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SIMILARITY OF SOME KINETIN AND RED LIGHT EFFECTS<sup>1</sup>

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The action spectra for control by light of flowering (1), bean leaf expansion (3), and lettuce seed germination (2) all strongly resemble one another. With each of these phenomena, red and far-red light have opposite effects. This has been interpreted to mean that all these growth responses are controlled by identical photoreactions (3). Therefore, information concerning control of the latter two phenomena probably can be applied to the problems of light control of flowering.

Conceivably, the above responses can be elicited or modified by certain chemicals applied to the plant material in darkness, and the discovery of such chemicals might be expected to point to the nature of the reactions by which light exerts its control. The expansion of etiolated bean leaf disks and germination of lettuce seeds are especially adaptable to the search for effective chemicals. The promotion by cobaltous salts of bean leaf disk expansion in the dark already has been reported (5, 6). However, these salts do not promote lettuce seed germination. Similarly, the promotion of seed germination by thiourea is very striking (12) but it does not promote leaf disk expansion. It is demonstrated in this paper that, in contrast to the chemicals already mentioned, kinetin (6-furfurylamino-purine) (7, 8) promotes both leaf expansion and lettuce seed germination in the dark.

All studies reported herein were conducted in a dark room kept at  $25 \pm 1^\circ \text{C}$ . Cutting operations were made under dim green light. Red light was obtained by filtering light from a 40-watt, white fluorescent tube through two layers of duPont red cellophane; exposures were made at a distance of 30 cm from the tube. Far-red light was obtained at a distance of 40 cm from a 200-watt tungsten bulb, the light being filtered through two layers of duPont red cellophane alternated with two layers of blue cellophane (11).

Disks 5.5 mm in diameter were cut from leaves of Burpee Dwarf Stringless Greenpod bean plants grown for 7 days in the dark (5). These disks were maintained on pads of filter paper wetted with  $8 \times 10^{-2} \text{ M}$   $\text{KNO}_3$ ,  $5.8 \times 10^{-2} \text{ M}$  sucrose (about 2%), and serial dilutions of the chemical being tested. After a period of 48 hrs, the diameters perpendicular to the main veins were measured. In table I are presented data showing that kinetin does cause a marked increase of

TABLE I  
EFFECT OF KINETIN AND LIGHT ON EXPANSION OF  
ETIOLATED BEAN LEAF DISKS DURING A 48-HR  
GROWTH PERIOD, 1/13/56

CONC OF KINETIN	LIGHT TREATMENT *	INCREASE IN DIAM
<i>M</i>		<i>mm</i>
0	None	$1.05 \pm 0.04^{**}$
$5 \times 10^{-6}$	"	$1.73 \pm 0.06$
$5 \times 10^{-5}$	"	$2.48 \pm 0.03$
$1 \times 10^{-4}$	"	$2.96 \pm 0.07$
0	5 min Red	$2.58 \pm 0.08$
0	5 min Far-red	$1.01 \pm 0.06$
0	5 min Red and then	
	5 min Far-red	$1.17 \pm 0.07$
$5 \times 10^{-5}$	5 min Far-red	$2.49 \pm 0.08$

\* Light treatments given at beginning of experiment.

\*\* Standard error. Ten disks per treatment.

expansion. This expansion was the result of cell enlargement. Kinetin promoted primarily the enlargement of laminar tissues and less so the elongation of the veins; this caused some distortion of the disks. The data of table I also show that expansion of the particular leaf disks used was affected oppositely by red and far-red light. Similar data have been reported previously by Liverman et al (4). The kinetin effect thus resembles that of red light. Unlike the red light effect, however, it was not prevented by the exposure to far-red radiation.

Kinetin also markedly influences the development of intact bean seedlings. In one experiment, the upper parts of 5-day-old, dark-grown seedlings were soaked in water or kinetin solutions for 2 hrs. The entire epicotyls, the cotyledons, and the uppermost portions of the hypocotyls were immersed in the solutions. The seedlings were then allowed to grow for an additional 46 hrs in the dark. At the end of this time, the average fresh weights of the epicotyls exposed to water or to  $4.6 \times 10^{-6} \text{ M}$ ,  $9.3 \times 10^{-6} \text{ M}$ , or  $2.3 \times 10^{-5} \text{ M}$  kinetin were respectively 0.19, 0.23, 0.32, and 0.30 gm. In such tests, kinetin promoted expansion of the leaves, elongation of the stems of the epicotyls, and elongation of the petioles. Exposure to red light affects bean seedling development in much the same ways (3); therefore, the similarity of the effects of kinetin and of red light is again apparent.

For the studies on germination, Grand Rapids let-

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TABLE II

EFFECT OF KINETIN AND LIGHT ON GERMINATION OF  
GRAND RAPIDS LETTUCE SEEDS DURING A 72-Hr  
PERIOD (TWO EXPERIMENTS)

CONC OF KINETIN	LIGHT TREATMENT *	GERMINATION	
		EXPT 1	EXPT 2
<i>M</i>		% **	% **
0	None	8	7
$1 \times 10^{-5}$	"	55	48
$2.5 \times 10^{-5}$	"	89	72
$5 \times 10^{-5}$	"	84	86
$1 \times 10^{-4}$	"	76	76
0	8 min Red	96	96
0	8 min Red and then		
	8 min Far-red	5	7
$5 \times 10^{-5}$	8 min Far-red	86	83

\* Light treatments given 16 hrs after start of experiment.

\*\* Percent given as nearest whole number, 95 to 105 seeds per treatment.

tuce seeds were placed in Petri dishes containing pads of filter paper (3 sheets of Whatman #1, 9 cm) wetted with 5 ml of distilled water or the appropriate concentration of kinetin. The dishes were kept in the dark for 72 hrs unless given a light treatment 16 hrs after the start of the test. It is evident from table II that the response to kinetin has not been very uniform from one test to the next. However, the kinetin at the optimal concentration has always given at least seven times as much germination as that which occurred on water. In considering these data, it is well to keep in mind that root growth of the lettuce seedlings was inhibited severely by kinetin and that this inhibition might be reflected in the data on germination. Although germination obtained with kinetin has never been quite as high as that resulting after exposure to red light, the similarity of the two effects on germination is quite strong. As in the leaf disk experiments, the kinetin effect was not reversed by far-red light.

In the leaf disk test, kinetin promotes cell enlargement. In the pea stem segment test, however, cell elongation is definitely inhibited by the compound even at low concentrations. Segments 5.2 mm long were cut from just below the plumular hooks of 7-day-old, dark-grown, Alaska #323 pea plants. The segments were floated on solutions containing  $1.1 \times 10^{-5}$  M indole-3-acetic acid and various concentrations of kinetin. In 24 hrs on the control solution, the length of the segments increased 2.90 mm. On the same solution with  $2.5 \times 10^{-5}$  M kinetin added, the increase was 1.72 mm. Although no concurrent tests of possible red light effects were made, red light is known to reduce the elongation of pea stem internodes (10).

Analogues of kinetin including 6-benzylamino-purine, 6-phenylamino-purine and 6-hexylamino-purine all show the same types of activity as kinetin in the various tests mentioned above. They have not been studied in detail however. These compounds previ-

ously have been reported to promote cell division in excised tobacco tissues (9). Adenine (6-aminopurine) is inactive in all these tests; thus, substitution in the amino group seems necessary.

The data presented in this paper clearly demonstrate the similarities of the kinetin and red light effects. It is reasonable to think that the two may act through the same biological mechanism. This, of course, needs to be tested much more thoroughly. Nevertheless, kinetin and related compounds may be regarded as promising tools in efforts to understand effects of red light on plants. Certainly, experiments should be performed to see if kinetin can affect flowering in the same manner as red light.

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