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WAVELENGTH DEPENDENCE ON PHOTOPERIODIC RESPONSES

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In a previous paper it was reported that the effect of a long day treatment on the flowering response of some plant species is controled by at least two photoreactions (MEIJER 1957). One of them is the nightbreak reaction for which a maximum of activity in the red part of the spectrum has been found. The effect of a red irradiation can be reversibly antagonised by a near infra-red irradiation given immediately after the red irradiation (BORTHWICK e.a., 1952). The other photoreaction takes place during the main light period. STOLWIJK e.a. (1955) has found that *Hyoscyamus niger*, a long day plant, needs violet, blue or infra-red irradiation during the main light period of a long day treatment to obtain flowering. In a long day in green light no flowering occurred, whereas in red light flower initiation was retarded.

The same blue or infra-red necessity to obtain a long day effect has also been found for some other plants, f.i. *Salvia occidentalis* a short day plant, *Petunia*, *Arabidopsis thaliana*, *Plantago major*, lettuce and *Silene armeria*, all long day plants (MEIJER, 1957).

The influence of the light quality of the main light period on the effect of a short day treatment of *Kalanchoë blossfeldiana*, a short day plant, was studied by WALLRABE (1943). She concluded that a short day in green light is not effective in inducing flowering. A short day treatment in blue light is more effective than the same treatment in red light.

In this paper experiments are described to give some more information about the influence of the light quality of the main light period on photoperiodic responses.

METHODS AND MATERIAL

The experiments were carried out in the plant growth cabinets described by VAN DER VEEN (1950), the characteristics of the light have been given by MEIJER (1957), Fig. 1. The day temperature was 22° C., the night temperature 17° C. The effect of a short day treatment on flowering was studied in experiments with the short day plants *Kalanchoë blossfeldiana* and *Salvia occidentalis*. *Larix leptolepis* was used to see whether there is an influence on the induction of winter dormancy or not.

The influence of the light quality for a main light period of 10 hours

combined with a night break of 10 minutes with coloured light has been studied in experiments with an annual strain of *Hyoscyamus niger* var. *pallida* and with *Salvia occidentalis*, respectively a long day and a short day plant.

Experimental results

1. *Short day experiments*

Kalanchoë, *Salvia* and *Larix* were grown in a glasshouse in a long day of at least 16 hrs. light per day. During the experiments plants were given a short day treatment of 10 hrs. light per day in red, green and blue light during 2, 4, 6, 8, 10, 12, 14 or 16 days. After the treatment each group of plants was kept in the glasshouse in a long day.

The light intensities for the red, green and blue light are respectively 950, 880 and 900 $\mu W/cm^2$.

Salvia

At the beginning of the treatment the youngest leaf pair of *Salvia* plants was marked and at the end of the experiment the number of new formed leaf pairs was counted. A treatment of 16 short days in red, green and blue light was necessary for the induction of a terminal inflorescence. The average numbers of leaf pairs formed before the inflorescence appeared are respectively 6.5, 6.5 and 5.5 for the plants treated with red, green and blue light. A treatment of 10 short days or less in red and blue and of 8 short days or less in green light did not have a flower inducing effect at all. At the end of the experiment these plants had formed 10, 10.5 and 10 leaf pairs in red, green and blue light respectively. A short day treatment of 12 and 14 days in red and blue light and of 10, 12 and 14 days in green light showed a slight indication of flower induction; one or two bract-like leaves were formed after which the development of normal leaves was continued. The number of new formed leaf pairs up to the first bract-like leaf was 6 in red, green and in blue light.

Kalanchoe

In *Kalanchoe* a short day treatment of at least 6 days in red and green light and of at least 8 days in blue light induced the initiation of flowerbuds. There was hardly any difference in the time after which the flower buds were macroscopically visible. These results are contrary to those of Wallrabe (1943) who found that *Kalanchoe* did not initiate flowers in short days with green light.

Larix

In previous experiments in white light, it has been shown that *Larix* is very sensitive to a short day treatment. About 7 short days of 10 hrs. light per day are already sufficient for the initiation of a terminal bud, which appears in about three weeks after the beginning of the treatment. Some time afterwards this bud resumes growth

again in long days. The duration of this induced dormancy period of the terminal bud depends on the length of the preceding short day treatment. A treatment of less than 7 days gave a slight indication of induction. Only a number of scale-like needles are formed, but growth is not stopped and after this brief intermezzo the formation of normal needles is continued. 23 days after the beginning of the treatment all plants treated during 10—16 days in red and green light and during 8—16 days in blue light showed a terminal bud. A treatment of two short days did not have any effect, whereas 4 and 6 short days in red light and 4 short days in blue and green light induced a number of scale-like needles. The plants treated with 6 short days in blue and green light and 8 short days in red light formed partly a terminal bud and partly only a number of these scale-like needles. The duration of the dormancy period of the terminal bud did not show any difference between plants induced in red, green or blue light.

2. *Night break experiments*

In another series of experiments, *Salvia* and *Hyoscyamus* plants were treated during respectively 16 and 37 days in red, green and blue light during 10 hrs. per day. Of each group some plants were irradiated during 10 minutes in the middle of the dark period with red, green or blue light, whereas an other part was kept in darkness during this time (control plants). The light intensities for red, green and blue light were respectively 900, 850 and 950 $\mu W/cm^2$ for the main light period as well as for the light used as a dark interruption. The results are given in table I and II. Both plant species reacted

TABLE I

The influence of the light quality of a main light period of 10 hrs. per day and of a dark interruption of 10 minutes on the flowering response of *Salvia occidentalis* (S. D. plant). Duration of the treatment: 16 days. Stage of the growing points 58 days after the beginning of the treatment. + = generative, — = vegetative. Number of plants 4.

night break / main light period	control	10′ red	10′ green	10′ blue
10 hrs red	+ + + +	— + + +	+ + + +	+ + + +
10 hrs green	+ + + +	+ + + +	+ + + +	+ + + +
10 hrs blue	+ + + +	— — — —	— — — —	+ + + +

TABLE II

The influence of the light quality of a main light period of 10 hrs. per day and of a dark interruption of 10 minutes on the flowering response of *Hyoscyamus niger* (L. D. plant). Duration of the treatment: 37 days. Stage of the growing points 37 days after the beginning of the treatment. + = generative, — = vegetative. Number of plants 3.

night break / main light period	control	10′ red	10′ green	10′ blue
10 hrs red	— — —	— — —	— — —	— — —
10 hrs green	— — —	— — —	— — —	— — —
10 hrs blue	— — —	+ + +	+ + +	— — —

very uniformly and it is very clear from these results that a long day effect can only be obtained when the plants receive blue light during the main light period and red or green light during the night break.

The *Hyoscyamus* plants grown in 10 hrs. blue light + 10′ red started bolting 10 days after the beginning of the treatment and at the end of the treatment flower buds were macroscopically visible. In 10 hrs. blue light + 10′ green no elongation of the stem was obtained even at the end of the experiment; flower buds however were microscopically visible at that time. In all other treatments plants remained vegetative.

Discussion

The experiments described in this paper indicate:

1° That the effect of a short day treatment is not much influenced by the quality of the light for the species used.

2° That the night break is only effective if the light given during the main light period contains blue radiation (or perhaps infra-red, which was not investigated in these experiments).

In a previous paper we concluded that for some short day and long day plants a long day treatment was effective only when the light given during this long day contained blue or infra-red radiation (Meijer 1957). This is in accordance with the experiments with *Hyoscyamus* of Stolwijk (1955).

It seems therefore that in order to induce a long day effect, a plant needs either a few hours of blue (or perhaps infra-red) irradiation and afterwards, as a night break red light, or the long day effect can be obtained by giving long days with blue or infra-red. In these last conditions red light is not at all necessary. So in the first case the plant needs blue and red, in the second only blue to show the long day reaction.

One explanation for this behaviour may be that blue light has still some activity when given as night break light, although much less than red. (Borthwick e.a., 1948) During the 16 hours illumination, which might be considered as a short day of 10 hours and an additional 6 hours, the last few hours may act as night break light. A few hours of blue night break light could possibly be as active as 10 minutes of red and therefore change the short day into a long day.

Another possibility is that in the blue long day the necessity for red is fulfilled by the fluorescence of the chlorophyll in blue light. A green plant can never be exposed to pure blue or green light only, because 1 to 0.1 % of the light absorbed is transformed into red + infra-red fluorescent light by the plant itself. This red fluorescent light might act as night break light during the last hours of the long day in blue.

It must be mentioned here that *Kalanchoe* and also *Euphorbia pulcherrima* did not flower and that *Larix* did not show any sign of dormancy when these plants are grown in 16 hours green light per day. The green used still contained a trace of red (Meijer, 1957; Fig. 1) and the fluorescence of the chlorophyll emits red and infra-red

radiation. Therefore it may be possible that for some very sensitive plants the need for infra-red and for red may have been sufficiently satisfied by a long day exposure to green light.

Of course these explanations must be considered as tentative. The subject is under further investigation.

SUMMARY

It has been shown in several plants that the effect of a short day treatment does not depend on the light quality of the main light period. However to obtain a long day effect by interrupting the long night period with a red or green irradiation it has been shown that a special blue light requirement for the main light period exists.

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