eventual number of flowers seems to depend on the developmental stage of the axillary meristems. The influence of light on the occurrence of abortion appears not to be equal for all stages. For 'Dark Pink Star' the irradiation in the first four weeks of the short-day period is most important (see 3.17). If the development is somewhat retarded by a day extension, the sensitive period also shifts (about one week later). Under Dutch conditions most axillary meristems of 'Dark Pink Star' reached stage 7 within the first four weeks (see 3.22). From Israelian research it was already clear that after this stage scarcely any abortion still occurs. From these observations it can be concluded that the amount of light is especially important as long as the axillary meristems have not yet reached stage 7. From the anatomical research it appeared that the development of meristems in "Monte Cassino' was slower than in 'Dark Pink Star'. This has some implications for the length of the period in which light plays an important role in the process of meristem abortion. Screening experiments in spring (see 3.18) showed that

for 'Dark Pink Star' with a photoperiod of 11 hours screening of light particularly in the first weeks of the short-day period resulted in much abortion. With a photoperiod of 13 or 13.5 hours, screening in the first weeks had less impact. For 'Monte Cassino' the most sensitive period appears to be between week 3 and 5 of the short-day period.
It was striking that for 'Dark Pink Star' screening of light resulted in far more abortion under a photoperiod of 11 hours than with 13 or 13.5 hours (60 and 30 % respectively). Thus *Aster* appears to be more susceptible for abortion by low light levels under a very short photoperiod than under slightly longer photoperiods.

4.3 THE INFLUENCE OF THE PHOTOPERIOD

Improvement of the quality of aster can be achieved by retardation of the development of the meristems during the first weeks of the short-day period by means of a day extension. The development of the meristems can be retarded by keeping the photoperiod close to a critical daylength. In this research a photoperiod around 13.5 hours, kept for at least 4 weeks for 'Dark Pink Star' and 5 to 6 weeks for 'Monte Cassino' worked out very well. An improvement was also seen with 13 hours, but the effects were generally smaller, and sometimes it did not work. Photoperiods between 13 and 11 hours have hardly any effect on the number of flowers and on the retardation of flowering.
The use of a day extension also implies a retardation of flowering. For a photoperiod of 13.5 hours this retardation was generally about 11 days. It seemed to be greatest in summer. Application of a day extension in summer is however not very useful, and the risk of a too vegetative growth, with a chance of overgrowth, becomes serious (see 3.1 and 3.2). It also appeared that a day extension later in the short-day period had hardly any effect on the final flower numbers in 'Dark Pink Star' (3.19), probably since no abortion occurs anymore after stage 7, a stage that almost all meristems had reached or passed after 4 to 5 weeks. For the same reason a photoperiod of 11 hours after 4 weeks would not cause a lot of abortion anymore, as indeed the results showed. The first few experiments however had given the impression that it was a prerequisite to return to 11 hours after four weeks, since otherwise the flower buds would not reach anthesis. Possibly this is true for the summer months and/or certain circumstances (high temperatures, high plant density), but in later experiments it became clear that a day extension during the whole short-day period did not cancel flowering. And since there was no significant difference between four and six weeks of 13.5 hours (see 3.19) it may be assumed that 4 weeks is the minimum, but that 5 or 6 weeks give more certainty. For 'Monte Cassino' a day extension for 5 or 6 weeks is even needed, since the meristems develop slower, and are later in a sensitive stage.
To resume it can be stated that the susceptibility of meristems to abortion depends on the stage of development. The susceptibility can be diminished by slowing down the rate of development by a day extension. Although not proven, it seems likely that a slower development reduces the amount of assimilates needed per unit of time. With a fast release from apical dominance, and a fast induction of axillary meristems a sudden big demand for assimilates arises. Especially under dark circumstances photosynthesis cannot meet this sudden demand, and axillary meristems may starve and abort. It is of course also well possible that there is a direct down regulation of photosynthesis by very short photoperiods, since short photoperiods induce the formation of a new winter rosette, and the onset of winter rest (Kadman-Zahavi & Yahel, 1985; Schwabe, 1985).

4.4 THE INFLUENCE OF THE LIGHT SPECTRUM

In this research no clear cut differences have been found between the use of compact discharge lamps (SL-Agro) and incandescent lamps. There was only a little more elongation with the use of incandescent, as a consequence of the far-red component of incandescent light. However in the last experiment (see 3.21) there were, with a day extension with incandescent lamps from a natural daylength to 13. 5 hours (day extension lighting in begin of experiment 2.50, end of experiment 5.50 hours), less flowers than with a day

extension from 11 to 13.5 hours (13.5 SL and GL: lighting with incandescent or SL 2.50 hours). Unfortunately there was no treatment in which the natural day was extended to 13.5 hours with SL, neither a treatment with a natural daylength without any day extension. Therefore it is not possible to conclude whether the differences in the number of flowers were due to differences in the amount of photosynthetic light or to the different red/far-red ratios between incandescent and SL lamps during the day extensions. The plants of the treatments with supplementary light to 11 hours were able to photosynthesize for 0.1 hour extra in the beginning to 3.1 hours in the end of the experiment thanks to the supplementary light (20-25 μmol m^{-2} s^{-1}). The estimated extra amount of photosynthetic light was for the whole shortday period only 7%. Since extra photosynthetic light had no effect on the number of flowers in the 11 hours compared with 11-nat, and since there was a real improvement in the 13.5 GL and SL, it seems likely that the lower flower number in the 13.5-nat was due to the prolonged irradiation with incandescent lamps. For better understanding: the incandescent light has a big share of far-red irradiation, SL does hardly emit any far-red. Far-red can exercise a negative influence on the development of axillary meristems. This was also manifested in the experiment with a far-red end of day treatment (see 3.20).

5. CONCLUSIONS

By day extension it is possible to improve the flower load of *Aster* shoots. The improvement is largest with a day extension to 13.5 hours. Daylengths shorter than 13 hours result hardly in any improvement.

The higher number of flowers achieved by day extension during the short-day period results from a decreased degeneration of axillary meristems. There is no increase in the number of axillary positions due to day extension.

Abortion of axillary meristems occurs in 'Dark Pink Star' predominantly in the first four to five weeks of the short-day period, and in 'Monte Cassino' in the first five to six weeks. From this it can be concluded that abortion occurs in those stages preceding the development of the perianth. In these stages there is an increase in the size of the capitulum and flower primordia are formed on top of it. When the capitulae of most axillary flower heads are fully covered with flower primordia, and when these primordia have a developed perianth, the axillary meristems are no longer very susceptible for abortion. After this stage a day extension or an increase of irradiation can hardly bring any improvement of flower load per shoot.

The amount of light during the short-day period has a tremendous effect on the number of flowers per shoot. This is particularly the case for the light during the first four to five weeks of the short-day period.

The day extension during the short-day period needs to be continued for at least four weeks in 'Dark Pink Star', and for at least five weeks in 'Monte Cassino'.

The success of a day extension strongly depends on the amount of *available* light. Here plant density plays an important role. A day extension on a very dense crop results hardly in a higher number of flowers, especially on the lower branches. It will however always lead to less abortion of axillary meristems below the top meristem.

The day extension causes a retardation of flowering of about 10 days. In periods with high irradiation the retardation is stronger than in periods with low irradiation. The retardation of axillary meristems is stronger than that of the apical meristems. This leads to a slightly less homogenous flowering per shoot.

Far-red irradiation has a negative influence on the number of flowers of *Aster*. In this research there were however no differences between the extent of abortion of meristems of plants with an incandescent and an SL day extension. In these experiments the day extensions with SL and incandescent were 2.5 hours. It remains well possible that a long day extension with incandescent lamps (in November to January, when natural daylength is very short), results in a decreased improvement of flower number.

LITERATURE

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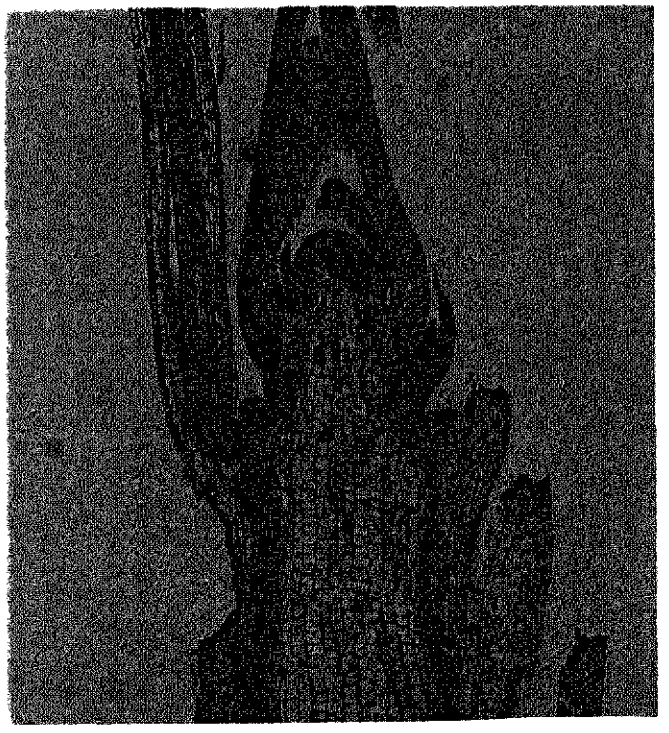
Appendix 1. Light integrals & Number of flowers

experiment	start SD	light integral mol m^{-2} PAP week 1-2	week 2-3	week 3-4	week 4-5	week 5-6	week 6-7
1	21-06-94	199	244	252	266	243	200
2	19-07-94	266	244	200	169	159	123
3	18-08-94	159	123	109	104	91	84
4	05-09-94	103	104	91	96	78	51
5	26-10-94	45	41	32	31	32	27
6	29-10-94	52	43	35	29	27	30
7	07-11-94	32	30	31	27	26	20
8	04-01-95	26	30	34	36	50	62
9	21-01-95	34	34	36	62	62	89
10	01-02-95	36	50	63	89	116	120
11	15-02-95	63	62	89	120	126	127
12	28-02-95	89	116	120	127	128	146
13	21-04-95	177	214	209	211	214	172

experiment	start short-day	Number of flowers on 30 upper nodes 11 hours	13 hours	13.5 hours
1	21-06-94	77	150	x
2	19-07-94	134	179	x
3	18-08-94	64	63	77
4	05-09-94	42	58	53
5	26-10-94	16	36	38
6	29-10-94	30	39	44
7	07-11-94	13	16	27
8	04-01-95	17	19	34
9	21-01-95	14	20	27
10	01-02-95	15	27	39
11	15-02-95	31	37	49
12	28-02-95	51	80	70
13	21-04-95	88	118	131

Appendix 2. Meristem development



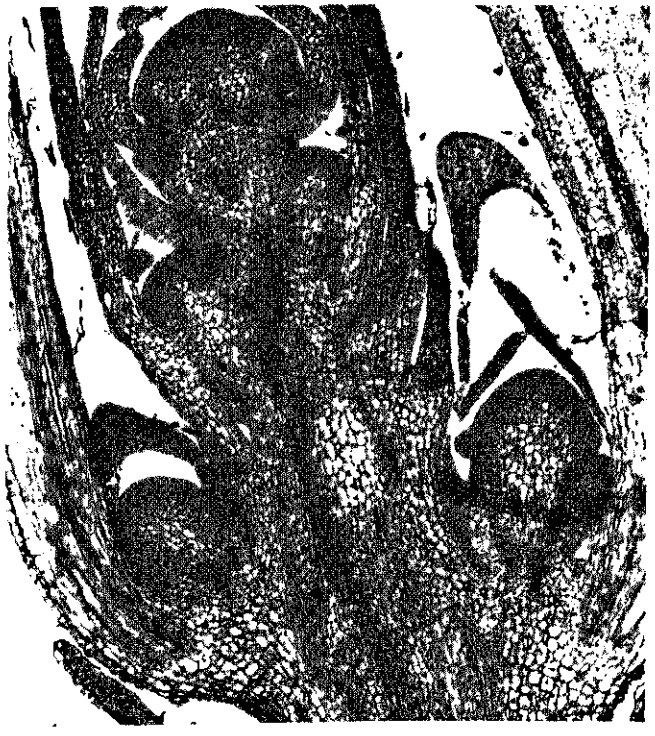
Picture 1.

Microscopic view of a vegetative meristem (stage 1). Axillary meristems are hardly visible, but may have been present, outside the plane of slicing (only 5 μm thick). The width of the apical meristem is about 0.15 mm.

Picture 2.

Microscopic view of an apical and of axillary meristems. The apical meristem is about 0.21 mm wide (in stage 2). The axillary meristems seem to enlarge, and are about 0.10 mm now.

Picture 3.



Apical meristem in stage 3 has a width of 0.3 mm. The axillary meristems most close to the apex are still in stage 1-2, the lower ones have already reached stage 3.

Picture 4.

The apical meristem is in stage 5. The flower head is covered with flower primordia for about ⅔ of its area. The only visible axillary meristem is in stage 2-3.

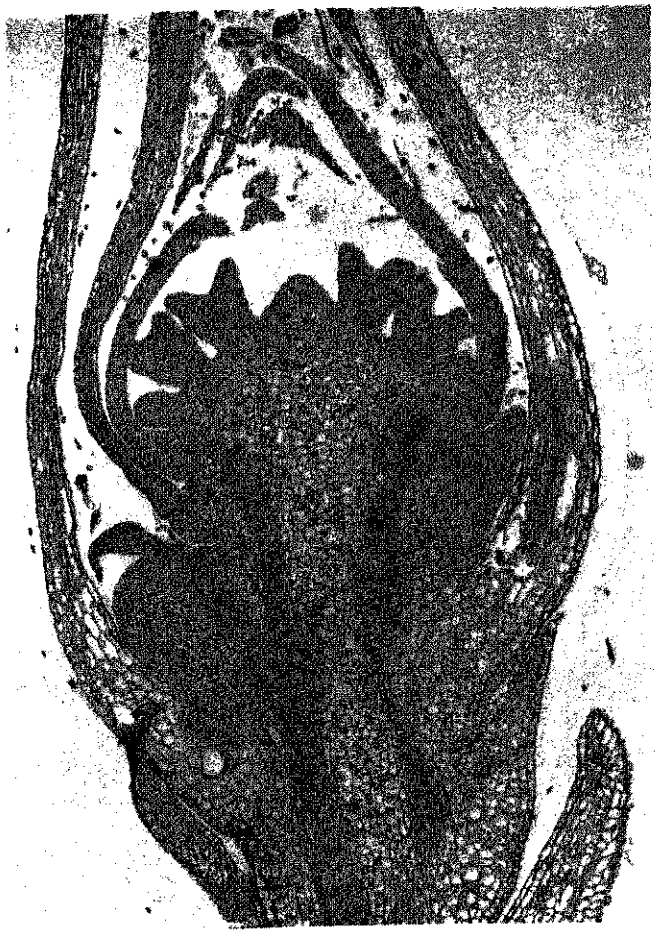
Picture 5 (left).

The apical meristem is 0.5 mm wide and fully covered with flower primordia (stage 5-6). Axillary meristems close to the apical meristem are less far developed than the lower meristems. Many of the axillary meristems are not visible.

Picture 6 .

The axillary meristems, located directly underneath the apical meristem, are in stage 3. The width of the apical meristem is 0.6 mm.

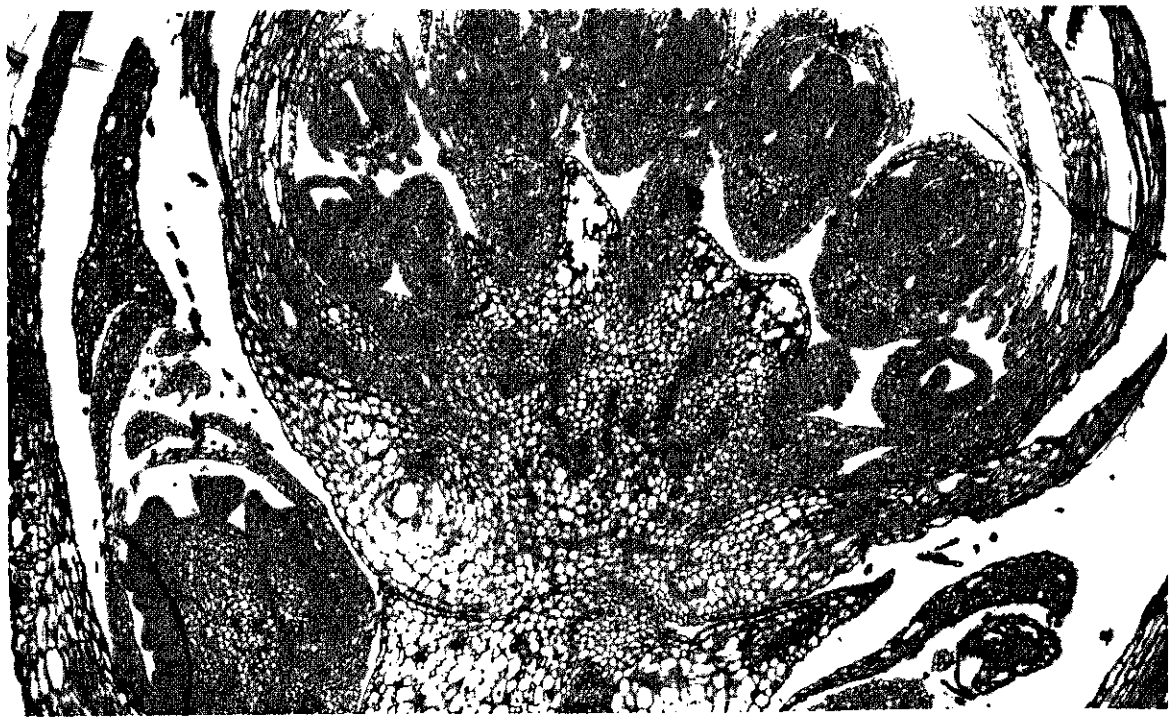
Picture 7.



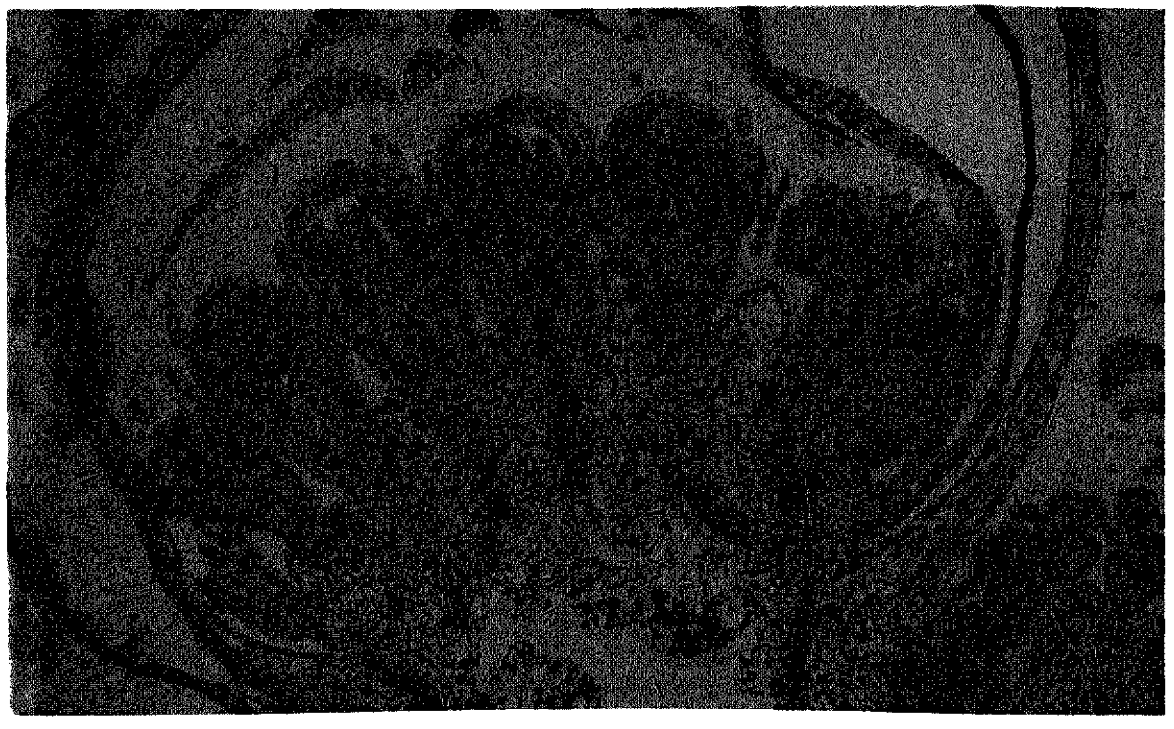
The apical meristem is in stage 7. The flower primordia are cup shaped. The flower head is about 0.7 mm. The one axillary meristem visible is still in stage 2-3.

Picture 8.

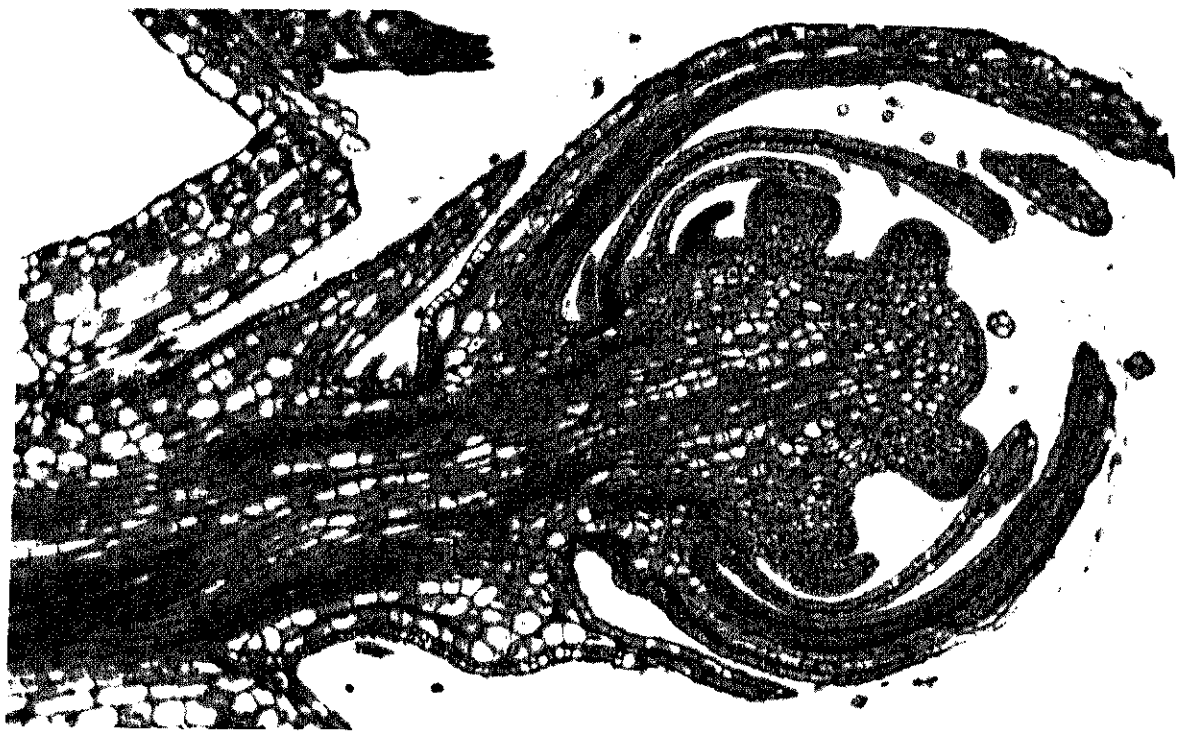
The flower primordia start to develop stamens. The primordia are in stage 9-10. The capitulum is about 1 mm wide. The axillary meristems on the photograph reached stage 5-6 (capitulum covered with flower primordia).



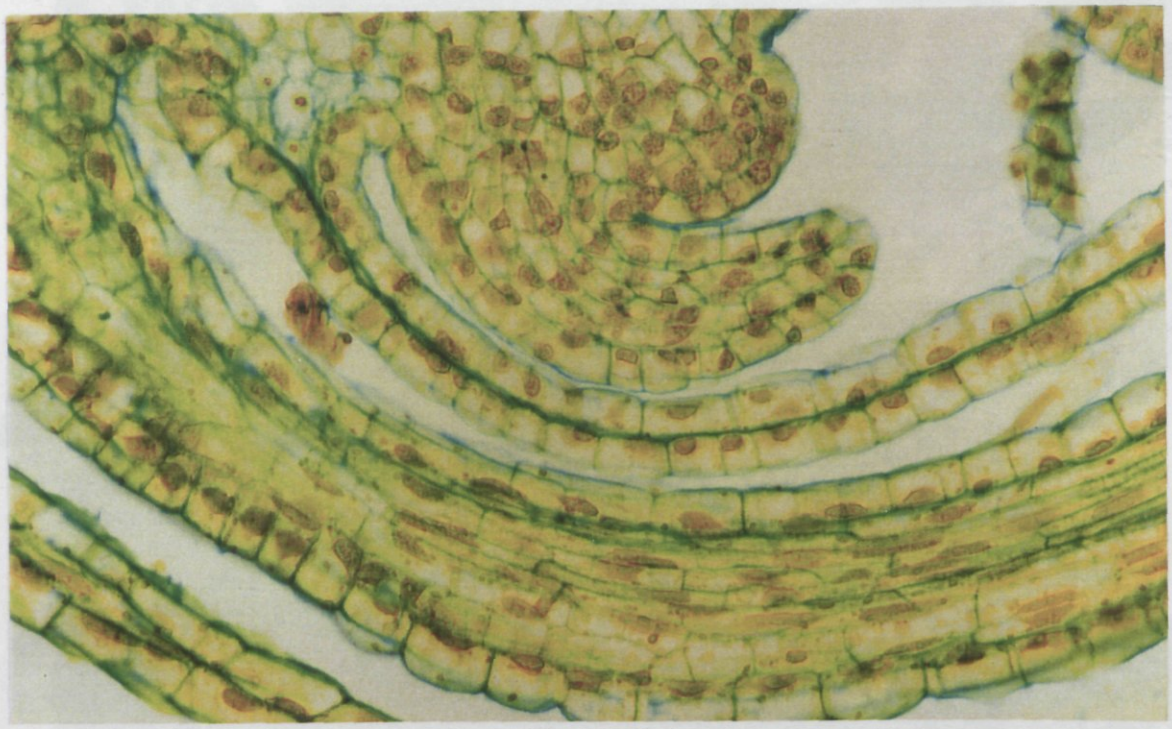
Picture 9. Stage 10 has been reached. The flower primordia contain developing stamens, with the corolla almost closed around them. The flower head of the apical meristem is about 1.4 mm wide. The axillary meristem (left)is in stage 7.



Picture 10. All flower parts have now been developed, a developing gynoecium is also visible. The flower head is 1.5 mm wide. The axillary meristem is in stage 9.

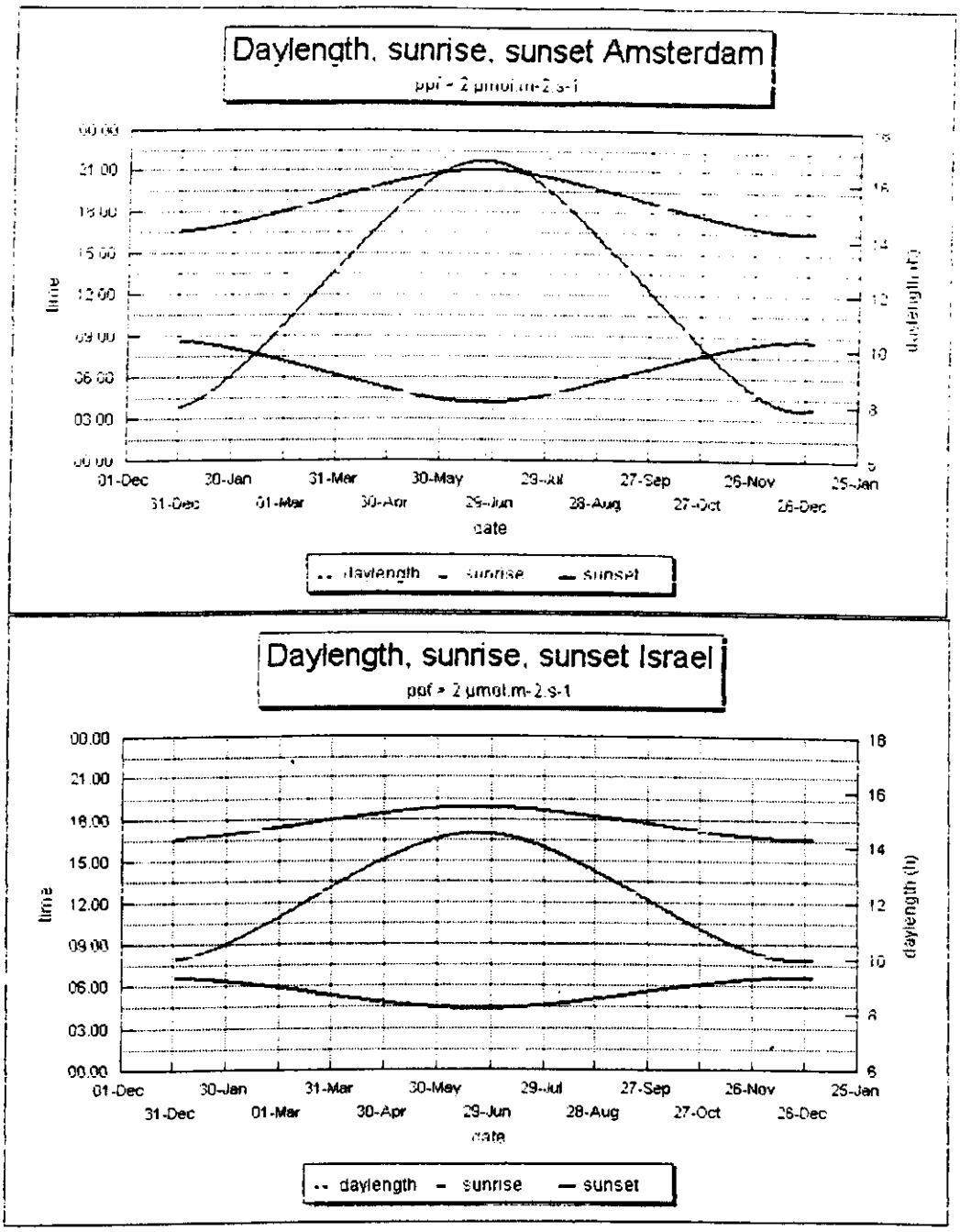


Picture 11. Withering axillary meristem in stage 5-6. Note the shrunken bracts, with a mesophyll that has disappeared, and a shrunken stem below the flower head.



Picture 12. Detail of aborting meristem. The cells of the flower primordia still seem vital, but the bracts have already withered. Only the upper and lower epidermis still remain.

Appendix 3. Yearly course of photoperiod.



Photoperiod, sunrise and sunset in the Netherlands (52 °N, time zone + 1 hour, 5 °E) and in Israel (34 °N, time zone + 2 hours, 34.3 °E). Photoperiods under clear wheather conditions, and a minimal light level of 2 μmol m^{-2} s^{-1} PPF.

Appendix 4. Reprint of journal article 1. 1995.

Verbetering bloembezetting bij aster

De jaarrondteelt van aster in Nederland wordt bemoeilijkt door de lage, natuurlijke instraling gedurende de wintermaanden. Licht is dan ook de belangrijkste factor voor de bloemaanleg. Echter, door manipulatie met stuurlicht is een aanzienlijke verbetering te behalen. In de praktijk wordt al gewerkt met tussenlicht, maar onderzoek heeft aangetoond dat meer valt te verwachten van dagverlenging.

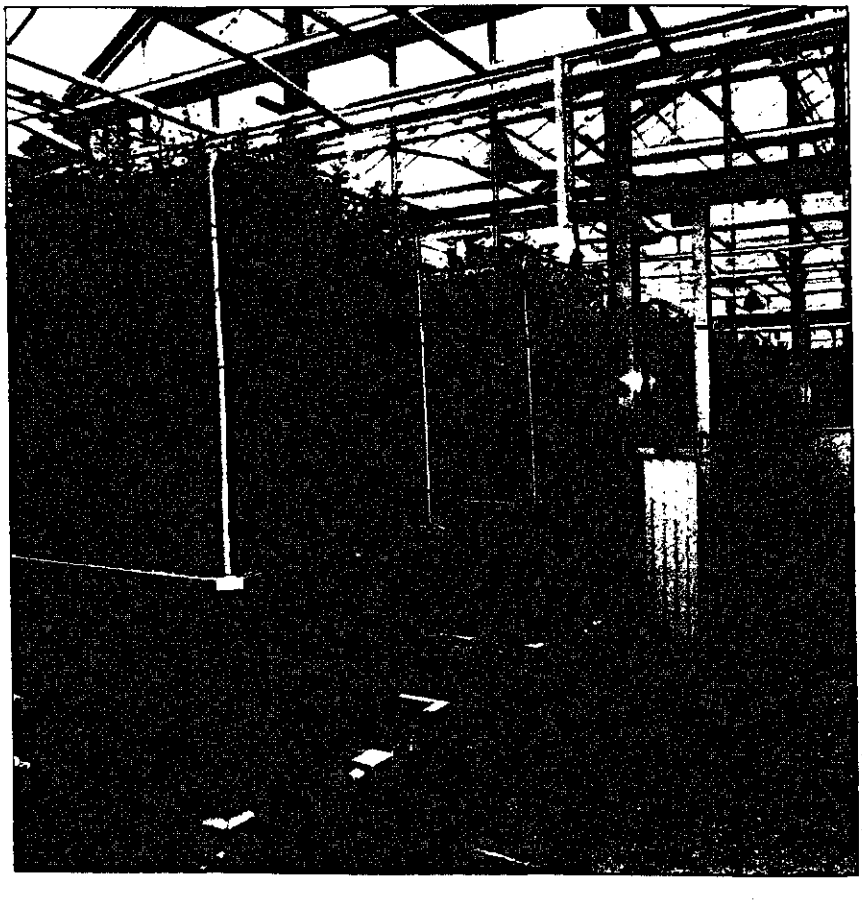
Op het proefstation Aalsmeer is in samenwerking met het Volcani-instituut in Israel een onderzoek gestart met als doel het verbeteren van de bloembezetting bij aster. Het onderzoek richt zich voornamelijk op de wintermaanden wanneer de kwaliteit van aster te wensen overlaat. Ondanks het feit dat Israel in de wintermaanden ruim driemaal zoveel licht heeft, speelt ook hier het probleem van een matige bloembezetting. In Nederland is door de lage, natuurlijke instraling in de winter geen asterteelt mogelijk.

Eerder onderzoek in Israel en Nederland naar de kritische daglengte voor bloeminductie bij aster bracht aan het licht dat een verlenging van de dag tijdens de korte-dagperiode extra bloemen geeft. Voor dat onderzoek is de verouderde cultivar 'Dark Pink Star' gebruikt, waarmee ook nu de proeven, uitgevoerd in de winter van 1994-1995, zijn gedaan. De bedoeling is dat voor de komende winter behalve 'Dark Pink Star' gewerkt gaat worden met 'Monte Cassino'. Het is wellicht mogelijk de periode waarin geen asters in Nederland worden geteeld, te verkorten met enkele weken. Voor praktische toepassing is het echter nog te vroeg harde conclusies uit dit onderzoek te trekken, omdat de proeven onder andere omstandigheden zijn uitgevoerd dan die van de praktijk. Zo is bijvoorbeeld de dag verlengd tot 11 uur door middel van assimilatiebelichting, terwijl dit in de praktijk niet of nauwelijks voorkomt. Een gedegen advies kan en mag dan ook nog niet worden gegeven.

Abortie in de wintermaanden

Aster heeft een kritische daglengte van ongeveer 12 uur. Dit wil zeggen dat boven deze daglengte inductie en bloemaanleg merkbaar worden vertraagd. De praktijk werkt met een korte-dagperiode met een daglengte van ongeveer 11 uur. Theoretisch kan het grote aantal abortie van bloemen in de wintermaanden als volgt worden verklaard:

- het gebrek aan licht. Door te weinig licht worden te weinig suikers aangemaakt voor het laten uitgroeien van de geïnduceerde meristemen, waarna deze door de plant worden geaborteerd. Het probleem van te wei-



Het onderzoek naar de optimale daglengte voor de bloemaanleg van aster, in het Aalsmeerse fototron, loopt door tot eind volgend jaar.

Foto: Gerdien de Nooy

A. Durieux en T. Blacquière

A. (Adri) Durieux is onderzoeksassistent en T. (Tjeerd) Blacquière is onderzoeker bij het Proefstation voor Bloemisterij en Glasgroente in Aalsmeer, 02977-52272/52432.

nig instraling speelt in Israel niet. Dit punt kan de abortie dus maar ten dele verklaren:
• de (te) korte dagen. De inductie en aanleg van bloemen bij aster verloopt sneller naarmate de dagen korter worden. Met anatomisch onderzoek zijn aanwijzingen verkregen dat dit proces, bij een tekort aan licht, te snel verloopt. Vaatbundeltjes die het meristeem van suikers moeten voorzien voor een verdere ontwikkeling, lijken nog niet geheel te zijn aangelegd. Dit zou een verklaring kunnen zijn voor het afsterven van het meristeem;
• apicale dominantie. Dit is een fysiologisch proces, waarbij de hoofdgroeipunten (hier: hoofdknoppen) de uitloop van axillaire knoppen (zijtakken ofwel zijknoppen) vertragen. Bij aster wordt de apicale dominantie van de hoofdknop opgeheven onder korte-dag. Hoe dichter de zijtakken zich bij de hoofdknop bevinden, hoe sterker de apicale dominantie is. Bij een daglengte van 11 uur wordt de apicale dominantie sneller doorbroken dan bij bijvoorbeeld 13 uur. Verondersteld wordt dat een te snelle opheffing van apicale dominantie een goede ontwikkeling van de axillaire meristemen belemmert.

Genoemde punten zijn voor het onderzoek, dat vorig jaar maart van start is gegaan, de uitgangspunten. Het onderzoek loopt door tot eind 1996. Het doel is het vaststellen van de optimale daglengte voor de bloemaanleg van aster.

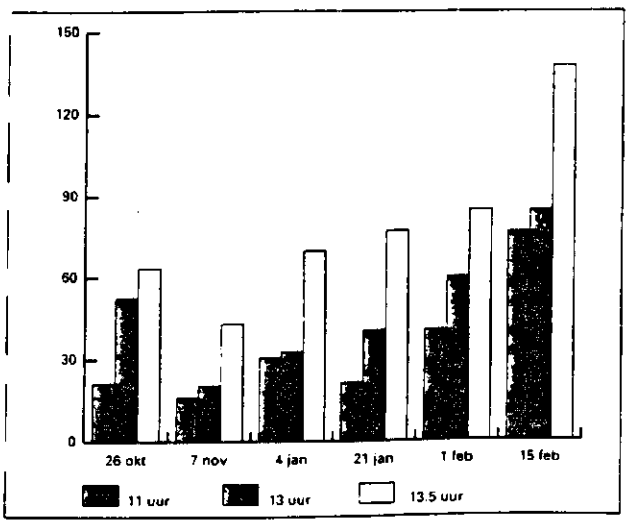
Meer bloemen bij 13 en 13,5 uur

Het bleek dat de behandelingen met een daglengte korter dan 13 uur (12 uur, 12,5 uur) nauwelijks verschillen te zien gaven ten opzichte van de behandeling 11 uur. Deze worden dan ook buiten beschouwing gelaten. De behandelingen 13 en 13,5 uur gaven in alle zes proeven veel meer bloemen dan de 11 uur behandeling. De behandeling 13,5 uur produceerde de meeste bloemen per tak (**figuur 1**). **Figuur 2** laat zien hoeveel groeilicht (Fotosynthetisch Actieve Straling 400-700 nm) de zes proeven gedurende de korte-dagperiode hebben ontvangen. Het is goed te zien dat de eerste twee proeven het minste licht hebben ontvangen. Dit is ook terug te vinden in het aantal bloemen per tak, wat betreft de behandeling 13,5 uur, maar de behandelingen 11 en 13 uur verbeteren zich pas aanzienlijk in de laatste proef. Figuur 2 laat ook zien dat de eerste vijf proeven in de eerste drie weken ongeveer dezelfde hoeveelheid licht hebben ontvangen, en dat alleen de zesde proef in deze periode meer licht heeft gekregen. Hieruit kan worden geconcludeerd dat het lichtniveau voor de behandelingen 11 en 13 uur in de eerste weken cruciaal is voor het uitgroeien van de bloemen. Het lijkt er verder op dat voor de behandeling 13,5 uur deze periode iets later valt. De vertraging in bloei was, ondanks de extra bloemen, zeer bescheiden en varieerde van drie tot zes dagen. Hierbij dient aangetekend te worden dat de vertraging groter wordt naarmate het licht toeneemt. De zomerproeven gaven beduidend grotere verschillen in bloeitijdstip te zien. Toepassing van dagverlenging in de zomermaanden moet nog nader worden bekeken.

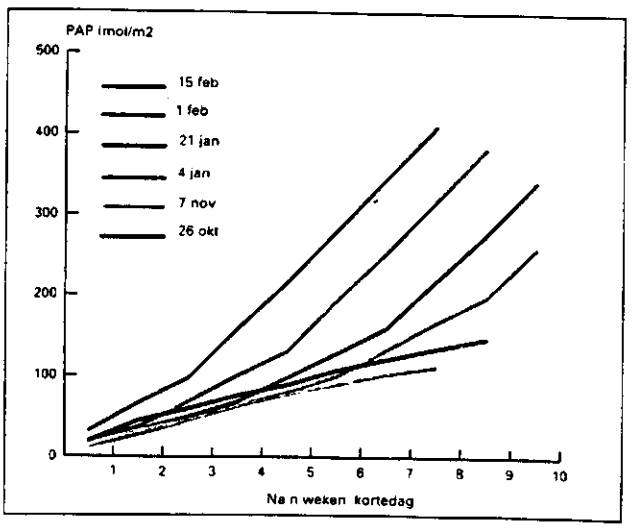
Licht is de belangrijkste factor voor het aantal geproduceerde bloemen per tak. Dit geldt dan vooral voor de eerste weken van de korte-dagperiode. In de wintermaanden en het vroege voorjaar kan een aanzienlijke verbetering in bloembezetting worden verkregen door de dag te verlengen tot ongeveer 13,5 uur. Bloeivertraging door dagverlenging tot 13,5 uur is klein in de wintermaanden, vooral als na vier weken de daglengte wordt teruggebracht naar 11 tot 12 uur.

Proefopzet

De proeven zijn uitgevoerd in het fototron op het PBG in Aalsmeer. Hier zijn tot nu toe tien achtereenvolgende proeven gedaan. De eerste twee proeven zijn minder interessant, omdat deze in de zomer zijn gedaan. De twee daaropvolgende proeven vonden plaats in de herfst. Zes proeven zijn in de winter uitgevoerd. In dit artikel komen de laatste zes proeven aan bod. De natuurlijke dag is gedurende het gehele jaar op 11 uur gehouden, dat wil zeggen door verduisteren of door bijbelichting met (zwak) assimilatielicht (ongeveer 15 µmol/m2.s). Om proeftechnische redenen is gewerkt met de harttakteelt. Tijdens de lange-dagperiode zijn de planten bijbelicht met SON-T lampen (lichtniveau = 30µmol/m².s ofwel ± 2.500 lux). De behandelingen bestonden uit verschillende daglengten (11, 12, 12,5, 13 en 13,5 uur), die zijn gerealiseerd door de 11-urige dag te verlengen met gloeilamp- of SL-licht. Al snel bleek dat de behandeling 13,5 uur zeer laat tot bloei kwam doordat de planten gedeeltelijk vegetatief bleven. Daarop is overgegaan naar een behandeling die in de eerste vier weken van de korte-dag een daglengte van 13,5 uur, en daarna tot aan de bloei 11 uur kreeg.



Figuur 1. Aantal bloemen per tak bij drie daglengten in de winterexperimenten 1994-1995.



Figuur 2. Cumulatieve lichtsom gedurende de korte-dagperiode P(hotosynthetic) A(ctive) P(hotons) (mol/m²).