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The influence of light on the germination of potato seeds

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Abstract

The influence of white and coloured light and of the darkness on the germination of potato seeds was investigated. Potato seeds germinate in light as well as in darkness. Red light is stimulative. Far-red and blue light depending of the origin of the seeds populations acted or inhibitive or only as a delaying factor.

The after effect of R after FR or FR after R was also studied. The R-FR or FR-R photoreaction observed by potato seeds, differ from the classic pattern established by lettuce and tomato seeds.

There is a general agreement that most freshly harvested potato seeds are dormant, the period of dormancy, however, shows intervarietal differences lasting from several weeks to months (Fischnitz and Krug 1959). One can assume that seeds stored in air and in laboratory temperatures reach after a year their optimal level of "readiness to germination". A high viability of germination capacity in such conditions is retained during 2-4 years or more (Simmonds 1963). It is very little known about the influence of light (respectively of darkness) on the germination of non-dormant potato seeds. According to Simmonds (1963) the germination of non-dormant seeds is slightly delayed in the dark or by short light treatment. But Simmonds added that: "more investigation is needed. There is no evidence to show whether this dark inhibition is an erratic feature of all potato seeds".

Shue Lock Lam and Erickson (1966) investigated the influence of the lenght of the day and of light intensity on the germination of newly harvested seeds. It results from their observations — that promotive is darkness and a shorter photoperiod 2 to 8 hours daily duration. Longer day duration than 8 h are acting as an inhibitory factor — inhibitive also was light of higher intensity.

Probably the light sensivity is changing with the age of the seeds.

MATERIAL AND METHODS

Our experiments were carried out with non-dormant seeds originated or from crossings (populations: PG 18 × PG 138, Merkur × Meise, Lori × USDA 95-56) or from self-pollination (cultivars Sitta and Wyszoborskie).

Seeds were germinated in Petri dishes in laboratory conditions temperature fluctuated between 19-23° (rarely and for a very short time rising to 24-25°C). In such range of temperature fluctuations we did not observe any change in germination rate. Only in one experiment in which the temperature rose in the end phase to 29-30° we observed a marked inhibition of the seeds germination.

According to Simmonds (1963) optimal temperature for germination lay between 19-25° Centigrade. Higher (29-30°C) as well as lover (8-12°C) being inhibitive, however Shue Lock Lam (1968) noted that GA deblocks the inhibitive influence of lower temperature.

The influences of following light conditions were tested:

1. Continuous darkness in relation to continuous light (white and of different colours).

2. Cyclic changes (12 h darkness — 12 h light) in relation to continuous light.

3. 10-16 h of dark — imbibition before irradiation compared to the light continuous from the beginning.

4. The influence of red, far-red, blue, yellow and green comparing to white.

5. The red, far-red reaction (far-red before red, or red after far-red).

6. The same in blue.

White light: natural day plus 80 W incandescent bulb (during night also).

As light filters were used monochromatic Jena-Zeiss glass-filters (red, blue, yellow, green, far-red).

The glass filters were additionaly verified through lettuce seed germination bioassay.

In total 22 experimental series were performed. It seems that it is not possible and not useful to quote the results of all particular experiments. Therefore we will summarize the results, the data presented in tables serving as illustrative pattern examples.

RESULTS

1. In many papers which dealt with the influence of light on germination, a dark pre-imbibition of seeds (during 10-16 h) was in use. Therefore, we tested in 3 experiments the influence of such pre-imbibition.

In general no effect was observed. Rarely — a slight after effect — negative for "red light", positive for "white" or "blue" (in such seeds, populations which only in part are inhibited through blue light). A 10-16 h dark pre-imbibition by potato is probably too short, because even in red the germination began after 4-5 days.

2. Cyclic changes — 12 h "day" — 12 "night". In relation to continuous day a slight speeding up of germination in white and inversely a slight retardation in red and yellow light was noted.

3. Continuous white light in relation to continuous darkness (see Exp. 1, 7, 9, 10). Potato seeds germinate in darkness as well as in light.

White light had a delaying effect, on the energy of the germination, but in general this effect is slight, rarely distinct. The capacity for germination remains on the same level in white light as in darkness.

4. The influence of coloured light (red, yellow, green, far-red and blue, see Exp. 1, 1a, 7, 9, 10, 12, 14, 16).

Red is promotive in relation to white light and mostly also in relation to darkness (see Exp. 1, 7, 9, 10, 12, 16). Both the energy and the capacity of germination are higher in red.

Yellow is a little weaker in its action than red. Green on the lèvel of white or slightly better. Far-red and blue are inhibitive. The inhibition is complete (see Exp. 1, 1a, 12, 14, 16) or partial although strong (see Exp. 16). Only in the more neutral as concerns the influence of light seeds populations originated from cultivar 'Wyszoborskie' far-red and blue acted only as a delaying factor (see Exp. 9, 10, 12a).

5. The after-effect of long period of irradiation with far-red or blue (see Exp. 1a, 12, 14) as well as the after-effect of white or red given before far-red (Exp. 5) was also investigated. In Exp. 14 — seeds imbibed at first during 10h in darkness were irradiated with F-R or blue from 1/2 to 64 h and then transferred to red. Far-red from 1/2 to 8 h caused only a slight delay in the course of germination and had no effect on germination capacity. Longer, 32-64 h lasting irradiation with FR delayed distinctly the process of germination. But even after 6-12 days of far-red or blue (see Exp. 1a and 12) the seeds conserved their germination ability.

Transferred to red light conditions they germinated, reaching after a longer or shorter period of time the normal level of germination capacity. Similar but weaker than after far-red is the behaviour after blue irradiation — here a distinct delay of germination was observed only after 64 h of blue.

Experiment 5 illustrated the reciprocal combination. Seeds after 144 h of red or white light were transferred to far-red.

In spite of this the rate of seeds germination was not disturbed. The seeds continued to germinate in a nearly normal rate. Here one can see a process which could be called a "pushreaction".

Therefore probably we could not observe any change in the course of germination, when a continuous red or white light irradiation, was interrupted with far-red for 7 or 21 h.

CONCLUSIONS AND DISCUSSION

1. Potato independently of their origin (from crossing or from self--pollination) are heterozygous.

The range of inter-seeds variability, even originating from one berry is therefore very large, and may involve many properties. One can suppose that also the photoreaction by the germinating process could be variable.

Perhaps even the fact noted by Simmonds (1963), on dark inhibition — just the reverse which was observed in our experiments — could be seen as resulting from genetical heterogenity of potato-seeds populations.

One can suggest that this heterogenity can be of double character:

— first, when two seeds populations of different origin will differ in their average reactions. Differences in photoreaction of seeds populations from Sitta and from Wyszoborskie may be cited as an example (see Exp. 9, 10, 12, 14).

— secondly, it can reflect, differences in the time scale of germination between particular seeds at a given seed-sample. The dispersal, may be very large here, and probably is bound with the genetic heterogenity of the seeds materials.

Moreover, of course, one cannot forget that partially such differences could be the result of differences in ripeness between seeds or berries — or in the method of seeds extirpation.

Especially the light/dark reaction seems to change with the age of the seeds. Shue Lock Lam and Erickson (1966) suggested that the light sensivity diminish with the age of the seeds. Newly harvested seeds being very sensitive.

2. Red light normally hastened the germination process, however the intensity of such stimulation effect varies in relatively large range. Blue or far-red — are acting as inhibitors.

Two distinct deviation from this rule could be noted:

a) Seeds population from self-fertilized berries from cultivar 'Wyszoborskie' are, in average nearly neutral against the change in light quality. They germinated partially in far-red (± 70%) as well as in blue (± 80%) (see Exp. 10 and 12a).

Table 1

Exp. 1. PG 18 × PG 138 (sown January 16)

Light	Hours from sowing						
	48	60	67	84	91	108	155
	% of germination						
White	0	0	0	40	65	65	75
Red	0	10	20	100	—	—	—
Far-red	0	0	0	0	0	0	0
Blue	0	0	0	0	0	0	0
Darkness	0	25	27	65	72	80	85

Exp. 1a. PG 18 × PG 138 (sown January 16)

Light combinations	Hours from sowing						
	0—140	155	200	224	249	244	298
		% of germination					
Far-red cont.	0	0	0	0	0	0	0
Blue cont.	0	0	0	0	0	0	0
Far-Red 140 h then red	0	0	0	15	25	45	95
Blue 140 h then red	0	5	10	15	20	25	98

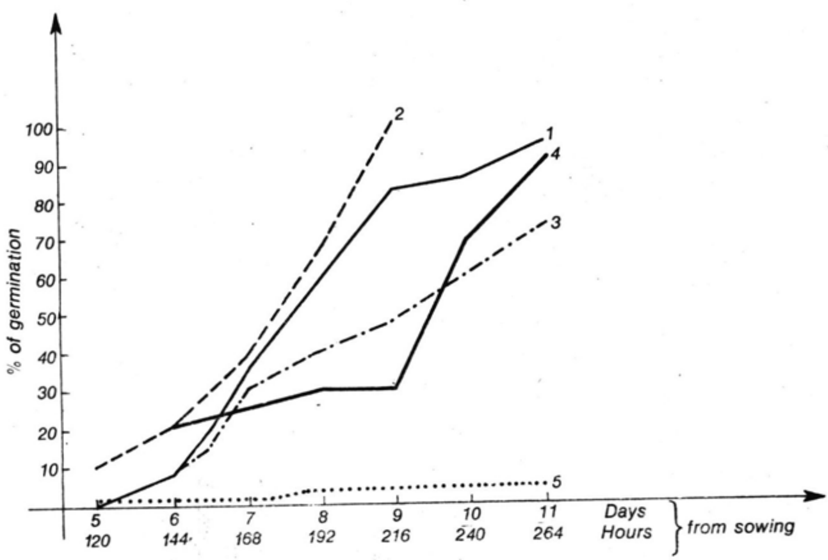

Fig. 1. Exp. 5. Lori × USDA 95-56. Sown May 27
1 — white (cont.); 2 — red (cont.); 3 — 144 h white then F-R; 4 — 144 h red then F-R: 5 — far-red (cont.)

Table 2

Exp. 6 and 6a. Germination of lettuce and potato seeds in far-red and red and after effect of far-red
Two level of light intensity: a=16 h ("day") 7000 Lux, 8 h ("night") 200 Lux; b=16 h ("day") 1500 Lux, 8 h ("night") 700 lux

	Lettuce						Potato							
	hours from sowing						hours from sowing							
	16→20	44	120	152	260	380	120	144	168	192	260	380	452	460
Far-red a	0			0 └→R	0 0 └→R	0 0 0	0	28	36	40	40 └→R	40 70	40 90	
Far-red b	0			0 └→R	0 0 └→R	0 0 0	0	0	0	0	0 └→R	0 15	0 30	0 90
16 h dark then far-red a	35	47		47 └→R	47 55	[47] 55	0	4	36	56	56 └→R	56 75	56 75	
16 h dark then far-red b	28			28 └→R	28 28	28 28	0	0	0 └→R	4 10	4 90	— 90	— —	
Red a 100% 140 h Red b 100% 90 h							Red a 95% 212 h Red b 100% 188 h							

Table 3

Exp. 7. Lori × USDA 95-56 (sown May 15)

Light	Hours from sowing						
	96	104	120	144	156	168	180
	% of germination						
White	0	0	0	25	50	60	85
Red	0	10	30	75	95	—	—
Darkness	0	10	40	70	80	85	93
Yellow	0	0	17	43	70	77	90
Green	0	0	23	52	70	76	80

Table 4

Exp. 9. Self-pollination 'Sitta' and 'Wyszoborskie' (sown November 2)

Seeds populations	Light onditions	Days from sowing										
		5	6	7	8	9	10	11	12	14	16	22
		% of germination										
from 'Sitta'	White	0	0	0	0	0	0	10	26	26	50	53
	Red	0	0	0	10	23	56	76	83	86	96	98
	Darkness	0	0	0	3	3	20	33	55	70	80	85
	Blue	0	0	0	0	0	6	6	10	10	10	10
from 'Wyszoborskie'	White	5	5	40	60	75	85	—	—	—	—	85
	Red	0	10	45	55	65	70	90	95	100	—	—
	Darkness	0	10	50	70	75	80	85	85	95	—	95
	Blue	0	0	25	60	60	70	85	—	—	—	85

Table 5

Exp. 10. Self-pollination 'Wyszoborskie' (sown November 18)

Light conditions	Days from sowing									
	5	6	7	8	9	10	11	12	16	19
	% of germination									
White	0	0	5	15	30	35	50	60	70	70
Red	30	45	75	80	95	95	—	—	—	95
Blue	0	0	5	10	35	35	45	55	60	60
Darkness	0	75	75	80	90	90	—	—	—	90

b. Another deviation was linked with the change in light intensity. Lettuce seeds and potato seeds (from crossing Meise × Merkur) — were germinated in white, red, far-red and blue in 2 levels of light intensity:

level a) at day hours 7000 lux, at night hours 2000 lux

Table 6

Exp. 12. Self-pollination from 'Sitta' (sown November 30)

Light conditions	Days from sowing								
	8	9	10	11	12	14—17	18	20	22
	% of germination								
Red	10	40	82	90					
Far-red	0	0	0	0	Red →	→	4	24	80
Blue	0	0	0	0	Red →	→	2	12	75
White	0	0	10	10	Red →	→	20	30	90

Exp. 12a. Self-pollination 'Wyszoborskie' (sown November 24)

Light conditions	Days from sowing									
	4	5	6	7	8	9	10	13	16	18
	% of germination									
White	0	0	4	8	16	38	66	75	86	88
Red	12	30	45	80	86	86	88	90	98	98
Far-red	0	4	15	40	50	70	74	—	—	74
Blue	0	0	28	40	48	50	54	70	84	84

Table 7

Exp. 14. Self-pollination from 'Sitta' (sown January 11)

Light		Days from sowing										
		6	7	8	9	10		6	7	8	9	10
		% of germination										
Red cont.		6	74	90	48							
Far-red cont.		0	0	0	0							
Blue cont.								0	0	0	0	0
1/2 h	Far-red then red	2	66	76	92	92	Blue then red	4	36	66	88	90
2 h	Far-red then red	6	64	86	94	94	Blue then red	2	58	74	88	90
4 h	Far-red then red	8	44	94	96	96	Blue then red	4	50	84	94	96
8 h	Far-red then red	2	58	84	90	90	Blue then red	8	72	88	92	96
16 h	Far-red then red	0	20	36	70	86	Blue then red	6	48	68	80	94
32 h	Far-red then red	0	8	26	50	56	Blue then red	2	40	54	80	90
64 h	Far-red then red	0	8	20	38	46	Blue then red	8	20	36	54	64

level b) at day hours 1500-1700 lux, at night hours 600 lux (see Exp. 6a and 6b).

By lettuce full inhibition in far-red and in blue at both intensity levels was observed.

By potato — a full inhibition took place only at lover level of light intensity.

Table 8

Exp. 16. Self-pollination from 'Sitta', PG × Merkur (sown February 4)

		Days from sowing								
		5	6	7	8	9	10	11	12	13
		% of germination								
'Sitta' self-pollination	Red	20	64	88	96	—	—	—		
	Far-red	0	0	0	2	2	2	2		
	Blue	0	0	2	10	10	10	10		
	Darkness	14	22	64	78	82	90	—		
PG 65 × × Merkur	Red	—	—	—	10	16	35	43	66	80
	Far-red	—	—	—	0	0	3	13	15	18
	Blue	—	—	—	0	0	3	23	30	30
	Darkness	—	—	3	11	13	15	33	46	65

At higher: 40% in far-red and in blue 80% of seeds were germinated. The seeds which did not germinate — after 150 h or after 210 h — of far-red were transferred in red light. Potato seeds germinate in such conditions normally, contrary to lettuce seeds which lost their viability.

In red light conditions lettuce and potato seeds showed a higher energy level of germination than on "b" level — but no differences were found between "a" and "b" level in relation to germination capacity. The same trend, however weaker, was observed in white light.

Our statements were not consistent with Shue Lock Lam and Erickson (1966) observations, but it is possible that on newly harvested seeds — (with such seeds experiments of Shue Lock Lam were performed) white light acted as an inhibitory factor. If it is so — then it is understandable — why the higher level of light intensity acted in a stronger inhibitive manner then the lower level.

3. The red — far-red reversible photoreaction of lettuce seeds which controls the germination and has been known since 1952 (Bortwick et al.) was found by many seeds.

One can suppose that in such potato seeds population in which a distinct FR-inhibition takes place the same control mechanism is present. But there are also differences in relation to the classic lettuce pattern or tomato pattern too (Mancinelli et al. 1967). Even after a very prolonged action of far-red potato seeds did not lose their germination ability.

After being transferred to red, they germinate normally sooner or later. The relation is here quantitative but not of "or-or" type.

One can point out to the hypothesis of Spruit and Mancinelli (1969). They recognised the presence of native P_{FR} phytochrome in dry seeds, which remain quantitatively on the same level during imbibition and germination. Then a "de novo" phytochrome synthesis took place. Therefore the "native" phytochrome in relation to the "de novo" phytochrome decreases constantly.

It was assumed that the inhibitive influence of far-red on seeds which are able to germinate in the darkness, is the effect of the fact that in far-red the relation between P native/P total reaches a particularly low level. This critical relation could lay at very different levels in different species or even cultivars.

It seems that potato seeds are not only less sensitive but also more adaptable to this different phytochrome relation. The relative neutrality against the length of the light waves in seeds of the "Wyszoborskie — population" could be interpreted as a feature of greater adaptability to variable light condition.

This fact reminds the phenomenon of escape from phytochrome control occuring in high temperature condition (Mancinelli et al. 1967) (Kadman-Zahavi 1960).

The inhibitive influence of blue light on germination is also not very well known. By interacting with red an inhibition as well as promotive aftereffect was observed. In our experiments red nullified the inhibitive influence of blue even quicker and stronger then of far-red. The control mechanism in blue is not known very well. The reactions of plants in blue light are so varied that it seems impossible that one deals here with one photoreceptor-system (Kandeler 1972), however, the interaction with red seemed to show that there is some link with the phytochrome system. Our experiments were carried out from a more applied point of view, but it seems that potato seeds are also an interesting object while studying the control mechanism of germination.

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Wpływ światła na kiełkowanie nasion ziemniaka

STRESZCZENIE

Nasiona ziemniaków o normalnej sile kiełkowania, pochodzące z krzyżówek oraz z owoców powstałych z samozapylenia na odmianach 'Sitta' i 'Wyszoborskie', kiełkowano w różnych warunkach świetlnych i w ciemności. Ogółem wykonano 22 doświadczenia.

Jako filtry przy ocenie wpływu światła barwnego stosowano monochromatyczne filtry z firmy Zeiss-Jena (sprawdzone poza tym na teście sałaty).

1. Nasiona ziemniaka kiełkują na świetle białym, jak i w ciemności. Energia kiełkowania jest na ogół nieco wyższa na świetle niż w ciemności (Exp. 1, 7, 9 i 10).

2. Zmiana cykliczna 12 godzin dnia (12 godzin ciemności) nie miała wpływu w porównaniu do światła ciągłego, podobnie jak i 6-godzinne pęcznienie nasion w ciemności przed ich umieszczeniem w danych warunkach świetlnych.

3. Światło czerwone, w porównaiu do białego, a również i ciemności, działa stymulująco na kiełkowanie. Wyższa jest zarówno energia, jak i siła kiełkowania (vide Exp. 1, 7, 9, 10, 12, 16). Światło żółte oddziaływa nieco słabiej od czerwonego.

Daleka czerwień i światło niebieskie hamują kiełkowanie całkowicie (Exp. 1, 1a, 12, 14, 16) lub częściowo (Exp. 16). Jedynie populacje nasion z samozapylenia 'Wyszoborskich' wydają się być bardziej naturalne, a zarówno daleka czerwień, jak i światło niebieskie opóźniają tylko proces ich kiełkowania (Exp. 9, 10, 12a).

Nasiona ziemniaka, po naświetlaniu daleką czerwienią lub światłem niebieskim przez dłuższy czas (32 godziny i dłużej), przeniesione potem na światło czerwone kiełkują normalnie (Exp. 1a i 12). Nawet jeszcze po 150-200 godzinach naświetlania daleką czerwienią zachowują, w przeciwieństwie do sałaty, siłę kiełkowania (Exp. 6 i 6a). Odwrotnie, nasiona, które z początku znajdowały się przez pewien czas na świetle czerwonym, kiełkują w dużej części, jeśli się je potem przeniesie do dalekiej czerwieni (Exp. 5).

Nasiona ziemniaka zachowują się więc inaczej niż sałaty używanej jako test na fotoreakcję: czerwień—daleka czerwień, i co więcej, obserwuje się tu wyraźne różnice między populacjami (pochodzeniowe) nasion.

Wydaje się, iż tam gdzie daleka czerwień działa inhibicyjnie na kiełkowanie, mamy do czynienia z mechanizmem fitochromowej regulacji, o tyle odmiennym od reakcji „wzorcowej" (sałaty), iż nasiona nie tracą zdolności kiełkowania. W przypadku zaś populacji nasion z samozapylenia u odmiany 'Wyszoborskie' można by mówić o neutralizacji świetlnej lub o „wyłamaniu" się procesu kiełkowania spod kontroli fitochromu.

4. Analizowano również wpływ natężenia światła (Exp. 6a i 6b). Wpływ inhibicyjny obserwuje się u sałaty przy różnym natężeniu, u ziemniaka zaś inhibicja występuje tylko przy niższym poziomie natężenia światła („dzień" 1500-1700 lux, „noc" 600 lux), przy wyższym poziomie („dzień" 7000 lux i „noc" 2000 lux) część nasion kiełkuje.