PHYSIOLOGY

ON THE EFFECT OF LIGHT OF VARIOUS SPECTRAL REGIONS ON THE SPROUTING OF POTATO-TUBERS

BY

E. C. WASSINK, N. KRIJTHE [1]) AND C. VAN DER SCHEER

(From the Laboratory of Plant Physiological Research, Agricultural University, Wageningen)

(Communicated by Prof. A. J. KLUYVER at the meeting of June 24, 1950)

Introduction.

It is well-known that potato-tubers, some time after being harvested, develop long sprouts in darkness at suitable temperatures. It has been known since a long time that in light, already at low intensities, the length of the developed sprouts is strongly decreased (1, 2, 3). In practice, this knowledge has been applied by the construction of store-houses with windows. In view of storage of potatoes in cellars and other rooms with artificial illumination, it was of importance to know something about the spectral sensitivity of the mentioned effect in relation with the choice of the most suitable light sources.

Moreover, a study of the sensitivity of the sprouting appeared of considerable physiological interest. The observation that light inhibits sprouting indicates that a photochemical process is at the base of the observed effect, and it appeared required to attempt an identification of the pigment, active as light absorber. Since stored potatoes do not contain large, obviously manifest amounts of pigments, which might, beforehand, be visualized as responsible for photochemical activities, it is probable that the photoactive pigment is present only in small amounts, and that the process is of of the 'stimulus' type, *i.e.*, that the energy for the reaction is for the greater part energy derived from the cell, directed only by a small amount of light energy (4).

In connection with experiments on the influence of temperature on sprouting of potatoes (5), the second author, in 1947, made some observations on inhibition of sprout elongation using a 'red' and a 'blue' fluorescent tube, and a HPW 75W (high pressure mercury vapour lamp) with Wood's glass bulb, transmitting chiefly ultra violet light. The 'red' and the 'blue' light were found to be more active in inhibiting the growth of the potato-sprouts than the ultra violet.

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[1]) "C.I.L.O."-Research Worker, stationed in the Laboratory of Plant Physiol. Res.

Preliminary observations along another line, using different light qualities, obtained by glass filters were made by the first mentioned author in collaboration with DR R. VAN DER VEEN, who published some preliminary results (6). A more detailed study, however, appeared worth while.

Observations and Discussion.

A first series was started in the equipment described (7). In each compartment 6 horizontal gauze plates were mounted, much like a staircase, yielding different intensities. The intensities as measured are collected in Table I, in which also the amounts of energy at wave lengths below 1 μ are indicated.

TABLE I

Energies incident upon the respective gauze plates (1—6) in the various compartments. A: radiation with wavelength $< 3\,\mu$; B: radiation with wavelength $< 1\,\mu$.

A

	1	2	3	4	5	6
violet	1150	600	450	250	120	60
blue	2850	1600	1500	750	250	100
green	3700	2000	1200	630	250	100
yellow.	10000	5400	2900	1450	540	160
red	4500	2750	1650	900	325	100
infrared	7500	3950	2750	1500	750	300

B

	1	2	3	4	5	6
violet	805	420	315	175	84	42
blue	2622	1472	1380	690	230	92
green	3108	1680	1008	529	210	84
yellow.	5000	2700	1450	725	270	80
red	3825	2337	1402	765	276	85
infrared	2100	1106	770	420	210	84

The light intensity was measured at each gauze plate in the various compartments, with the aid of a selenium photronic cell, calibrated for each spectral region. For the infrared region a standardized thermopile was used. It has been shown in (7) that none of the radiations used was completely free from infrared of wavelengths beyond 1 μ. In some compartments, *e.g.*, yellow and infrared, the amount of this radiation was considerable. Its magnitude was established as expounded in (7); for the greater part, probably, it may be considered as photochemically inactive in the process studied (*cf.* below). Moreover, some compartments contained radiation which was not the one desired, but which could not be considered to be inactive. This held especially for violet and red which contained a non-negligible amount of radiation between ~ 0.7 and 1 μ. It must be considered as "impurity" of our spectral light, and as an inadequacy still inherent in our present experiments, which we hope to master more completely in the near future.

Experiments are now in progress to check the activity of the radiation $> 1\,\mu$ directly.

On each gauze plate 30 tubers of the same size-class of the early potato variety 'Eersteling' were exposed to the light. The tubers had been de-sprouted once and had been stored at 2° C. A dark control was added. The experiment was started Nov. 11, 1949. The temperature was 17° C, the light burnt continuously. Temperature readings in the compartments were taken twice a day; at each reading they did not differ more than 1° C for 5 of 6 gauze plates (the upper one excepted) in all compartments. A small ventilator in each compartment caused air circulation. On Dec. 6, Dec. 20, 1949 and Jan. 3, 1950, 10 tubers of each plate were examined, and the sprouts measured. In Table II, the length of the longest sprout,

TABLE II

Sprout lengths in mm (longest sprout, average of 10 tubers) at various dates reached upon the irridiations summarized in Table I. Start of the experiment: Nov. 11, 1949.

6.12.'49	1	2	3	4	5	6	dark
violet	11.3	11.5	11.4	12.6	13.6	16.4	
blue	10.8	11.7	11.1	13.0	12.2	14.8	
green	16.0	20.7	26.2	29.5	36.9	48.1	200.0
yellow	19.7	22.6	34.1	39.0	44.4	40.5	
red	9.8	10.2	10.0	10.5	11.0	11.2	
infrared	8.8	10.8	11.2	11.2	11.7	11.6	
20.12.'49							
violet	15.0	17.0	16.1	17.8	17.1	38.4	
blue	15.1	14.3	16.9	15.8	19.0	18.9	
green	39.8	40.2	62.1	106.9	104.2	124.8	400.0
yellow	35.5	49.5	54.8	79.1	92.3	98.7	
red	12.6	14.6	14.0	15.0	14.2	15.2	
infrared	12.3	13.4	14.2	13.2	15.1	15.2	
3.1.'50							
violet	19.3	22.7	22.0	22.7	33.6	75.3	
blue	21.6	20.8	21.1	23.0	23.7	35.4	
green	63.0	88.5	113.0	15.5	15.9	20.8	680.0
yellow	56.0	62.0	99.2	131.0	130.0	166.0	
red	18.2	19.7	18.6	20.6	21.0	26.3	
infrared	16.5	18.6	17.5	18.3	22.1	22.3	

taken as a measure, averaged over 10 tubers, is recorded in mm. Photographs of representative tubers are presented on Plate 1 (one tuber of each gauze plate, decreasing intensity from bottom to top of the photograph).

It is seen that all of the intensities used in violet, blue, red and infrared yield a nearly complete suppression of sprouting. Only the last harvest shows slightly weaker inhibition in the lowest intensities blue and violet; nevertheless, the procentual inhibition does not decrease considerably. Yellow and green, in the intensities used, show longer sprouts but also here, the weakest inhibition still is of the order of 70 % (*cf.* Table III,

TABLE III
Percentage inhibition of sprouting (as compared with dark control) by exposure to various radiations. Experiment started Nov. 11, 1949.

6.12.'49	1	2	3	4	5	6
violet	94.3	94.2	94.3	93.7	93.2	91.8
blue	94.6	94.1	94.4	93.5	93.9	92.6
green	92.0	89.6	86.9	85.2	81.5	75.9
yellow.	90.1	88.7	82.9	80.5	77.8	79.8
red	95.1	94.9	95.0	94.7	94.5	94.4
infrared	95.6	94.6	94.4	94.4	94.1	94.2
20.12.'49						
violet	96.2	95.7	96.0	95.5	95.7	90.4
blue	96.2	96.4	95.8	96.0	95.2	95.3
green	90.0	89.9	84.5	73.3	73.9	68.8
yellow.	91.1	87.6	86.3	80.2	76.9	75.3
red	96.8	96.3	96.5	96.2	96.4	96.2
infrared	96.9	96.6	96.4	96.7	96.2	96.2
3.1.'50						
violet	97.2	96.7	96.8	96.7	95.0	88.9
blue	96.8	96.9	96.9	96.6	96.5	94.8
green	90.7	87.0	83.4	77.2	76.6	69.4
yellow.	91.8	90.9	85.4	80.7	80.9	75.6
red	97.3	97.1	97.3	97.0	96.9	96.1
infrared	97.6	97.3	97.4	97.3	96.7	96.7

showing the percentage inhibition of sprouting). In order to evaluate the inhibiting effect of the various regions the experiment has to be extended to lower intensities or shorter exposures which is now in progress.

The preliminary results shown reveal a few interesting facts. First, the activity of the red region of the spectrum may be deemed to rule out the possibility that a carotenoid is the photosensitive pigment. The weaker action of yellow and green, as compared with red, blue and violet would be in accordance with the assumption that a chlorophyllous pigment is in play. If this is true, it must, already in low concentrations, be able to cause the observed effect, since only during harvesting, the tubers may have been exposed to light, and, accordingly, showed only very slight amounts of chlorophyll. In the colours violet, blue, green, yellow, and red, however, considerable amounts of chlorophyll are formed both in the tubers and in the sprouts during the expositions (*cf.* Table IV, fig. 1.).

The determinations of chlorophyll were made separately in the tubers and the sprouts. Of each group 4 discs, 15 mm in diameter and 3 mm thick out of the surface part of the tuber, and 3 sprouts of comparable size and known weight were extracted. The tissues were killed in boiling water, and extracted till colourless in 25 cc ethanol 90 % at 60° C. The optical density of the extracts was determined with a "lumetron, model 400A", colorimeter, using the red filter.

TABLE IV

Relative chlorophyll contents ("optical densities") of tubers and sprouts from various irradiations. Experiment started Nov. 11, 1949. Analysis of Dec. 20, 1949, and Jan. 3, 1950. *Cf.* text.

Tuber							
20.12.'49	1	2	3	4	5	6	dark
violet	0.17	0.20					0.04
blue	0.27	0.20					
green	0.55	0.77				0.07	
yellow	1.14	1.00				0.15	
red	1.55	1.60				0.60	
infrared	0.05						
3.1.'50							
violet	0.22	0.17	0.13	0.08	0.07	0.07	0.03
blue	0.26	0.23	0.22	0.16	0.09	0.09	
green	1.43	1.06	0.75	0.34	0.20	0.18	
yellow	1.69	1.21	0.88	0.62	0.38	0.24	
red	2.03	2.11	1.67	1.25	0.58	0.48	
infrared	0.08	0.04	0.12	0.06		0.04	
Sprout							
3.1.'50	1	2	3	4	5	6	dark
violet	1.23						0.15
blue	2.00	1.56	1.60	1.40	1.08	0.85	
green	3.15						
yellow	2.85						
red	3.40	3.70	3.30	3.57	2.47	2.03	
infrared	0.18						

Chlorophyll formation was found strongest in the red light, less in blue and violet, intermediate in yellow and green. In the infrared no increase in optical density as compared with darkness was detectable. A comparison of data obtained on Jan. 3, with those of Dec. 20, showed that in most groups the chlorophyll content of the tubers still had increased.

It might be assumed that protochlorophyll is the photosensitive pigment involved in the process inhibiting sprouting. In this connection the results obtained in infrared, are of considerable interest. In this region the inhibition of sprouting is not less complete than in corresponding intensities of the visible red, but very little chlorophyll is formed. One might assume that nevertheless protochlorophyll might be responsible for the inhibition of sprouting with a much higher quantum efficiency than for the formation of chlorophyll. However, the behaviour in yellow and green seems to contradict this, for, here, less inhibition of sprouting is found than in the infrared, whereas much more chlorophyll has been formed.

A second possibility to be considered is that chlorophyll itself is the pigment involved in the inhibition of sprouting. The fact that the tubers and sprouts, after exposition to our infrared showed practically no greening (the optical density of the extract was of the same order as

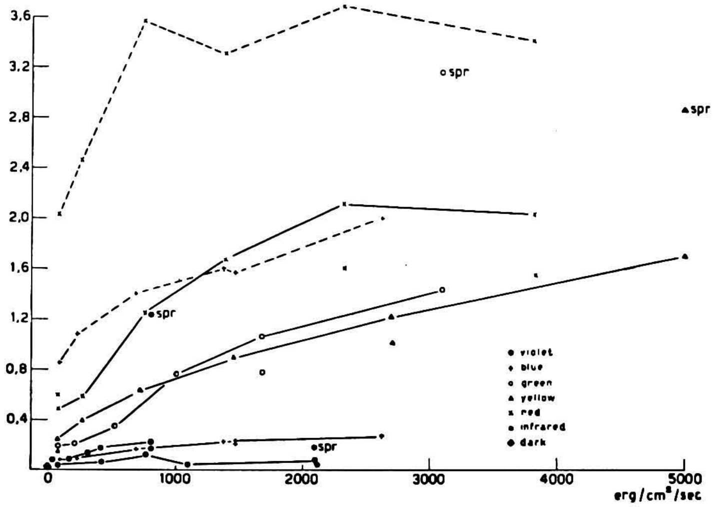


Fig. 1. Relative chlorophyll contents of tubers and sprouts from various irradiations. Experiment started Nov. 11, 1949. Records of Dec. 20, 1949 and Jan. 3, 1950 Abscissa: Intensity of irradiation of wavelengths $< 1\ \mu$, in ergs/cm² sec. Ordinate: Optical density of extract. Solid line: tuber; --- sprout; connected points: Jan. 3, 1950; separate points: Dec. 20, 1949.

that found after sprouting in darkness) does not exclude that the considerable inhibition found in the infrared might be due to the presence of traces of chlorophyll formed during harvesting.

In this connection it appeared of importance to try to establish the long wave length limit of the activity in the infrared.

To this purpose separate cases were built, of $128 \times 35 \times 30$ cm, each with a loose roof, in which, at one end, in the middle of a short side, a square window was made, provided with coloured filters. The following filters were used: SCHOTT RG 2, RG 5, RG 8, RG 5 + BG 3, RG 10, RG 7 and the combination no. 21 + no.1, of our own glasses, being used for the infrared in the previous experiment. All were combined with our glass no. 7, yielding less further infrared radiation. Incandescent lamps of 100 and 60 Watt were used as light sources, mounted directly above the filters. Fig. 2 shows the amounts of radiation transmitted in the various wave lengths regions (*cf.* also 7). From this graph the amount of radiation $> 1\ \mu$ was computed. Direct checks were made using the filter RG 7 as differential filter which yielded results agreeing within 10 % with those of the above method.

Ten rows of 5 tubers each were placed parallel to the short sides on the case floor, at suitable distances. The light intensities were measured at a number of places in each case with the aid of a thermopile and the values for the other places were interpolated. The intensities in the various cases are given in Table V (total radiation, and radiation $< 1\ \mu$).

The results are given in Plate 2*A*, which shows very clearly that the region transmitted by RG 10 and RG 7 is much less active than that transmitted by the other filters, so that the activity is concentrated in the near infrared, at wavelengths chiefly lower than 0.96 μ. Nevertheless, in

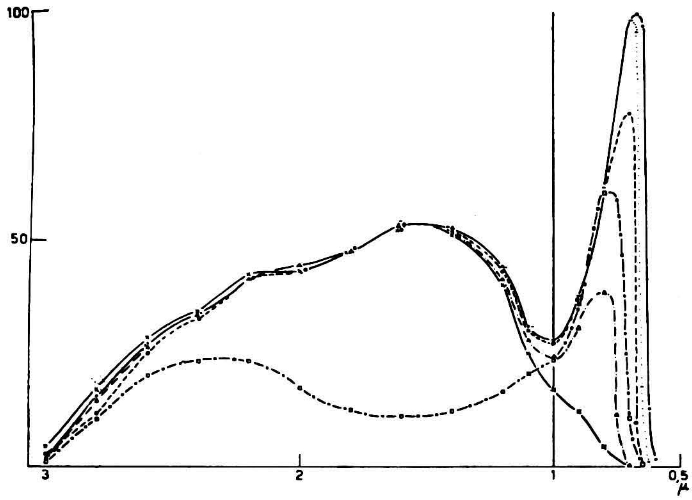


Fig. 2. Spectral distribution of energy of incandescent radiation as transmitted by various filters. From right to left: RG 2 + 7; RG 5 + 7 (weak dots); RG 8 + 7; BG 3 + RG 5 + 7; RG 10 + 7; RG 7 + 7. Beyond 1μ: All equal except BG 3 + RG 5 + 7.

TABLE V

Energy incident upon the respective rows (1—10) in the various cases. A: radiation with wavelength < 3 μ; B: radiation with wavelength < 1 μ. Experiment started Feb. 6, 1950.

A	1	2	3	4	5	6	7	8	9	10
RG 2 + 7	9294	7609	981	947	700	507	400	313	255	200
RG 5 + 7	10055	6919	918	722	530	388	318	260	195	150
RG 8 + 7	8855	3708	1008	832	620	466	372	301	248	194
21 A + 1 + 7. . .	3587	2770	272	204	150	107	92	74	60	45
BG 3 + RG 5 + 7	8334	6424	3706	1176	740	467	370	291	218	157
RG 10 + 7	6258	1432	418	270	222	180	126	91	66	48
RG 7 + 7	8305	5675	1850	702	570	463	335	254	192	139
B										
RG 2 + 7	2170	1780	230	222	164	119	93.5	73.5	60	47
RG 5 + 7	2140	1474	196	154	113	83	68	55.5	41.5	32
RG 8 + 7	1630	681	184	153	114	86	68	55.5	46	36
21 A + 1 + 7. . .	1076	831	81.5	61	45	32	27.5	22	18	13.5
BG 3 + RG 5 + 7	2425	1870	1080	342	215	136	108	84.5	63.5	45.5
RG 10 + 7	662	152	44.5	28.5	23.5	19	13	9.5	7	5
RG 7 + 7	267	182	59	22.5	18.5	15	11	8	6	4.5

this series, the light transmitted by RG 10 shows some inhibitory effect in the highest intensities used. The sprout lengths and the percentage inhibition found in the various regions is given in Table VI.

TABLE VI

A: Sprout lengths in mm (longest sprout, average of 5 tubers) for the irradiations of Table V.

B: Percentage inhibition of sprouting as compared with dark controls, from the data under A. Experiment started Feb. 6, 1950. Record of March 6, 1950.

A	1	2	3	4	5	6	7	8	9	10
RG 2 + 7	15.2	14.0	14.1	14.8	13.7	16.8	15.8	16.8	16.4	14.8
RG 5 + 7	14.0	13.0	14.8	14.0	13.2	15.0	15.0	16.2	15.9	16.0
RG 8 + 7	14.4	13.3	12.9	15.2	14.4	12.8	15.3	14.7	15.9	16.6
21 A + 1 + 7. . .	14.8	14.7	16.5	16.2	17.4	16.2	17.8	45.4	73.0	85.6
BG 3 + RG 5 + 7	14.0	13.1	14.0	15.0	16.2	16.9	16.8	18.2	18.8	22.4
RG 10 + 7	93.4	125.6	154.2	197.8	164	194	136	167	178	187
RG 7 + 7	158.0	177.5	179.5	167	156.5	191	174	169	186	173
dark	148.0		147		153		137		148	139
B										
RG 2 + 7	92.4	93.0	93.0	92.6	93.1	91.6	92.1	91.6	91.8	92.6
RG 5 + 7	93.0	93.5	92.6	93.0	93.4	92.5	92.5	91.9	92.0	92.0
RG 8 + 7	92.8	93.3	93.3	92.4	92.8	93.6	92.3	92.6	92.0	91.7
21 A + 1 + 7. . .	92.6	92.6	91.7	91.9	91.3	91.9	91.1	77.3	63.5	57.2
BG 3 + RG 5 + 7	93.0	93.4	93.0	92.5	91.9	91.5	91.6	90.9	90.6	88.8
RG 10 + 7	53.3	37.2	22.6	1.1	18.0	3.1	32.0	16.3	10.8	6.5
RG 7 + 7	21.1	11.3	10.3	16.4	21.7	4.6	13.0	15.7	7.0	13.6

TABLE VII

Relative chlorophyll contents ("optical densities") of tubers and sprouts from various irradiations. Experiment started Feb. 6, 1950. Record of March 6, 1950.

	Tuber									
	1	2	3	4	5	6	7	8	9	10
RG 2 + 7	1.06		0.53		0.38					0.28
RG 5 + 7	0.47		0.34							0.08
RG 8 + 7	0.36		0.16							0.07
21 A + 1 + 7. . .	0.16						0.08			0.13
BG 3 + RG 5 + 7	0.07		0.06		0.03					
RG 10 + 7	0.03									
RG 7 + 7	0.04									
dark	0.09									
	Sprout									
RG 2 + 7	2.41		1.48		0.91					0.47
RG 5 + 7	1.70		0.71							0.17
RG 8 + 7	0.68		0.28							0.17
21 A + 1 + 7. . .	0.15		0.09				0.06			0.05
BG 3 + RG 5 + 7	0.15		0.10		0.06					
RG 10 + 7	0.03									
RG 7 + 7	0.04									
dark	0.03									

Chlorophyll determinations were also made (Table VII, fig. 3), yielding results which, in general, agreed with those obtained before.

In a following series the light intensities applied were decreased in the cases with the filters RG 2 — (RG 5 + BG 3) included, by substituting 15 Watt bulbs for the 60 Watt ones, and increased in those with RG 10 and RG 7 by using 200 Watt instead of 100 Watt lamps. These substitutions yielded changes in the relation of the radiations $< 1\,\mu$ and $> 1\,\mu$ of only a few per cents which where neglected.

The results of this series are shown in Tables VIII and IX, and fig. 3.

TABLE VIII

Energy incident upon the respective rows (1—10) in the various cases. *A*: radiation with wavelength $< 3\,\mu$; *B*: radiation with wavelength $< 1\,\mu$. Experiment started March 14, 1950.

A	1	2	3	4	5	6	7	8	9	10
RG 2 + 7	2620	2150	276	224	178	125	87	63	46	37
RG 5 + 7	2670	2000	256	207	161	109	76	58	43	30
RG 8 + 7	2120	1686	266	234	168	118	87	61	51	38
21 A + 1 + 7. . .	412	53	37	29	15	11	8	5	4	3
BG 3 + RG 5 + 7	921	645	90	79	56	44	25	19	18	11
RG 10 + 7. . . .	23924	9094	1600	1358	1004	670	492	341	263	210
RG 7 + 7	22200	13390	2270	1790	1368	917	648	475	362	267
B										
RG 2 + 7	612	502	64.5	52.5	41.5	29	20.5	14.5	11	8.5
RG 5 + 7	568	426	54.5	44	34	23.5	16	12.5	9	6.5
RG 8 + 7	390	310	49	43	31	21.5	16	11	9.5	7
21 A + 1 + 7. . .	123	16	11	8.5	4.5	3.5	2.5	1.5	1.2	0.9
BG 3 + RG 7 + 7	267	187	26	23	16.5	13	7	5.5	5	3
RG 10 + 7. . . .	2540	964	170	142	107	71	52	36	28	22
RG 7 + 7	710	428	72	57.5	44	29.5	20.5	15	11.5	8.5

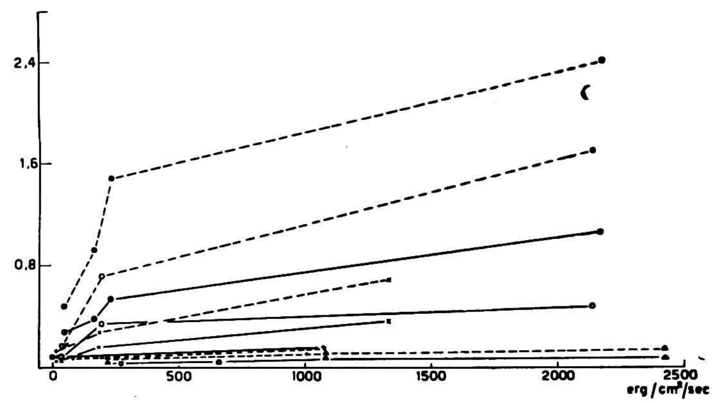
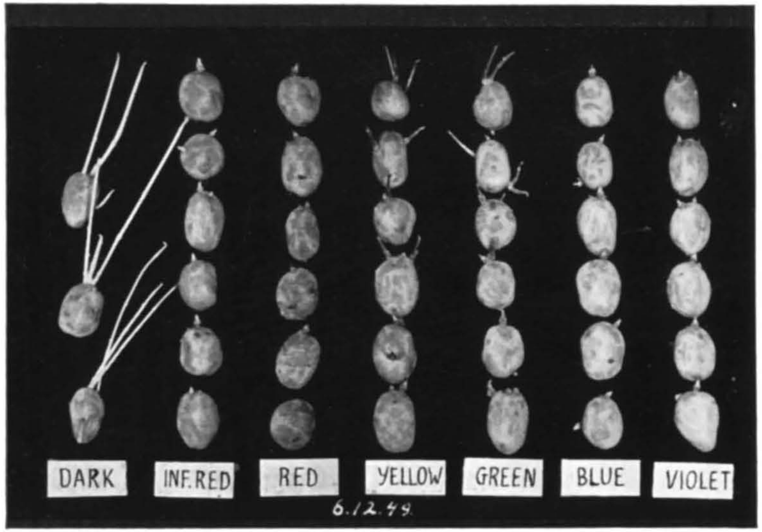
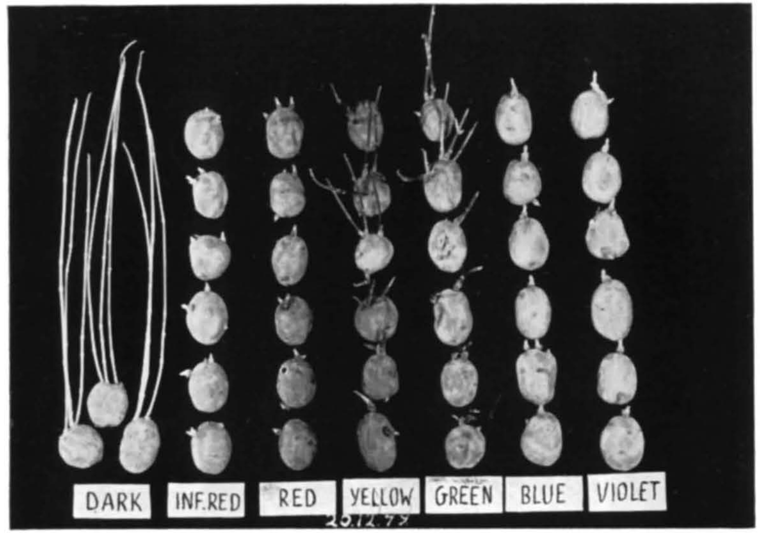


Fig. 3. Relative chlorophyll contents of tubers and sprouts from various irradiations. Experiment started Feb. 6, 1950. Record of March 6, 1950. Abscissa: Intensity of irradiation of wavelength $< 1\,\mu$, in ergs/cm² sec. Ordinate: Optical density of extract. Solid line: tuber; - - - sprout. ● RG 2 + 7; ○ RG 5 + 7; × RG 8 + 7; △ BG 3 + RG 5 + 7; (+) 21 A + 1 + 7; ⊗ RG 10 + 7; □ RG 7 + 7. Four last ones: all values below 0.2, *cf.* Table VII.





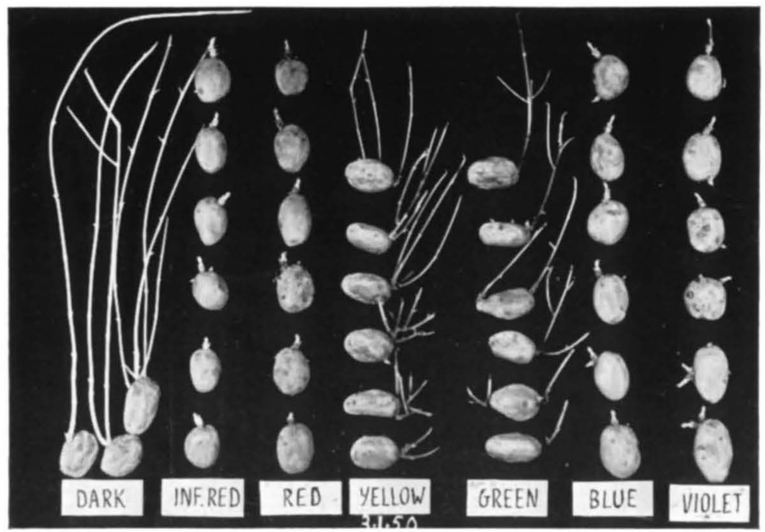
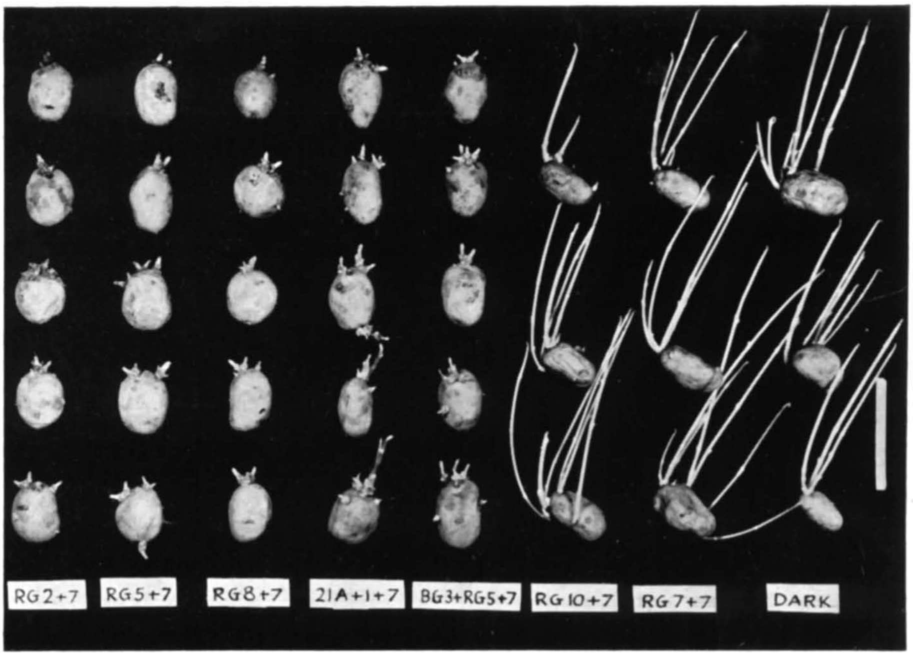


Plate 1. Representative tubers of each gauze plate from the various coloured irradiations. Decreasing intensity from bottom to top of each photograph. Experiment started Nov. 11, 1949. Photographs of Dec. 6 (left), Dec. 20 (right, top), Jan. 3, 1950 (right, bottom).

A



B

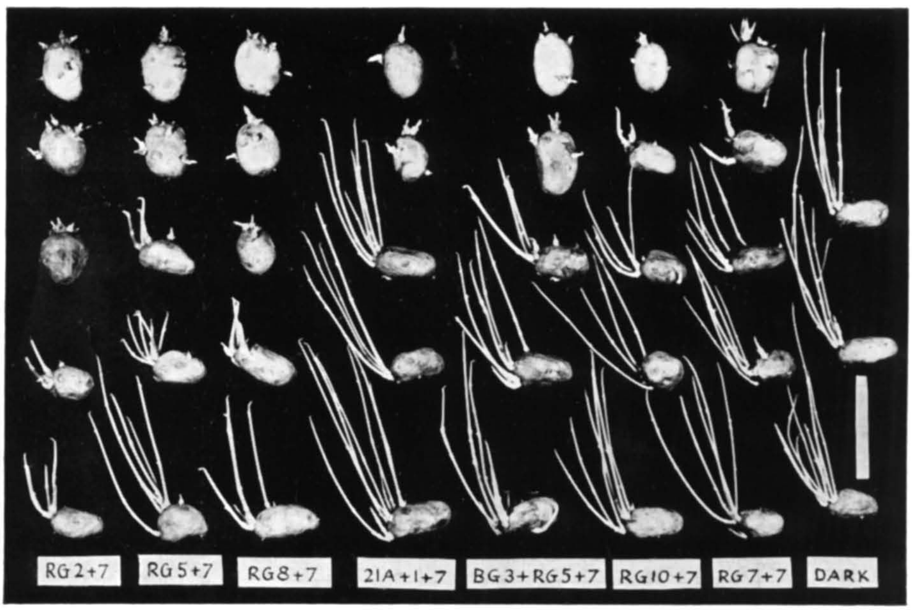


Plate 2. *A*. Representative tubers of various rows from the various cases. Decreasing intensity from top to bottom. Experiment started Feb. 6, 1950. Photograph: March 7, 1950. Bar at right side: 10 cm. From top to bottom of photograph: For the filters RG 2 to BG 3 + RG 5 included: tuber from rows 1, 4, 6, 8, 10 respectively. For RG 10: tuber from rows 1, 3, 5. For RG 7 from rows 1, 4, 6. For dark from rows 5, 7, 9.

B. Representative tubers of various rows from the various cases. Decreasing intensity from top to bottom. Experiment started March 14. Photograph: April 13, 1950. Bar at right side: 10 cm. From top to bottom of photograph: For the filters RG 2, RG 8: tuber from rows 1, 3, 5, 6, 8 respectively. For RG 5: tuber from rows 1, 4, 5, 7, 9. For 21 A c.s., BG 3 c.s.: tuber from rows 1, 2, 3, 5, 7. For RG 10, RG 7 tuber from rows 1, 2, 3, 4, 5. For dark tuber from rows 1, 5, 10.

TABLE IX

A: Sprout lengths in mm (longest sprout, average of 5 tubers) for the irradiations of Table VIII.

B: Percentage inhibition of sprouting as compared with dark controls, from the data under *A*. Experiment started March 14, 1950. Record of April 12, 1950.

A	1	2	3	4	5	6	7	8	9	10
RG 2 + 7	14.0	15.0	15.2	17.5	16.5	40.5	58.0	70.5	85.2	83.5
RG 5 + 7	15.0	14.8	17.2	18.8	44.5	50.8	55.5	97.2	105.3	107
RG 8 + 7	14.8	15.8	16.5	17.5	17.8	50.2	73.2	107.8	102.2	105.2
21 A + 1 + 7. . .	19.8	19.2	126.8	128.0	175.8	141.2	163	206	207	179
BG 3 + RG 5 + 7	18.0	17.0	76.0	93.5	113.2	146.8	152.2	155	178	187.5
RG 10 + 7	23.8	37.5	99.2	138	163	166	138	147	155	180
RG 7 + 7	36.8	44.8	97.2	128	157	179	144.5	195	150	177
dark	183		191		196		178		150	172
B										
RG 2 + 7	93.0	92.5	92.4	91.2	91.7	79.7	71.0	64.7	57.4	58.2
RG 5 + 7	92.5	92.6	91.4	90.6	77.7	74.6	72.2	51.8	47.3	46.5
RG 8 + 7	92.6	92.1	91.7	91.2	91.1	74.9	63.4	46.1	48.9	47.4
21 A + 1 + 7. . .	90.1	90.4	36.6	36.0	12.1	29.4	18.5	0	0	10.5
BG 3 + RG 5 + 7	91.0	91.5	62.0	53.2	43.4	26.6	23.9	22.5	11.0	6.2
RG 10 + 7	88.1	81.2	50.4	31.0	18.5	17.0	31.0	26.5	22.5	10.0
RG 7 + 7	81.6	77.6	51.4	36.0	21.5	10.5	27.7	2.5	25.0	11.5

The intensities of irradiation are collected in Table VIII; Plate 2, *B* gives a survey of the results. The range of slight inhibitions has been reached in most cases, whereas with RG 10 and RG 7 now considerable inhibitions have been obtained. We calculated the percentages inhibition, on the basis of sprout length of the dark control tubers (table IX), and established the energy at which 50 % inhibition was reached. Calculated upon the total energy $< 3\,\mu$, we arrived at the figures collected in table X, column I.

TABLE X

Energy/cm² sec. required for 50 % inhibition of sprout elongation in red and infrared radiation (continuous illumination). Experiment of March 14—April 12, 1950.

Filter (+ no. 7)	Energy ($\lambda < 3\,\mu$)/cm²sec. I	Energy ($\lambda < 1\,\mu$)/cm²sec. II
RG 2, RG 5, RG 8 . . .	~ 45 ergs	~ 10 ergs
RG 5 + BG 3	~ 55 „	~ 20 „
RG 10	~ 1600 „	~ 170 „
RG 7	~ 3000 „	~ 100 „

There is a considerable gap in the energy required for 50 % sprout inhibition between the filters RG 2, RG 5, RG 8, RG 5 + BG 3 on the one hand, and RG 10, RG 7 on the other hand. This indicates that the effectiveness of the energy, thus, the absorption of the photoactive pigment strongly declines in this region. Provisionally, we also calculated the energy required in the various regions to cause 50 % inhibition under the assumption that only energy of wavelengths $< 1\ \mu$ are active. This assumption, of course, is arbitrary, but the slight response to the energy passing RG 10 and RG 7 indicates that, at least, the energy with $\lambda > 1\ \mu$ is not very active. We thus arrive at the numbers of column II, Table X.

The energies indicated by VAN DER VEEN (6) for red light are considerably lower than those given in Table X. So far we have no explanation for this discrepancy.

It is interesting to compare sprout inhibition with chlorophyll formation under the various filters. In Table XI, *A* some data on chlorophyll formation and sprout inhibition are compared, effected by about equal energy in various spectral regions. In Table XI, *B* energies are chosen in a region showing a clear range of sprout inhibition (in this experiment no chlorophyll determinations were made). It is seen that chlorophyll formation shows a sharp decline in the region between RG 2 and BG 3 *c. s.*, and a slow decline between BG 3 *c. s.* and RG 7; sprout inhibition shows the reverse behaviour. This is additional evidence that protochlorophyll is not the pigment involved in sprout inhibition.

TABLE XI

Decline in activity as to inhibition of sprout elongation, and chlorophyll formation in the near infrared. A: Experiment of Feb. 6—March 6, 1950. *B*: Experiment of March 14—April 12, 1950.

	A					*B*		
Filter (+ no. 7)	Energy /cm²sec $\lambda < 1\ \mu$	Chloroph. content	Ratio	% Inhib. sprout elong.	Ratio	Energy /cm²sec $\lambda < 1\ \mu$	% Inhib. sprout elong.	Ratio
RG 2	230	1.48		93		29	80	
			25		1.01			1.3
BG 3 c.s.	215	0.06		92		26	62	
			1.5		4.3			4.0
RG 7	267	0.04		21		29.5	15	

In (7), fig. 2, a curve representing the absorption of a chlorophyll-protein complex has been drawn. It extends into the infrared at least up to 0. 8 μ. In how far straylight may have influenced the curve in this region is difficult to say. As such this curve doesn't contain definite evidence against the supposition that the chlorophyll-protein complex acts as light absorber in the process of photo-inhibition of sprout elongation.

Summary.

Sprouting of potatoes was studied in light of various spectral regions. For the quality of these regions, *cf.* (7). Continuous exposure with various energies was applied. In green and yellow light inhibition of sprout elong-

ation is less effective than in blue, violet and red. Near infrared also causes strong inhibition. In this region the sprouts and tubers do not form appreciable amounts of chlorophyll, whereas in the other regions they do. A steep fall in chlorophyll formation occurs between the filters SCHOTT RG 2 and RG 5 + BG 3, a steep fall in inhibition of sprout elongation between RG 5 + BG 3 and RG 7. The inhibitions in the regions between 0.3 and 0.7 μ suggests that a chlorophyllous pigment is active in absorbing the light energy inducing the inhibitory action. It seems improbable that protochlorophyll is the active pigment. It is possible that low concentrations of chlorophyll — bound to protein — are responsable for the observed effect.

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