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Dependence of formative and photoperiodic reactions in *Brassica Rapa* var., *Cosmos* and *Lactuca* on wavelength and time of irradiation

BY

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DEPENDENCE OF FORMATIVE AND PHOTOPERIODIC REACTIONS IN *BRASSICA RAPA* VAR., *COSMOS* AND *LACTUCA* ON WAVELENGTH AND TIME OF IRRADIATION

BY

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(Communicated by Prof. A. J. KLUYVER at the meeting of April 28, 1951)

Introduction

In a previous paper [1] it has been shown that *Brassica Rapa* f. *oleifera* subf. *annua* reacts with flowering and stem elongation upon supplementing a 10-hour day in strong artificial white light with weak irradiations of white, violet, blue and infrared. With green, yellow and red additional irradiation, and in darkness the plants remained short and vegetative.

In the present paper experiments are described in which 8 hours white light was supplemented by 4 hours spectral irradiations. These experiments were set up in order to see in how far the distinct activities of various spectral regions were manifest also within a "short day". Furthermore, with the same equipment, preliminary studies along similar lines were carried out with *Cosmos bipinnatus* CAV. and *Lactuca sativa* L.

A preliminary report of the present work was given by one of us [2] at a meeting of the 32nd Nederl. Natuur- en Geneeskundig Congres (Eindhoven, March 28, 1951).

Material and methods

The plants used in these experiments were: *Brassica Rapa* L. f. *oleifera* subf. *annua*, a long-day plant [1], *Cosmos bipinnatus* CAV., a short-day plant, and *Lactuca sativa* L., var. "*Meikoningin*", a long-day plant.

The young plants were transplanted into pots or square dishes 7 to 10 days after germination while the photoperiodic treatment started 7 days later. From emergence till the beginning of the treatment with supplementary light the plants received a photoperiod which prevented flowering, from a set of 40 W fluorescent tubes of the daylight type. The light intensity was about 3.5×10^4 ergs/cm²/sec. at the leaf surface. The plants were grown in fertile soil without nutrient solution added. Each treatment consisted of a number of hours (5, 8 or 10) white light, obtained as described above, followed by a number of hours (8 or 4) supplementary light from various spectral regions. A treatment, further on referred to as (10 + 8), *e.g.*, consisted of 10 hours of white light of high intensity, followed by a supplementary irradiation during 8 hours, after which the plants were placed in uninterrupted darkness for 6 hours. The supplementary irradiations were given in the equipment described in [3], consisting of 6 compartments in which illuminations with narrow wavelength regions can be given. The temperature throughout all these experiments was 20 ± 1°C, in the light periods as well as in the dark. The humidity was kept as constant as possible and never fell below 60 %. All experiments had both controls in white light and in dark. The intensity of the supplementary irradiation was 1000 ergs/cm^2/sec. in all spectral regions, unless indicated otherwise. Equal intensities were obtained in the various compartments by varying the distance between light source and plants. The intensity was regulated in such a way that in all cases the youngest fully expanded leaves received the intensity at which the experiment was taken to be made. The white controls received the same number of hours additional light from a daylight type fluorescent tube. The light intensity was the same as that of the additional irradiation in the coloured compartments. The dark control did not receive any supplementary light. These white and dark controls had the same conditions of humidity and temperature as given in the other treatments. In most of the graphs in this paper the various spectral regions have been indicated by their optical centres of gravity. For the extension of the spectral regions used *cf.* [3].

Experiments with Brassica Rapa *f.* oleifera *subf.* annua

In previous experiments [1] this plant has been shown to react photoperiodically as a long-day plant. Red, yellow and green irradiations applied for a period of 8 hours supplementary to a short day of 10 hours at intensities of 1000 and 3000 ergs/cm^2/sec. were practically ineffective. However, irradiations of similar intensities with wavelengths between 4000 and 5000 and beyond 7000 Å were very effective in the promotion of flowering. In the treatments resulting in flowering, an appreciable elongation of the stem was observed. An attempt was made to separate flowering and elongation by applying irradiations of 1000 ergs/cm^2/sec. of various spectral regions or white light during a period of 4 hours daily, subsequent to 8 hours white light of high intensity. The period of irradiation was followed by 12 hours of uninterrupted darkness, whereas the dark controls received 16 hours of darkness.

Photoperiodic and formative effects of (8 + 4) treatment. Flower buds developed in blue light after 36 days, in violet after 40 days, and in infrared after 42 days of treatment. Flowers opened in blue light after 48 days of treatment. The white control did not flower in this experiment so that it can be concluded that under the conditions of our experiment in white light a 12-hour photoperiod is not sufficient to induce flowering in this plant. Neither did the dark control nor the plants in green, yellow or red supplementary light develop flower buds or flowers. These results indicate that in this plant blue, violet and infrared regions of the spectrum actively promote flowering even when given as supplementary light *within a short day* which in white light does not induce flowering (Plate 1A).

In this experiment also elongation of the stem occurred in those plants that responded to the treatment with flowering. However, as is shown in fig. 1, in blue, violet and infrared elongation started almost immediately after the start of the experiment. Unfortunately, in these early stages no investigation of the growing point could be made, in order not to disturb the experiment by too great reduction of the number of plants.

When the data about stem elongation from this experiment are compared with those of previous experiments with 10 + 8 hours, the resemblance is striking, although there is the important difference in the behaviour of the controls in white light, which flower and elongate in a photoperiod of 10 + 8 hours, and stay vegetative, without stem elongation in a photo-

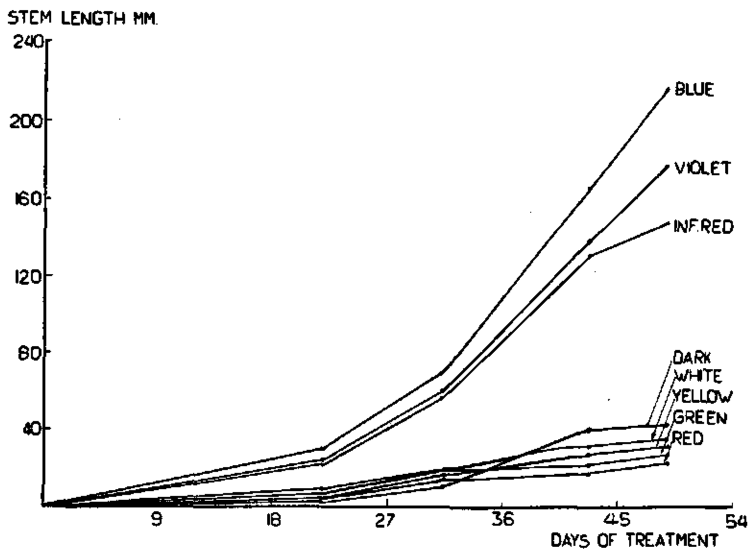

Fig. 1. Stem elongation in *Brassica Rapa* f. *oleifera* subf. *annua*, resulting from (8 + 4) treatment at an intensity of 1000 ergs/cm²/sec.

period of 8 + 4 hours (fig. 2, in which the 10 + 8 hours' curve has been taken from [1], fig. 1. From [1], fig. 1, it may be seen, moreover, that after 54 days, the elongation in white [and in infrared] still has strongly increased).

Photoperiodic and formative effects of (5 + 4) treatment. In view of the results obtained with the 8 + 4 hours experiment it seemed of considerable interest to attempt at a further restriction of the total photoperiod. An attempt to grow young plants in a 5 + 4 hours treatment was undertaken. This did not yield fully satisfactory results, because the total amount of light per day proved to be insufficient to produce vigorous plants. The plants grown in this photoperiod were rather weak while growth was rather poor, and some elongation of the stem occurred in all treatments, including the white and dark controls. Nevertheless, some interesting differences showed up. Plate 1B shows representative plants of this series 21 days after the beginning of the treatment. In this stage elongation is only observed in the plants receiving violet, blue or infrared additional irradiation.

In all kinds of irradiation flower primordia and even flower buds were finally produced, even in the dark controls. However, these primordia and flowerbuds died; only in the plants receiving violet, blue or infrared supplementary irradiation they developped normally into bigger flowerbuds which, however, did not open. The same behaviour was observed in a repetition of this experiment.

The stem length of these plants after 50 days of treatment is also included in fig. 2. It is shown that the resulting curve is similar to those obtained in the (10 + 8) series and in the (8 + 4) series. Differences only occur in the absolute values, especially in those treatments which did not

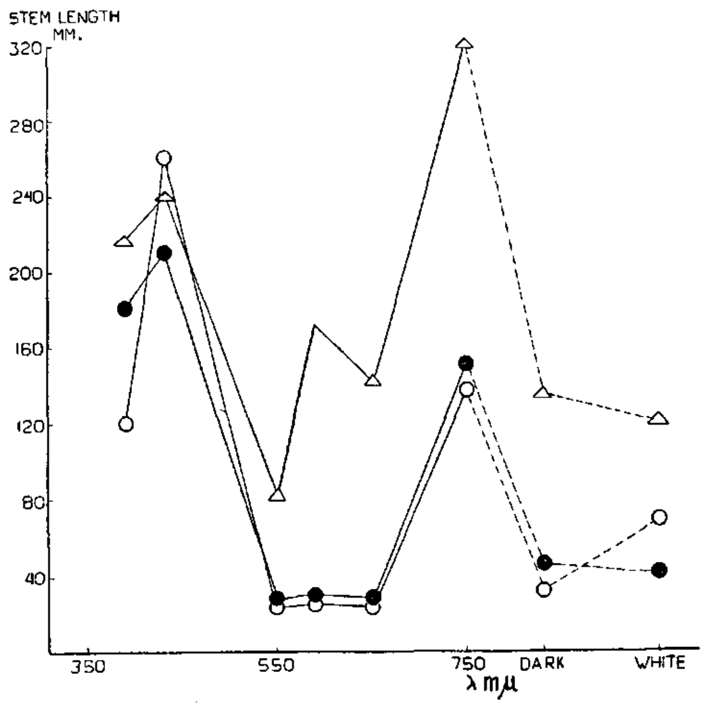

Fig. 2. Wavelength dependence of stem elongation in *Brassica Rapa* f. *oleifera* subf. *annua*, in treatments of 10 + 8 hrs (○, after 42 days), 8 + 4 hrs (●, after 48 days), 5 + 4 hrs (△, after 50 days); (10 + 8): measurements of 4-4-'50, taken from [1]; (8 + 4): measurements of 31-5-'50; (5 + 4): measurements of 6-3-'51.

result in elongation in the previous experiments. However, the elongation in blue supplementary light in the (5 + 4) experiment is about the same as that in the (8 + 4) experiment and far bigger than *e.g.* (8 + 4) white.

If it is assumed that all radiation of wavelengths < 5000 Å is effective in promoting elongation, it is of interest to compare the amounts of this radiation supplied to the (5 + 4) blue and to the (8 + 4) white plants, after the fifth hour of each cycle. It is then found that the (5 + 4) blue plants only receive about one third of the effective energy supplied to the (8 + 4) white plants. This calculation leads to suppose that other parts of the spectrum have an antagonistic effect.

Experiments with Cosmos bipinnatus Cav.

The seed for these experiments was obtained from plants which had reacted as short-day plants elsewhere.

Photoperiodic reaction. The first series received a (10 + 8) treatment. This treatment started 14 days after germination, when the plants had just expanded their first pair of leaves. The photoperiod before the start of the experiment was 18 hours. The intensity of the supplementary irradiation was 1000 ergs/cm²/sec. The number of plants in each alternative treatment was 9.

As is shown in Table 1, all wavelength regions were effective in either suppressing or retarding flowering. The flower buds formed in the plants

TABLE 1

Number of days from the beginning of (10 + 8) treatment at the intensity of 1000 ergs/cm²/sec. until development of macroscopical flower buds or flowers, in *Cosmos bipinnatus* CAV.

Treatment	Flower bud	Flower
White	> 67	—
Violet	47	> 67
Blue	54	> 67
Green.	> 67	—
Yellow	> 67	—
Red.	> 67	—
Infrared	43	> 67
Dark	28	42

receiving infrared additional radiation were very small and in many cases the plant developed a new vegetative shoot, whereas the terminal flower bud stopped development. Nevertheless, a distinct difference is observed between the group of colours: violet, blue, infrared and the group: white, green, yellow, red.

The results obtained led to another experiment in which the plants were exposed to intensities of 100, 500 and 1000 ergs/cm²/sec. in each colour. As is shown in Table 2, within the duration of the experiment flower buds developed in the plants receiving violet, blue and infrared additional irradiation only if the intensity of the irradiation was 500 ergs/cm²/sec. or less. This experiment was made with large plants, pretreated for a long time in 18 hours white light. Even at an intensity of only 100 ergs/cm²/sec. the green, yellow and red parts of the spectrum fully inhibit the formation

TABLE 2

Number of days from the start of (10 + 8) treatment until development of flower primordia and flower buds in *Cosmos bipinnatus* as related to intensity of supplementary light.

Treatment	1000 ergs/cm²/sec.		500 ergs/cm²/sec.		100 ergs/cm²/sec.	
	fl. prim.	fl. bud	fl. prim.	fl. bud	fl. prim.	fl. bud
White	—	—	—	—	—	—
Violet	53	—	*)	32	*)	29
Blue.	53	—	52	—	*)	50
Green	—	—	—	—	—	—
Yellow.	—	—	—	—	—	—
Red.	—	—	—	—	—	—
Infrared	47	—	*)	39	*)	32
Dark	flower buds after 28 days					

*): no observation; —: more than 53 days (end of the experiment).

of flower buds, whereas the blue, infrared and violet supplementary light have a retarding effect on flower bud formation. Contrary to what is found in *Brassica*, the retarding influence of the infrared in *Cosmos* may be due to the small amount of red light in the region of 7000 Å present in the infrared radiation [3]. It is clear that light of wavelengths between 5300 and 7000 Å is extremely effective in the inhibition of flowering in this plant.

The photoperiodic response of *Cosmos bipinnatus* to supplementary light in the various spectral regions is the reverse of that observed in *Brassica Rapa* var. In the latter case wavelengths between 5300 and 7000 Å were not effective at the low intensities as applied also in the experiment with *Cosmos*, whereas shorter and longer wavelengths were effective in prolonging the short day.

The difference observed corresponds to FUNKE's distinction between groups I and IV [4]. In group I, red behaved as "light", blue as darkness; in group IV, blue and red were reversed. The same ensues from a comparison of the results obtained with *Brassica* in [1] with the results on *Cosmos* reported in this paper. Curiously, the plants preparing flowering occur in the same spectral regions in both cases, only in *Brassica* they join "light", in *Cosmos* "darkness". It has to be investigated whether this is connected furthermore with the fact that *Brassica* is a long-day plant, *Cosmos* a short-day plant.

Formative effects of the supplementary light. It is especially evident that the length of the individual internodes differs greatly dependent on the quality of the supplementary irradiation. Fig. 3 illustrates this for a series of plants the general appearance of which is given in Plate 2 A. The values indicated in fig. 3 are averages of 9 plants, the lengths are indicated so that the oldest internode is at the left side, the youngest internode at the right side. The effect of the difference in inter-

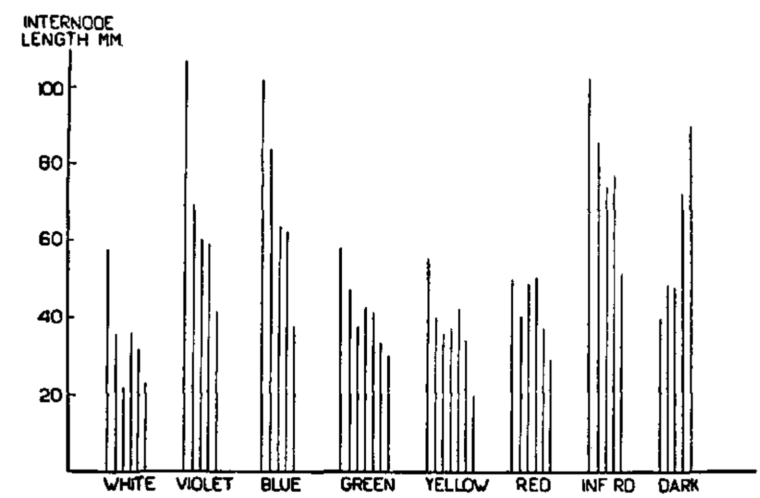

Fig. 3. Internode length in *Cosmos bipinnatus*, as affected by (10 + 8) treatment at an intensity of 1000 ergs/cm²/sec. after 56 days of treatment. Measurements of 13-6-'50.

node length on the total stem length, however, is somewhat compensated by the fact that the number of internodes is increased in those cases in which they are shorter (see fig. 3).

It is obvious that in blue, violet and infrared supplementary irradiation the internodes are much longer than those in white, green, yellow or red additional light. The younger internodes are relatively short in all cases because of the fact that they have not yet fully grown out. The behaviour of the dark control seems to be in contradiction with this, as these plants get longer internodes at the end. This, however, is due to the elongation of the flower stalk around the time of opening of the flower. In this case also the internode just beneath the flowerstalk is affected and elongates a bit.

It is curious to notice that in all cases where flower primordia or flower buds were developed, especially the youngest internodes elongate as compared with the vegetative plants. However, in our experiment there is no direct connection between elongation and formation of flower primordia, since elongation already starts long before the formation of flower primordia. This is especially evident from the length of the lower internodes in fig. 3, which by the time of measurement have already fully grown out. Fig. 3 was obtained from a measurement, 52 days after the start of the treatment. Only 9 days before, some plants from each spectral region were examined for flower primordia which then were only found in dark and infrared. In this period of nine days the total stem length in all colours increased smoothly, in blue and infrared, *e.g.*, from 31 to 41 cm, in white (the shortest ones) from 17 to 22 cm. Already 31 days after start of treatment the sequence in total stem length was the same as furtheron. In the dark series flower buds were macroscopically visible 28 days after the start of the treatment. Increased elongation of the upper internodes, in the dark series was found not earlier than between 31 and 43 days.

The elongating effect on the internodes in violet, blue and infrared remained of the same order when the intensity of the additional irradiation was reduced to 500 or 100 ergs/cm^2/sec. Fig. 4 shows the average length of the 2nd internode in one of the experiments. It is evident that the elongation cannot be considered as representing "etiolation", since the dark control does not show any elongation before the flower bud is opening. When all the regions of the spectrum are given together, as in the white controls, the plants neither show any elongation. This might be explained by assuming that besides the part of the spectrum (violet, blue and infrared) which actively promotes elongation, another part (green, yellow and red) inhibits it in some way. Of course these processes need not be directly related, and the mentioned assumption requires further investigation.

It was observed that whenever the plants had appreciable amounts of anthocyanins they were not going to flower. The plants receiving violet, blue or infrared additional radiation as well as the dark controls, had colourless to greenish stems, whereas the other plants had a certain amount of anthocyanins in the stem.

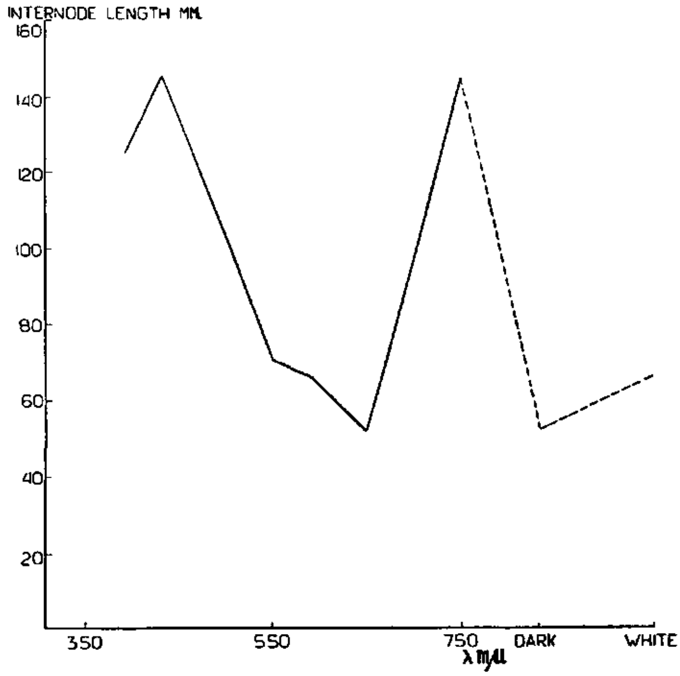

Fig. 4. Wavelength dependence of the length of the second internode in *Cosmos bipinnatus*. After 52 days; second 10 + 8 hrs experiment. Measurements of 23-2-'51.

Plate 2 A suggests that root development is rather different; in white, green, yellow and red it is much more profuse than in violet, blue, infrared and dark. This is only a preliminary observation which will have to be followed further.

Photoperiodic and formative effects of additional spectral irradiations within a short day. Also in the case of *Cosmos* we were interested in the behaviour of plants exposed to supplementary spectral irradiations within a 12-hour period. An 8 + 4 hours experiment was made.

In this case formation of flower buds was not restricted to special parts of the spectrum. The stemlength and especially the length of the separate internodes showed the same reaction to the various spectral regions as in the 10 + 8 hours series. Plate 4 A shows very clearly that the internodes in violet, blue and infrared are much longer than those in dark, white, green, yellow and red.

In the subsequent development the plants with short internodes formed a larger number of internodes, so that the differences in total stem length gradually became less pronounced.

The still somewhat scanty data collected until now indicate that under the conditions of this experiment, flowering was somewhat retarded in those wavelength regions in which stem elongation was promoted, so that the final aspect of flowering was somewhat contrary to the one observed in the 10 + 8 hours series.

It looks as if the consumption of matter in the elongation is prohibitive for the development of the flower, which may result from the rather low energy balance on which these briefly illuminated plants live.

Plates 2 B, 3 A, and 3 B give a survey of the plant material of this series. The length of the internodes in blue, violet, and infrared is obvious, as well as the somewhat retarded flowering in these cases.

Experiments with Lactuca sativa L., var. "Meikoningin"

The "Meikoningin" variety of *Lactuca sativa*, a long-day plant, has been submitted to a treatment of 10 + 8 hours, with supplementary light of the various spectral regions at an intensity of 1000 ergs/cm^2/sec. The treatment started 13 days after germination; in the period between germination and the beginning of the treatment the plants have been exposed to a photoperiod of 10 hours. Growing points of the experimental plants were examined after 43 and 69 days of treatment. Under our experimental conditions the plants failed to produce any flower primordia. As it was possible that the light intensity during the period of white light might have been too low for normal development, the experiment was repeated while the plants were placed in a greenhouse during the daily 10-hour period (in August). After this, 8 hours of supplementary light in the various spectral regions, followed by a 6-hour dark period completed the cycle. Because of this arrangement the conditions during the 10-hour white light period could not be controlled as usual, especially in regard to the temperature. The average temperature was about 23—25° C. After 48 days of treatment no flower primordia were observed. This behaviour of a variety which shoots very readily in a long day under field conditions is perhaps due to thermoperiodic requirements [5], which, at present, is under investigation.

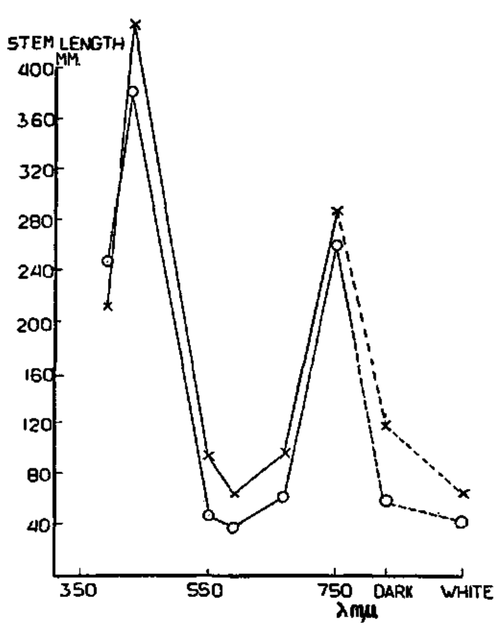

Fig. 5. Stem length in *Lactuca sativa* as dependent on wavelength of supplementary irradiation in a 10 + 8 hours experiment. After 49 (o, ordinates doubled) and 67 (×) days of treatment. Measurements of 6-6 and 24-6-'50.

Formative effects of the supplementary irradiation. The violet, blue and infrared supplementary irradiation resulted in strong elongation of the stem (*cf.* Plate 4B). In this case the separation of elongation from photoperiodic induction is very obvious. Fig. 5 shows the stem-length of this plant as affected by supplementary irradiation with various spectral regions. Elongation starts almost immediately after the beginning of the treatment, but is found neither in the plants receiving red, yellow or green supplementary irradiation nor in the dark and white controls. The elongation reminded very strongly of etiolation, as can be seen from Plate 4B. Since, however, also the dark control forms rosettes, the elongation in violet, blue and infrared cannot be due to etiolation. The elongating plants formed leaves at a slower rate than the non-elongating ones (Table 3) and the lower leaves died about as soon as new leaves expanded at the top

TABLE 3
Average number of leaves per plant as affected by supplementary light in *Lactuca sativa.* Averages of 5 plants per treatment.

Treatment	Number of days of treatment				
	8	15	22	29	35
White	5	7	9	13	25
Violet	5	6	7	7	14
Blue	5	6	8	9	18
Green	5	7	9	12	24
Yellow	5	7	9	12	25
Red	5	7	9	12	24
Infrared	5	6	7	9	14
Dark	5	7	10	13	20

of the plant. As can be seen from fig. 6 leaf length (leaf blade + petiole) was affected in much the same way as stem length.

Plate 4 B suggests that also in *Lactuca* elongation concurs with scanty root development. This observation has not yet been followed in greater detail.

Discussion

With a view to the general evidence on wavelength dependence of the photoperiodic reaction [6, 7, 8, 9, 10, 11] it should be remarked that our experiments with *Brassica Rapa* f. *oleifera* subf. *annua* are in accordance with FUNKE's statement that *Cruciferae* stand apart with respect to the wavelength dependence of their photoperiodic reaction. One might conclude that the first stage of the photoperiodic reaction, the light perception, has a mechanism different from that in most other plants. In view of the most striking resemblance between the pictures obtained for the three widely different plants studied in the present investigation, however, it seems more tempting to assume that in the various types of plants the perception mechanism is similar, whereas the divergence of the ultimate result is initiated only in a further stage of the reaction chain.

The photoperiodic reaction of *Cosmos bipinnatus* to supplementary light of different wavelength regions is in accordance with the action spectrum for photoperiodic control of floral initiation in cocklebur, soybean, barley and *Hyoscyamus niger* as worked out by BORTHWICK and

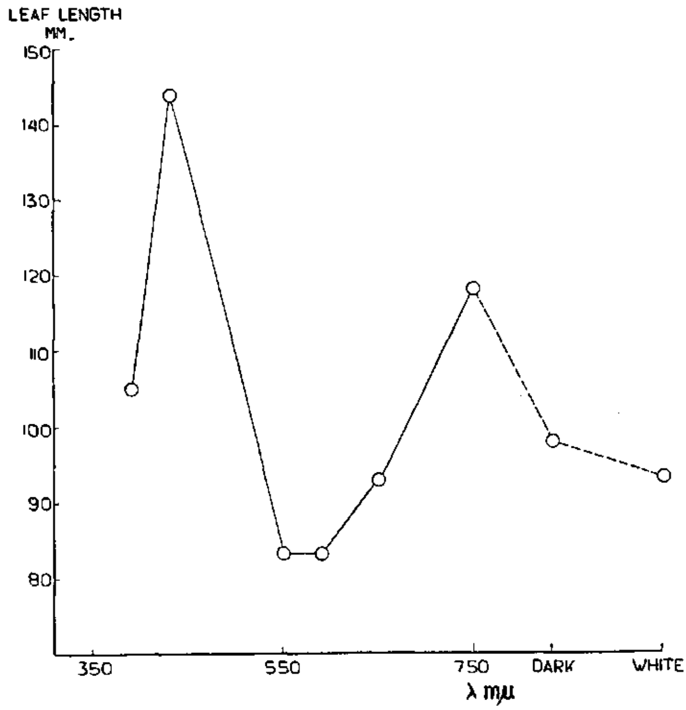

Fig. 6. Leaf length in *Lactuca sativa* as affected by (10 + 8) treatment. Supplementary light of various wavelengths at an intensity of 1000 ergs/cm²/sec. after 24 days of treatment. Measurements of 12-5-'50.

PARKER, *c.s.* [9, 10, 11]. A comparison of *e.g.* the 8 + 4 white and 5 + 4 blue series in *Brassica* suggests that the red, yellow and green parts of the spectrum have an antagonistic effect on the activity of the violet, blue and infrared. This assumption also applies for the elongation of the stem in *Cosmos bipinnatus* and *Lactuca sativa,* since in these cases the stem elongation in the lower internodes when the plants still are vegetative does not occur in the white and dark controls.

The elongation is promoted by blue, violet and infrared. When, however these wavelength regions are given together with the rest of the spectrum to obtain white light, the elongating influence does not occur. The experiment with *Lactuca sativa* and the behaviour of the lower internodes in *Cosmos* show that in these cases stem elongation can occur apart from photoperiodic induction.

Summary

Brassica Rapa L. f. *oleifera* subf. *annua* has been exposed to supplementary irradiation of various wavelength regions within a short day

which in white light is not sufficient to bring about flowering. In this experiment, in which supplementary light was given for 4 hours (1000 ergs/cm^2/sec.) subsequent to an 8 hours day in strong artificial white light (TL tubes $\sim$ 35000 ergs/cm^2/sec.) the plants flowered in the same wavelength regions as in the long-day experiment, *viz.* in violet, blue and infrared. However, the white control now remained vegetative. Also the stem elongation shows exactly the same wavelength dependence as in the long day.

In *Cosmos bipinnatus* Cav. the red, yellow and green parts of the spectrum are most effective in suppressing flowering when given supplementary (8 hours) to a short day in strong artificial white light (10 hours). Violet, blue and infrared irradiation have an elongating effect upon the length of the internodes of this plant, which seems independent of flowering.

With *Cosmos* also a short-day series has been run (8 hours white light + 4 hours supplementary coloured light) followed by 12 hours darkness). The length of the internodes was similar to that observed in the long-day series. All plants developed flowers, remarkably most quickly in the plants with short internodes, so in the colours which prevent flowering in the long day. A certain competition between flowering and elongation was manifest.

Lactuca sativa L., the long-day variety "Meikoningin" was exposed to 10 hours white light (35000 ergs/cm^2/sec.) and 8 hours supplementary coloured light (1000 ergs/cm^2/sec.). The plants remained vegetative in all cases. However, considerable elongation occurred in blue, violet and infrared additional illumination. White and dark remained short.

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REFERENCES

1. Wassink, E. C., C. M. J. Sluysmans and J. A. J. Stolwijk, Proc. Kon. Ned. Akad. v. Wetensch. Amsterdam **53**, 1466–1475 (1950).
2. Stolwijk, J. A. J., Hand. 32nd Ned. Nat. Geneesk. Congr. Preprint, 17–18 (1951).
3. Wassink, E. C. and C. van der Scheer, Proc. Kon. Ned. Akad. v. Wetensch. Amsterdam **53**, 1064–1072 (1950).
4. Funke, G. L., *in* Murneek and White, Vernalization and photoperiodism, Lotsya **1**, p. 79–82, Waltham, (Mass., 1948).
5. Richards, A. A., The Grower **35**, 70–73 (1951).
6. Withrow, R. B., and H. M. Benedict, Plant Physiol. **11**, 225–249 (1936).
7. ——— and J. P. Biebel, Plant Physiol. **11**, 807–819 (1936).
8. Katunsky, V. M., Compt. Rend. (Doklady) de l'Ac. d. Sci. de l'URSS **15**, 509–512 (1937).
9. Parker, M. W., S. B. Hendricks, H. A. Borthwick and N. J. Scully, Bot. Gaz. **108**, 1–26 (1946).
10. Borthwick, H. A., S. B. Hendricks and M. W. Parker, Bot. Gaz. **110**, 103–118 (1948).
11. Parker, M. W., S. B. Hendricks and H. A. Borthwick, Bot. Gaz. **111**, 242–252 (1950).

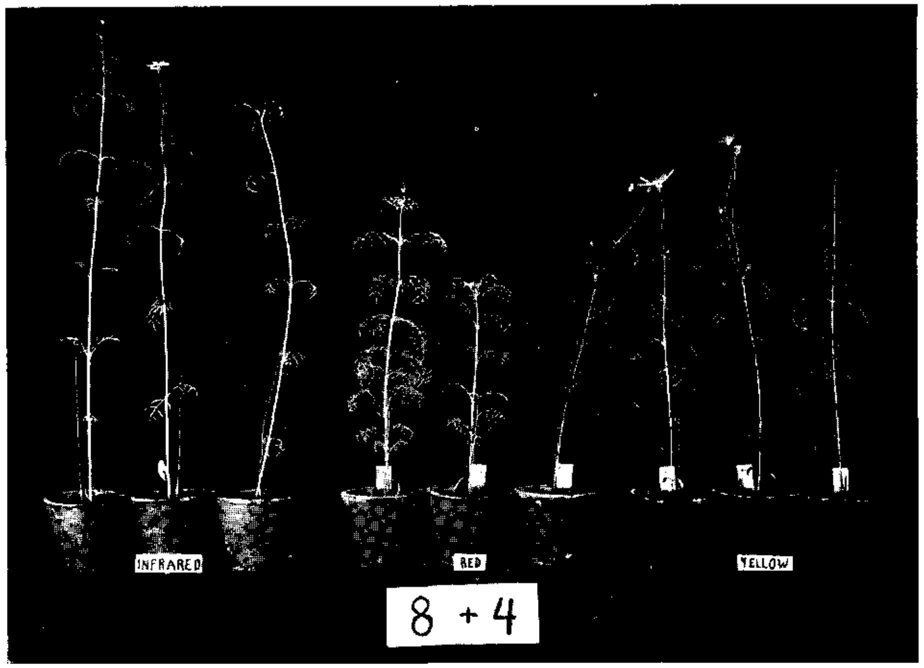
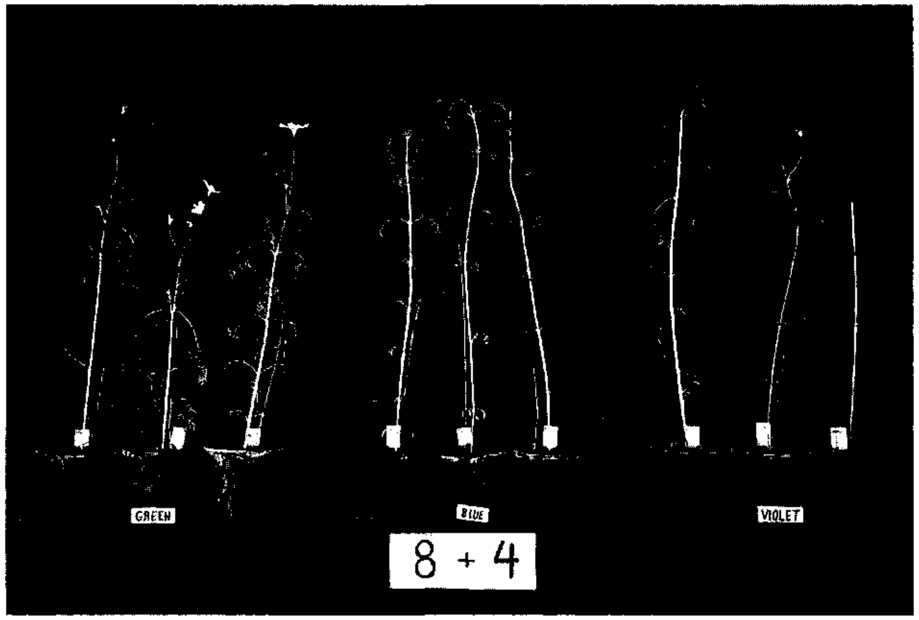


Plate 3. *Cosmos bipinnatus* exposed to light of various wavelength regions in (8 + 4) treatment. Intensity of supplementary light 1000 ergs/cm²/sec. Photographs of 14-4-'51, after 60 days of treatment (*cf.* also Plate 2B).



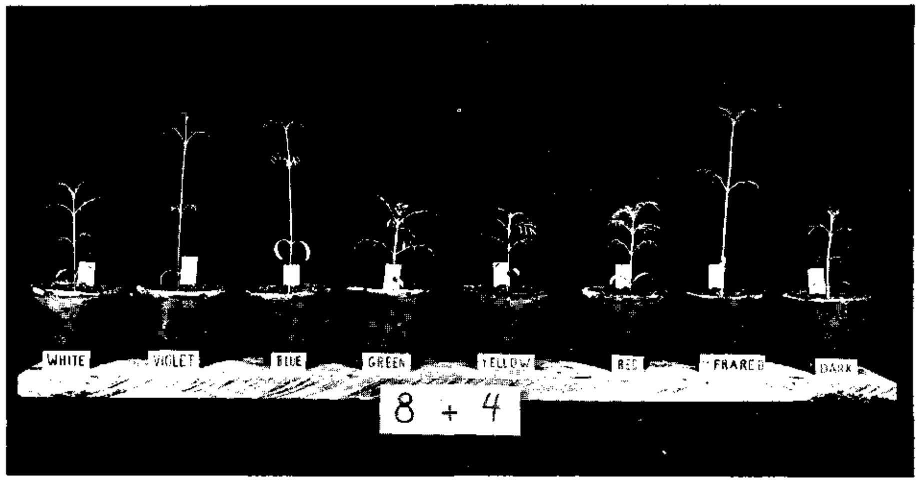


Plate 4A. The same plants as on Plates 2B and 3, after 21 days of (8 + 4) treatment with various spectral regions. Photograph of 6-3-'51.

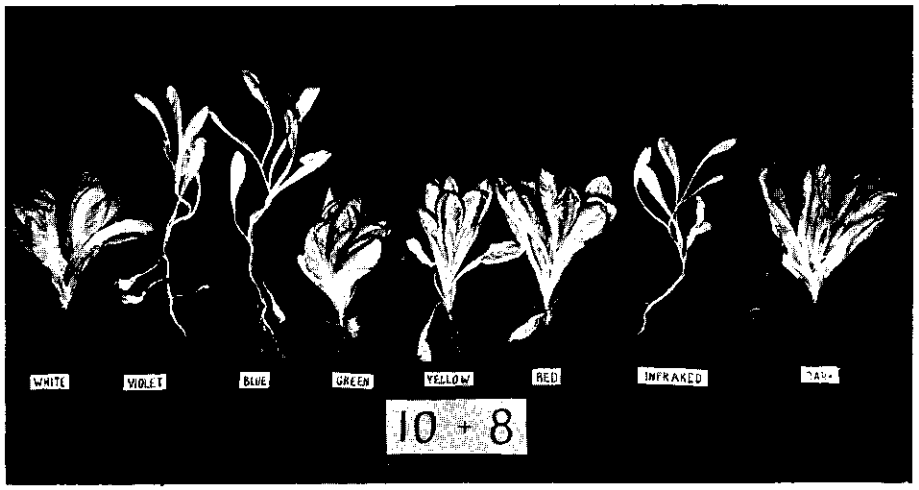


Plate 4B. *Lactuca sativa* exposed to light of various wavelength regions in (10 + 8) treatment. Intensity of supplementary light 1000 ergs/cm²/sec. Photograph of 13-6-'50 after 56 days of treatment.

E. C. WASSINK, J. A. J. STOLWIJK AND A. B. R. BEEMSTER: *Dependence of formative and photoperiodic reactions in* Brassica Rapa *var.,* Cosmos *and* Lactuca *on wavelength and time of irradiation.*

Plate 1A. *Brassica Rapa* f. *oleifera* subf. *annua* exposed to light of various wavelength regions in (8 + 4) treatment. Intensity of supplementary light 1000 ergs/cm²/sec. Photograph of 13-6-'50, after 56 days of treatment.

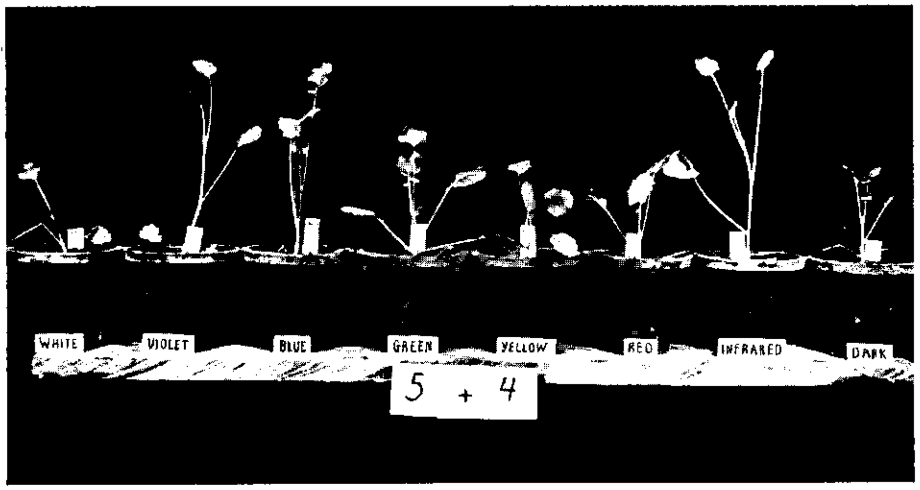


Plate 1B. *Brassica Rapa* f. *oleifera* subf. *annua* exposed to light of various wavelength regions in (5 + 4) treatment. Intensity of supplementary irradiation 1000 ergs/cm²/sec. Photograph of 6-3-'51, after 21 days of treatment.

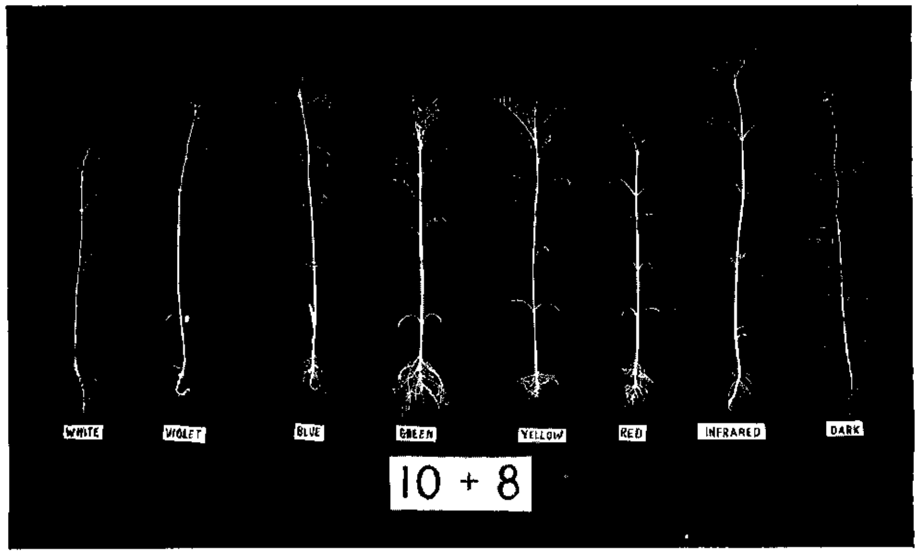


Plate 2A. *Cosmos bipinnatus* exposed to light of various wavelength regions in (10 + 8) treatment. Intensity of supplementary light 1000 ergs/cm²/sec. Photograph of 31-5-'50 after 43 days of treatment. (Plate slightly touched up by the printer).

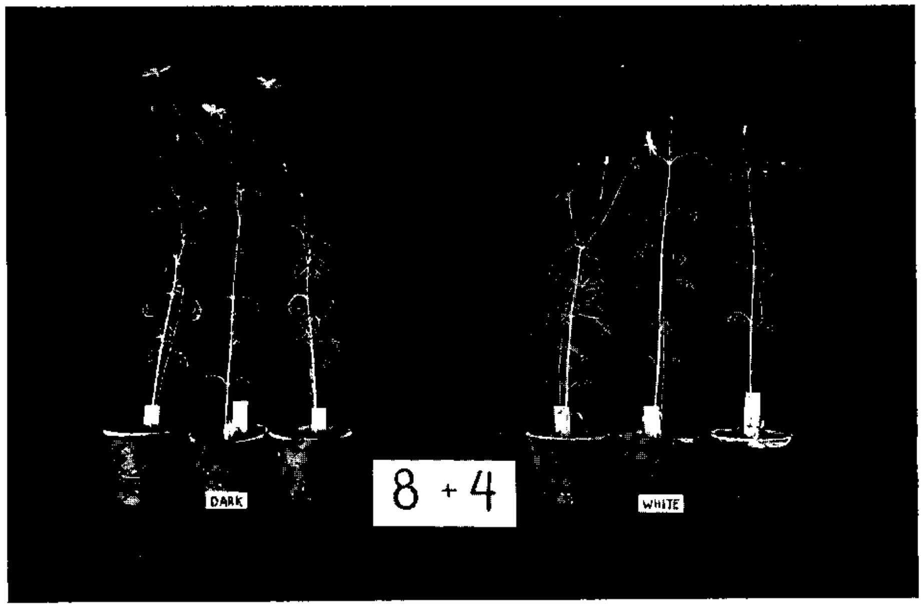


Plate 2B. *Cosmos bipinnatus* exposed to light of various wavelength regions in (8 + 4) treatment. This Plate contains the white and dark controls. Intensity of supplementary light 1000 ergs/cm²/sec. Photograph of 14-4-'51 after 60 days of treatment (*cf.* also Plate 3).