RAPID GROWTH INHIBITION OF GHERKIN HYPOCOTYLS IN BLUE LIGHT[1]

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SUMMARY

The elongation of dark-grown gherkin hypocotyls has been recorded continuously in darkness and on exposure to blue, red or far-red light. Evidence was obtained that the inhibition of elongation in blue light is not mediated by the phytochrome and "high energy reactions" but that a specific blue-light absorbing pigment is involved.

1. INTRODUCTION

Investigations into the spectral dependence of photomorphogenetic effects have shown that there are 3 active spectral regions: blue (B, 400–500 mμ), red (R, 600–700 mμ) and far-red (FR, 700–750 mμ) light. The effects of red light are mainly mediated by the transfer of P_R, the red-light absorbing form of the pigment phytochrome, into the far-red-light absorbing form P_{FR}. If, after exposure to red light ($P_R \xrightarrow{R} P_{FR}$), far-red light is given, the P_{FR} is reversed into P_R, the red-light effect being largely prevented. The effects of blue and of far-red light have been interpreted in 2 different ways. HENDRICKS *c.s.* (1959a, b) originally suggested that the response to blue and far-red light was also mediated by phytochrome *(scheme, Ia)*. This suggestion was made more plausible after BUTLER *c.s.* (1964) had presented the absorption spectra of both forms of phytochrome. P_R has, in addition to a maximum in red, some absorption in the blue and the far-red regions also. In addition to a maximum in far red, P_{FR} also shows some absorption in the red and blue-light regions. BUTLER *c.s.* (1963) have shown that far-red light indeed slightly shifts $P_R \rightarrow P_{FR}$. It has been reported occasionally that the photomorphogenetic effect of blue light can be nullified by a subsequent irradiation with far red (BERTSCH 1963) and that the effect of red light can be prevented by a following exposure to blue light (MEYER 1958, 1959).

Recently, however, HENDRICKS mentioned in a letter (1966) that experiments with *Hyoscyamus* gave evidence of a specific blue, far-red-sensitive reaction *(scheme, Ib)* with a corresponding pigment absorbing in the blue and far-red regions. Some authors *(schemes IIa & III)* postulated that in addition to a phytochrome reaction, a blue, far-red-light-sensitive reaction, not effectuated by phytochrome, was probable. After BUTLER showed that far-red light may cause a shift of $P_R \rightarrow P_{FR}$, some of them have now adopted the view that the effects of the blue and far-red spectral regions *(scheme IIb*, HARTMANN 1966; WAGNER & MOHR 1966), or at least those of the far-red region *(scheme IIb,*

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Scheme Interpretation of photoreactions

a: 10 years ago b: now	Red light	Blue light	Far-red light
Ia	Phytochrome	Phytochrome	Phytochrome
Ib	Phytochrome	Blue, far-red light-sensitive reaction	
IIa	Phytochrome	"High energy reaction" (MOHR) = "Prolonged-exposure reaction" (VINCE) = "Blue, far-red-light-sensitive reaction" (MEIJER)	
IIb	Phytochrome	Phytochrome	Phytochrome
or			
	Phytochrome	?	Phytochrome
IIIa	Phytochrome	"Blue, far-red-light-sensitive reaction"	
IIIb	Phytochrome	Blue-light-sensitive reaction	Far-red sensitive reaction (Phytochrome)
and			
		"Blue, far-red-light-sensitive reaction".	

WAGNER & MOHR 1966) are brought about by a shift of $P_R \rightarrow P_{FR}$. Results of some experiments have been interpreted in this way (VINCE & GRILL 1966); ROLLIN & MAIGNAN 1966, 1967) but other explanations, not based on changes of the state of phytochrome, still remain possible. By recording the elongation of dark-grown gherkin hypocotyls in darkness and on exposure to light evidence is obtained that a specific photoreaction confined to the blue part of the spectrum exists.

2. MATERIAL AND METHODS

Gherkin seedlings *(Cucumis sativus*, "Venlose niet plekkers", strain Tercken VI) were grown in darkness at 25 °C and were used three days after sowing, the length of the hypocotyls then being 25–30 mm.

Irradiation was carried out in light cabinets with light of different spectral regions, the characteristics of which have been given before (MEIJER 1957, 1965). The temperature was maintained at 25 °C, the air humidity at 80%.

Growth was recorded with the aid of a modified displacement pick-up (PR 9310/01) in combination with a measuring bridge (PR 9300) and a recorder *(fig. 1)* The growing hypocotyl moves a core in a magnetic field induced by a primary coil. The displacement of the core changes the induction of the two secondary coils differentially. The weight of the core is compensated for the greater part by a spring and varies from 80 mg (lowest position) up to 85 mg (highest position). The measurements are linear for a displacement of 1 mm only. At the end of the scale (1 mm displacement = 250 mm full scale) the

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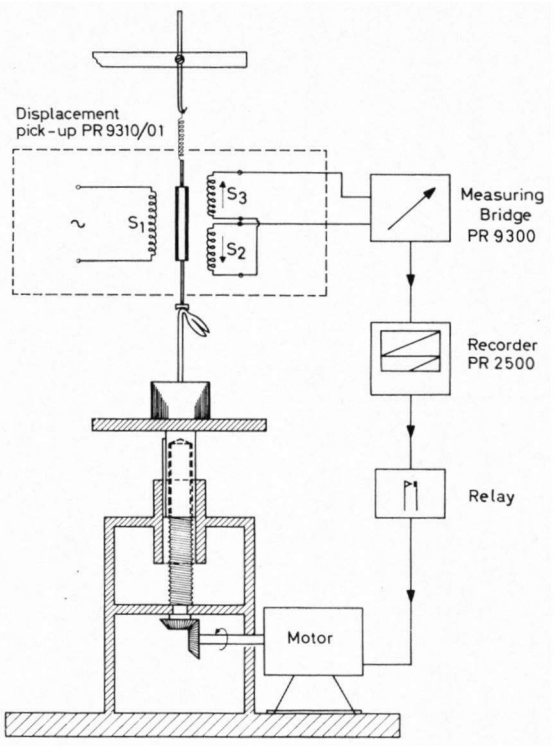

Fig. 1. Apparatus for recording growth continuously.

recorder pen switches on a motor. The table on which the plant is fixed moves down over 1mm, the motor is switched off when the recorder pen reaches the beginning of the scale. In this way growth can be recorded for a longer period.

3. RESULTS

The results of 3 experiments are given in *figs. 2* and *3*. As can be seen in *fig. 2*, the blue light inhibits the elongation instantly and the decrease in growth rate *(fig. 3)* is very fast. The inhibition by red and by far red, on the contrary, shows a lag period and in both cases the drop in growth velocity occurs more gradually.

Higher and lower light intensities did not change the results qualitatively. The ultimate inhibition of the growth rate diminished with decreasing light intensities.

4. CONCLUSION

As early as 1922 KONINGSBERGER studied light growth reactions of Avena coleoptiles in relation to phototropism. The time needed for a certain elongation was recorded and the growth rate calculated. With the low light intensities

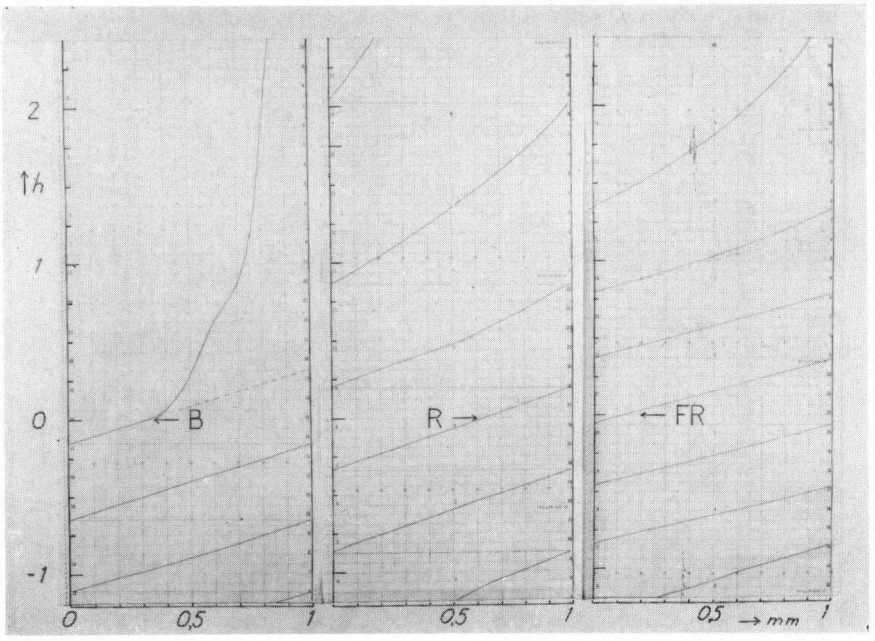

Fig. 2. Records of the elongation of dark-grown gherkin seedlings in darkness and on exposure to light (←) of the blue (500 μW/cm²), the red (600 μW/cm²) and of the far-red (600 μW/cm²) region. Ordinate: time in hours, abscissa: length in mm.

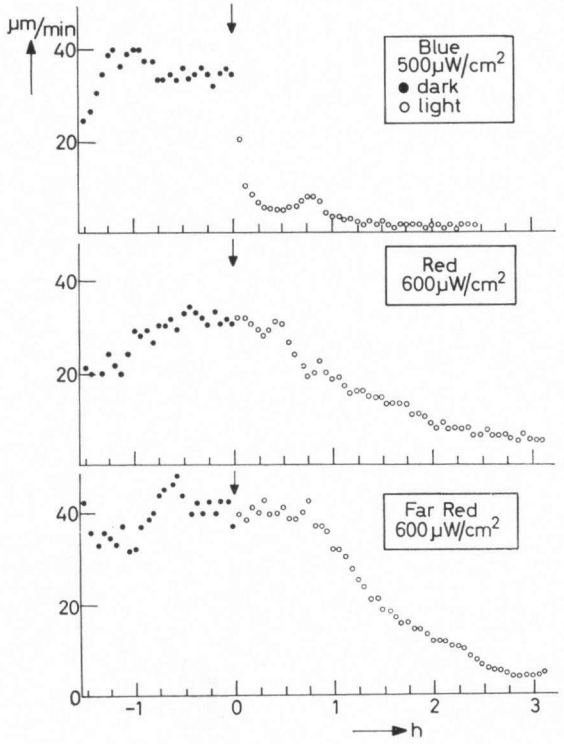

Fig. 3. Growth rate in μm/min of dark-grown gherkin hypocotyls in darkness and on exposure to light (↓) calculated from the curves in fig. 2 (per 3¾ min).

used, it was found that only light of shorter wavelength regions (400–620 mμ) and far red (700–800 mμ) decreased the growth rate of dark grown coleoptiles. Red light (620–700 mμ) did not show any significant activity. In addition, after passing a minimum in about 36 minutes (or 70 minutes in light of 440–460 mμ) the growth rate gradually increased. The length of the lag period cannot accurately be determined from the curves presented. It appears, however, that the lag period for far-red light is about the same as for light of 440–460 mμ (20–30 minutes) which is longer than for light of 420–440 mμ and of 460–480 mμ. It was concluded that the Avena coleoptile is more sensitive to light of shorter wavelength than to light of longer wavelength.

The differences between these results and those presented in the present paper (sensitivity to red light, restoration of growth rate) may be due to differences in organs used (coleoptile versus hypocotyl) and other experimental conditions.

By means of time-lapse photography GALSTON *c. s.* (1964) have shown that the lag for a temporary decrease in growth rate of etiolated pea seedlings induced by red light is about 6 hrs.

The growth records of the gherkin hypocotyl show clearly that the activity of blue light is not effectuated in the same way as the activities of red and of far-red light. The "High-energy reaction" ("Prolonged-exposure reaction"), depending very much on the length of irradiation, is certainly not involved, as in this case the plant reacted instantly.

We may conclude that in the photoinhibition of the growth of the gherkin hypocotyl a distinct, blue-light absorbing pigment is involved, in addition to the "phytochrome reactions" $P_R \xrightarrow{red} P_{FR}$ and possibly $P_R \xrightarrow{far\ red} P_{FR}$. The results do not permitany conclusion as to whether the effect of far-red light is mediated by phytochrome or not.

In this connection it may be mentioned here that EVANS *c.s.* (1964) have shown that lettuce seedlings older than 60 hours had lost their sensitivity to far-red light but that the inhibiting effect of blue light still existed.

It is possible, however, that a "blue, far-red reaction" (MEIJER & ENGELSMA 1965) and a specific far-red reaction are involved as well *(scheme III)*. This assumption is supported by the spectral dependence of light-controlled leaf movement of *Mimosa pudica*. FONDEVILLE *c.s.* (1967) have shown that at least three photoreactions, mediated by phytochrome, a blue, far-red absorbing pigment (or two different pigments) and a blue-light absorbing pigment are involved.

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REFERENCES

BERTSCH, W. F. (1963): The photoinhibition of growth in etiolated stem segments. III. Far-red reversibility of blue light effects in Pisum. *Am. Journ. Bot.* **50**: 754–760.

BUTLER, W. L., H. C. LANE & H. W. SIEGELMAN (1963): Nonphotochemical transformations of phytochrome in vivo. *Plant Physiol.* **38**: 514–519.

—, S. B. HENDRICKS & H. W. SIEGELMAN (1964): Action spectra of phytochrome in vitro. *Photochem. Photobiol.* **3**: 521–528.

EVANS, L. T., S. B. HENDRICKS & H. A. BORTHWICK (1965): The role of light in suppressing hypocotyl elongation in lettuce and Petunia. *Planta* **64**: 201–218.

FONDEVILLE, J. C., M. J. SCHNEIDER, H. A. BORTHWICK & S. B. HENDRICKS (1967): Photocontrol of Mimosa pudica L. leaf movement. *Planta* **75**: 228–238.

GALSTON, A. W., A. A. TUTTLE & P. J. PENNY (1964): A kinetic study of growth movements and photomorphogenesis in etiolated pea seedlings. *Am. Journ. Bot.* **51**: 853–858.

HARTMAN, K. M. (1966): A general hypothesis to interprete "high energy phenomena" of photomorphogenesis on the basis of phytochrome. *Photochem. Photobiol.* **5**: 349–366.

HENDRICKS, S. B. & H. A. BORTHWICK (1959): Photocontrol of plant development by the simultaneous excitation of two interconvertible pigments. *Proc. Nat. Acad. Sci.* **45**: 344–349.

— E. H. TOOLE, V. K. TOOLE & H. A. BORTHWICK (1959): Photocontrol of plant development by the simultaneous excitation of two interconvertible pigments. III. Control of seed germination and axis elongation. *Bot. Gaz.* **121**: 1–8.

KONINGSBERGER, V. J. (1922): Tropismus und Wachstum. *Rec. trav. bot. néerl.* **19**: 1–138.

MEIJER, G. (1957): The influence of light quality on the flowering response of Salvia occidentalis. *Acta Bot. Neerl.* **6**: 395–406.

— (1958): Influence of light on the elongation of gherkin seedlings. *Acta Bot. Neerl.* **7**: 614–620.

— (1959): The spectral dependence of flowering and elongation. *Acta Bot. Neerl.* **8**: 189–246.

— & G. ENGELSMA (1965): The synergistic influence of a pre-irradiation on the photoinhibition of gherkin seedlings. *Photochem. Photobiol.* **4**: 251–258.

MOHR, H. (1957): Der Einfluss monochromatischer Strahlung auf das Längenwachstum des Hypocotyls und auf die Anthocyanbildung bei Keimlingen von Sinapis alba L. *Planta* **49**: 389–405.

ROLLIN, P. & G. MAIGNAN (1966): La nécessité du phytochrome $P_{rl}(= P_{730})$ pour la germination des akènes de Lactuca sativa L. variété "Reine de Mai". *C.R. Acad. Sc. Paris* **263** D: 756–759.

— & — (1967): Does phytochrome act in the photoinhibition of germination? *Nature* (Lond.) in press.

VINCE, D. & R. GRILL (1966): The photoreceptors involved in anthocyanin synthesis. *Photochem. Photobiol.* **5**: 407–411.

WAGNER, E. & H. MOHR (1966): Kinetic studies to interpret "High-energy phenomena" of photomorphogenesis on the basis of phytochrome. *Photochem. Photobiol.* **5**: 397–406.

— & — (1966): "Primäre" und "sekundäre" Differenzierung im Zusammenhang mit der Photomorphogenese von Keimpflanzen (Sinapis alba L). *Planta* **71**: 204–221.