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EFFECT OF LIGHT ON PRECLIMACTERIC LIFE OF BANANAS

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SUMMARY

Exposure to artificial light is shown to shorten the preclimacteric life of harvested bananas. The percentage loss appears to be independent of the stage of maturation of the fruit at harvest, but dependent on the period of exposure, at least for a short time after harvest. Exposures to light immediately after harvest are shown to produce a greater effect than if delayed for some time. Two possible mechanisms of the effect are considered.

I. INTRODUCTION

Many effects of visible radiation on plant growth and behaviour have been studied, most work being centred on photosynthesis, photoperiodism and phototropic responses. Its effect on the senescence of plant tissues, however, has had comparatively little study.

Light has been shown to retard the senescence of leaves (Goldthwaite and Laetsch 1967; Eaves and Forsyth 1968; Lewington and Simon 1969; Schwabe 1970) and chloroplasts (Haber *et al.* 1969), but while it has been shown to modify the type and rate of pigmentation of ripening fruits (Nettles, Hall and Dennison 1955; Shewfelt and Halpin 1967; Boe and Salunkhe 1967; Shewfelt 1970), it is not known if it exerts any influence on the initiation of senescence (ripening) of such tissue.

This fact was appreciated by Smock (1970), who stated "there are effects of light on pigmentation of certain fruits after harvest, but there is not good evidence that there is any direct effect of light on ripening". That author could find no effect of this nature when working with pears and bananas.

This paper reports the results of an investigation into the effect of light on the green-life of bananas. (Green-life of climacteric fruit has been defined by Peacock and Blake (1970) as the time that elapses between harvest and the onset of the respiratory climacteric, under defined conditions).

II. MATERIALS AND METHODS

The bananas used in this investigation (cultivar Giant Cavendish, Queensland synonym Mons Mari: Simmonds 1959) were obtained locally and treatments commenced on the day of harvest.

Light for the experiments was provided by combinations of Philips "Warm White" and Atlas "Daylight" 40 W fluorescent tubes together with 100 W tungsten lamps. The usual combination used was four of each. Due to insufficient lights being available, this combination was varied when larger quantities of fruit were used, to a ratio of 4:3:2. Light intensities were measured using an EEL photo-electric photometer.

Fruit were exposed to the light in one of two ways. If respiratory data were being determined, fruit were held individually in clear polystyrene containers ventilated at approximately 60 ml/min with humidified air, the containers being set centrally between two banks of lights. If respiratory data were not required, fruit were held in bulk in glass battery jars, but displayed in the jar so fruit obtained the maximum light possible. The jars were again set between two banks of lights and ventilated with humidified air at approximately 60 ml/min/fruit. The fruit were held as described to avoid effects of ethylene produced by the light ballasts (Wills and Patterson 1970).

Ventilating air streams were monitored for ethylene contamination using an Aerograph 204 gas chromatograph with flame ionization detector and aluminium oxide column. Respiratory rates were followed using a Grubb Parsons infrared gas analyser, the rates of ventilation being monitored with manometric capillary flowmeters. Green-life was determined from the respiratory data by estimating when the climacteric rise commenced. In some experiments, the time that elapsed between harvest and the first detectable change in skin colour was used as a measure of green-life. Peacock (1966) has shown that, at constant temperature, this time varies from green-life by a constant amount.

The experiments reported here were not all conducted at one temperature, due to shortage of facilities. The temperatures used are shown below. Fruit exposed to light were always 0·5 to 1·0°C higher in temperature than fruit held in the dark due to radiant heating, even though rapid air movement was maintained about the containers.

Experiment 1.—Twenty fruit were selected from a hand of freshly harvested bananas, 10 fruit being exposed to light (806 lumens/sq ft), the remainder being kept in the dark. The experiment was conducted at 15°C. Respiratory rates were monitored.

Experiment 2.—Five hands of bananas, judged on the degree of filling of the fingers to be at different stages of maturation, were harvested. Four fruit were used from each hand, two being held in the light (806 lumens/sq ft) and two in the dark. The experiment was conducted at 15°C and respiratory rates monitored.

Experiment 3.—Three samples of eight fruit were selected from one hand of freshly harvested bananas and exposed to the following treatments:

Treatment (a) Held in the dark continuously,

Treatment (b) Held in the light continuously,

Treatment (c) Held in both light and dark, 12 hr of each, continuously cycling.

The experiment was conducted at 25°C and respiratory rates monitored. Light intensity was approximately 809 lumens sq ft.

Experiment 4.—One hand was selected from each of four freshly harvested bunches (trial a). The fingers from each hand in turn were randomized and spread over nine treatments, viz. 0, 2, 4, 6, 8, 10, 12, 14 and 16 days exposure to light (661 lumens/sq ft). While in the light, fruit were ventilated with humidified air at approximately 60 ml/min/fruit. On removal from the light, fruit were held in the dark, in bulk, in a specially designed cabinet in which they were ventilated with humidified air at a rate in excess of 100 ml/min/fruit. The cabinet was temperature controlled, the experiment being run at 20°C. Fruit were examined daily and the time to the first detectable change in skin colour was recorded. The fruit due to receive 0 days of light were inadvertently misplaced, but the remaining data are reported.

The experiment was repeated (trial b) using in all 36 fruit from two hands of each of three bunches. Fruit from each hand were randomized as before into six treatments, viz. 0, 1·5, 3, 4·5, 6, 7·5 days of light (661 lumens/sq ft). All other conditions were maintained.

Experiment 5.—Five hands from each of two freshly harvested bunches were divided into eight samples, each containing two fruit from each hand. Samples were exposed to light (661 lumens/sq ft) for 2 days after first being held in the dark for 0, 2, 4, 6, 8, 10 and 12 days. One sample was kept in the dark continuously as a control. Before and after exposure to the light, fruit were held in the cabinet described above. The experiment was conducted at 20°C, the fruit again being examined daily and the time to the first detectable change in skin colour recorded.

III. RESULTS

Experiment 1.—From the results (Table 1), it can be seen that the green-life of bananas is significantly reduced ($P<0·001$) in the presence of light.

TABLE 1

EFFECT OF LIGHT ON GREEN-LIFE (DAYS) OF BANANAS

Light	Dark
5·25	13·00
5·25	10·50
4·50	9·75
4·50	6·50
5·00	11·25
4·50	10·25
4·25	10·50
5·00	9·75
7·25	10·00
7·25	12·25
Mean .. 5·28	10·38
S.D. .. 1·096	1·740

$P < 0·001$

Experiment 2.—The reduction in green-life is not a function of the stage of maturation of the fruit (Figure 1) since, even though fruit used ranged in green-life (in the dark) from 16·5 to 61·4 days, the reduction in green-life was constant at 44%. Again the reduction in green-life was highly significant ($P<0·01$).

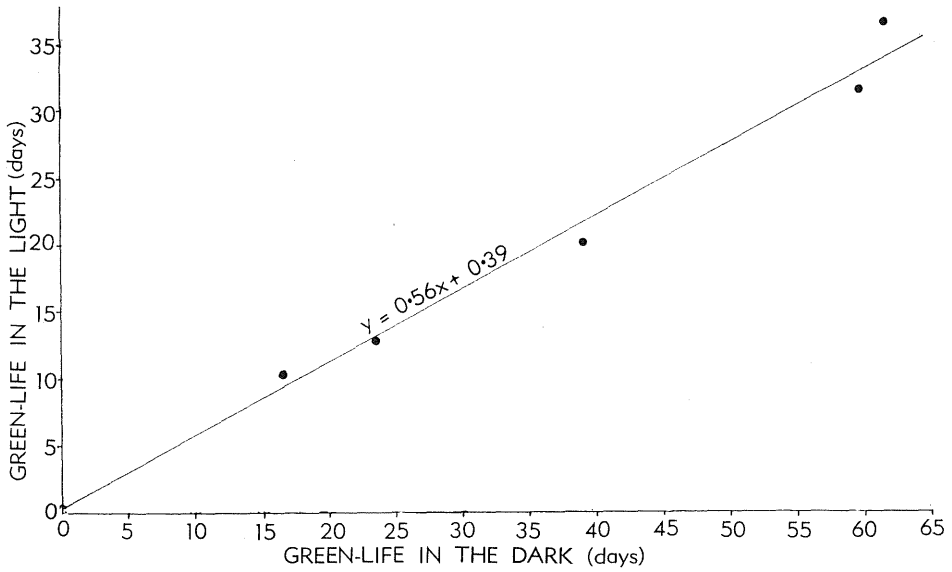

Fig. 1.—Relationship between green-life under continuous light and stage of maturation at harvest (green-life in the dark).

Experiment 3.—An initial experiment to determine if this effect of light was dependent on the period of exposure produced the results shown in Table 2. The application of light in the form of 12 hr cycles ensured that this treatment received approximately half the quantity of light received by the fruit of the continuous light treatment, irrespective of the green-life of the fruit employed. The green-life of fruit in the continuous treatment was reduced by 46·6%, while that in the cycling treatment was reduced by 21·3%, nearly half as much. Both reductions are highly significant ($P<0·01$). Thus it appears that the effect of light is a linear function of the period of exposure.

TABLE 2

EFFECT OF CONTINUOUS AND DISCONTINUOUS LIGHT ON GREEN-LIFE (DAYS)

Green-life in the Dark	Green-life in Cycling Light (12 : 12)	Green-life in Continuous Light
11·3	8·3	5·2
9·3	8·2	4·8
7·8	6·9	4·9
10·8	7·2	4·8
7·3	6·1	4·7
10·4	6·1	4·7
8·8	8·0	5·0
7·5	6·9	5·2
9·15	7·20	4·91

$P < 0·01$

Experiment 4.—This experiment was conducted to verify the result of experiment 3. In the first trial (trial a—Table 3), exposure to light for periods greater than 6 days did not produce any further reduction in green-life, whereas in the second (trial b—Table 4), this was so after 3·0 days. These results indicate that the process being affected by light is virtually completed within 3–6 days of the exposure to light commencing and that over this period the amount of reduction obtained is a linear function of the period of exposure. This means that the effect obtained in experiment 3 was probably due solely to the light applied soon after harvest.

TABLE 3

EFFECT OF LENGTH OF EXPOSURE TO LIGHT ON GREEN-LIFE (DAYS)—TRIAL (a)

Period of Exposure (days)	2	4	6	8	10	12	14	16
Bunch 1	26	17	10	10	11	11	10	12
	26	21	11	11	11	11	11	12
	28	22	19	13	12	12	11	14
Mean	26·7	20·0	13·3	11·3	11·3	11·3	10·7	12·7
Bunch 2	19	12	10	11	10	10	10	11
	21	14	10	12	10	10	10	10
	26	17	9	13	11	9	10	13
Mean	22·0	14·3	9·7	12·0	10·3	9·7	10·0	11·3
Bunch 3	28	22	10	16	12	12	13	12
	30	25	21	17	12	12	13	14
	31	28	22	22	16	15	13	15
Mean	29·7	25·0	17·7	18·3	13·3	13·0	13·0	13·7
Bunch 4	16	15	9	11	10	10	10	11
	21	19	10	12	10	12	10	11
	26	22	13	12	11	13	9	14
Mean	21·3	19·0	12·3	13·0	10·5	12·3	9·8	12·0
Overall mean ..	24·6	19·5	13·2	13·6	11·3	11·6	10·8	12·4

Necessary differences for significance between overall means: 2·38 (5%), 3·24 (1%).

$2 \gg 4, 6, 8, 10, 12, 14, 16$

$4 \gg 6, 8, 10, 12, 14, 16$

$6, 8 > 14$

Experiment 5.—The results of this experiment (Figure 2) demonstrate that the effectiveness of a light exposure in reducing green-life decreases, apparently linearly, with time, the later the exposure is applied after harvest.

In view of recent data (Peacock and Blake 1970; Blake and Peacock 1971) on the quantitative effects of temperature on the green-life of bananas, the results obtained in these experiments cannot be accounted for by the small temperature differences (0·5–1·0°C) that existed between light and dark treatments. The observed results hence demonstrate a real effect of light on green-life.

TABLE 4

EFFECT OF LENGTH OF EXPOSURE TO LIGHT ON GREEN-LIFE (DAYS)—TRIAL (b)

Period of Exposure (days)	0	1·5	3·0	4·5	6·0	7·5
Bunch 1—						
Hand 1	48	28	23	20	22	18
	54	36	24	22	24	23
	56	49	24	25	32	24
Hand 2	42	30	22	24	23	25
	54	32	24	34	32	29
	58	35	25	37	34	27
Mean	52·0	35·0	23·7	27·0	27·8	24·3
Bunch 2—						
Hand 1	38	24	22	20	17	17
	41	25	24	22	21	25
	45	28	25	23	22	27
Hand 2	33	27	23	24	23	20
	40	28	24	25	24	25
	41	28	32	27	24	25
Mean	39·7	26·7	25·0	23·5	21·8	23·2
Bunch 3—						
Hand 1	37	28	24	23	24	17
	38	38	25	25	26	17
	38	41	34	26	30	23
Hand 2	37	23	24	17	24	17
	37	24	27	24	25	23
	38	27	29	24	27	27
Mean	37·5	30·2	21·2	23·2	26·0	20·7
Overall mean	43·1	30·6	23·3	24·6	25·2	22·7

Necessary differences for significance between overall means: 3·80 (5%), 5·26 (1%).

$0 \gg 1{\cdot}5, 3{\cdot}0, 4{\cdot}5, 6{\cdot}0, 7{\cdot}5$

$1{\cdot}5 \gg 3{\cdot}0, 4{\cdot}5, 6{\cdot}0, 7{\cdot}5$

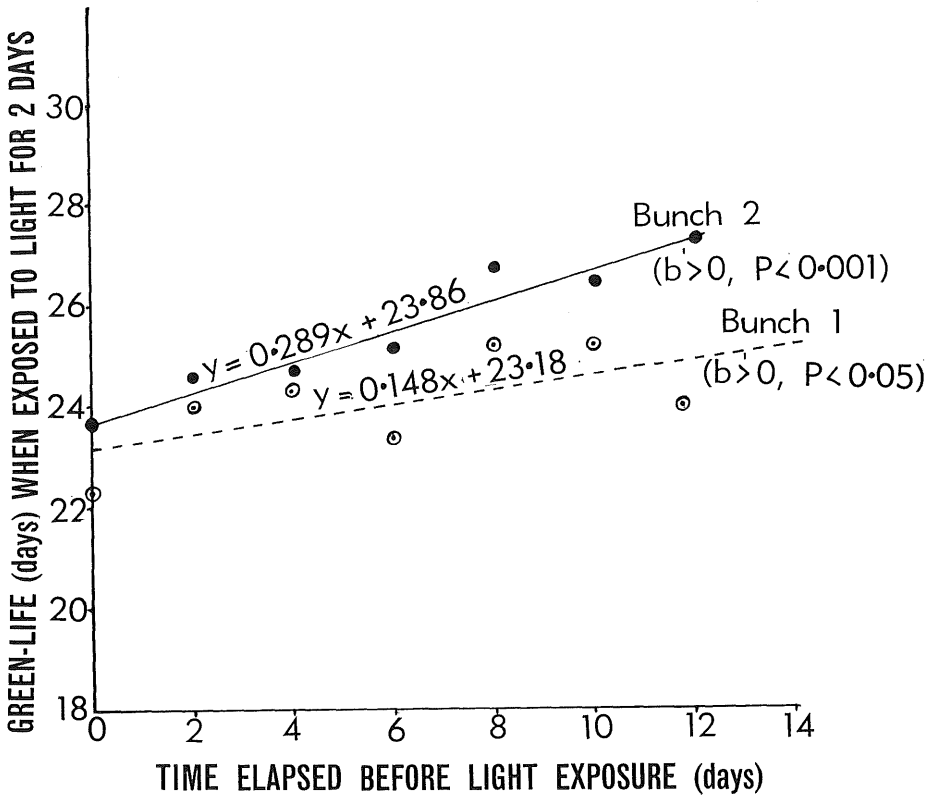

Fig. 2.—Effect of an exposure of 2 days to light on green-life when exposed at varying times after harvest. Green-life bunch 1 (absence of light) = 26·9 days. Green-life bunch 2 (absence of light) = 32·4 days.

IV. DISCUSSION

Light has been shown to shorten the green-life of bananas, an opposite effect to that which it exerts on the senescence of leaves (Goldthwaite and Laetsch 1967; Eaves and Forsyth 1968; Lewington and Simon 1969; Shwabe 1970) and chloroplasts (Haber *et al.* 1969). Goldthwaite and Laetsch (1967) concluded that the retarding effect of light on the senescence of leaves was mediated through photosynthesis, whereas Haber *et al.* (1969) concluded that its effect on chloroplast senescence was not. A separate study, probably based on the behaviour of tissue pieces, would be required to ascertain this fact. However, the results of recent investigations do suggest some processes that may be involved.

Rogers (1968) has shown that exposure to light increases the ethylene production rate of citrus leaves. A similar result has been obtained in this laboratory using leaves of *Nymphoides indica* (Peacock, unpublished data). Photocontrol of ethylene production has also been demonstrated in *Lactuca sativa* (Abeles, Holm and Gahagan 1967). Recent evidence (Peacock 1971) has shown that the green-life of bananas can be shortened by a brief exposure to

ethylene, the exposure being insufficient to induce immediate ripening. Thus, should light increase the ethylene production rate of fruit, this perhaps accounts for the observed results. Peacock (1971) has also shown that after harvest bananas become more sensitive to ethylene as they approach maturity (the onset of the respiratory climacteric). This, however, is contrary to the effectiveness of light, which produces the greatest reduction of green-life if applied immediately after harvest (experiment 5). Any proposal that ethylene is a factor involved would have to explain this difference.

In recent years evidence has been presented with implicates plant hormones in the senescence of plant tissues in general (Varner 1961; Sax 1962), and fruit in particular (Dilley 1969; Looney 1970; Vendrell 1969, 1970*a*, 1970*b*). Vendrell (1969) provides good evidence that endogenous auxins may play a key role in fruit ripening. Using banana slices he was able to demonstrate that both 2,4-dichlorophenoxyacetic acid and indoleacetic acid were effective in delaying the initiation of ripening. This result indicates that ripening in fruit may be initiated through a decrease in the concentration of endogenous auxins. If this is so, then the effects of light may be made manifest through the destruction of endogenous auxins. Light-activated enzymic destruction of indoleacetic acid is well documented (Galston, Bonner and Baker 1953; Fang and Butts 1957; Collins and Irving 1967), while it is known that non-enzymic photo-oxidation of auxin can also occur (Fukuyama and Moyed 1964).

The high sensitivity of bananas to light immediately after harvest, and the fact that the intensities used are only approximately 6% of the intensity of full sunlight, indicate that the effect could be of commercial significance and that field handling practices should be such that fruit are protected from light as much as possible prior to packing.

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