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EFFECT OF WATER STRESS ON ETHYLENE  
PRODUCTION BY PRECLIMACTERIC BANANA  
FRUIT

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SUMMARY

Ethylene production in preclimacteric banana fruit was increased by water stress, but diminished exponentially when the stressing conditions were removed. Under continuing stress, ethylene production was maintained at a high level. It is concluded that ethylene is a likely mediator of green-life reduction and of the higher respiration rates found in water-stressed fruits.

I. INTRODUCTION

The stimulation of ethylene production in preclimacteric fruit which have been subjected to stresses of various types is well documented (Burg 1962; Pratt and Goeschl 1969). Radiation, wounding, disease, chilling and high oxygen concentration are some of the stresses implicated.

Although water stress has not been reported as increasing ethylene production, it has been found (Littmann 1972*a*, 1972*b*) to effect two known responses to ethylene by fruit in the preclimacteric state (Regeimbal, Vacha and Harvey 1927; Harvey 1928). These responses are an increase in the respiration rate and a reduction in green-life. (Green-life of preclimacteric fruit is defined (Peacock and Blake 1970) as the time that elapses between harvest and the onset of the respiratory climacteric). The increased ethylene production found in mechanically wounded banana fruit appears to be the cause of their earlier ripening (Maxie *et al.* 1968).

The aim of the work reported in this paper was to establish if water stress also stimulated ethylene production in preclimacteric banana fruit.

II. MATERIALS AND METHODS

Preclimacteric banana fruit (*Musa acuminata* Colla cv. Giant Cavendish) were obtained from a local grower. Each fruit was placed in an individual container ventilated with air at either high or low humidity. The details of the method are those given by Littmann (1972*a*).

After a number of days, samples of stressed and unstressed fruit were removed, and measurements were made of ethylene production and water potential. Water potential was determined by the method of Chardakov (1953) and ethylene production by holding fruit in individual containers and allowing ethylene to accumulate to measurable levels.

Periods of accumulation of ethylene were between 16 and 26 hr, and the containers were so constructed that changes in carbon dioxide and oxygen concentration were minimized. Wide-mouthed reagent bottles (550 ml) with ground-glass stoppers were used. Two  $\frac{1}{4}$  in. holes were drilled in opposite sides of the jar. One of these held a septum suitable for taking gas samples by syringe and the other supported a glass U-tube which functioned as a water trap. This in turn supported a glass tube about 4 in. long containing pellets of "Purafil" (alumina pellets infiltrated with potassium permanganate). The ground-glass stopper was made air-tight by smearing with stopcock grease, and other glass-to-glass joints were made with short lengths of polyvinyl tubing, the joints being sealed with a film of "Aquadhere" (an adhesive manufactured by Selleys Chemical Co.). To each container was added 20 ml of 10% KOH solution to absorb carbon dioxide. The banana fruit were supported over this solution by standing in porcelain crucibles. The jars were held at constant temperature (20°C) and as the fruit respired, external air freed of ethylene was drawn in.

Gas samples were taken from the jar using a gas syringe, and ethylene concentration was determined by gas chromatography, using an aluminium oxide column and flame ionisation detector. Intercellular spaces of banana tissue are reported as amounting to at least 10% by volume (Palmer and McGlasson 1969), so in the calculation of ethylene production rate from concentration of ethylene in the jar, air-space was determined by subtracting, in addition to KOH volume, 90% of the fruit volume from that of the jar. The precautions outlined by Burg and Burg (1961) were taken on a number of occasions to make certain that ethylene was responsible for the chromatographic peak measured.

To ensure that ethylene production rates of non-ripening fruit were being taken, readings were made for a number of days. After each daily reading the containers were opened and were allowed to stand in air for approximately 1 hr, after which the lids were resealed and initial ethylene readings taken. Blank determinations taken from time to time indicated that no measurable amounts of ethylene were leaking into the containers.

### III. RESULTS

In Table 1 are shown the results of three experiments where ethylene production was measured during the first day after removal from the stressing conditions. In each experiment, the decrease in water potential caused an increase in ethylene production to more than double the unstressed level. Water potentials were decreased by from 1.3 atm (-9.5 to -10.8 atm) to 3 atm (-10.3 to -13.3 atm). All increases in ethylene production rates were statistically significant.

In Table 2 are shown the ethylene production rates of fruit from a fourth experiment over the first 3 days following removal from stress and control (unstressed) conditions. Although no significant change occurred in the level of the unstressed fruit, the ethylene production of the stressed fruit fell from 0.1061  $\mu\text{l}/\text{kg}/\text{hr}$  to 0.0626  $\mu\text{l}/\text{kg}/\text{hr}$  ( $P < .01$ ) in 3 days.

TABLE 1  
EFFECT OF WATER STRESS ON ETHYLENE PRODUCTION  
 $\mu\text{l/kg/hr}$

Expt. No.	Days Under Treatment	Unstressed				Stressed				Significance of Differences ( $P <$ )	Relative Rate Ethylene (stressed) / (unstressed)
		Weight Loss (%)	Water Potential (atm.)	No. of Fruit	Mean Ethylene Production $\pm$ S.E.	Weight Loss (%)	Water Potential (atm.)	No. of Fruit	Mean Ethylene Production $\pm$ S.E.		
1	3	0.35	- 10.0	4	0.0230 $\pm$ 0.0035	8.22	- 12.3	3	0.0564 $\pm$ 0.0108	0.05	2.46
2	6	- 0.43	- 10.3	3	0.0357 $\pm$ 0.0064	14.75	- 13.3	4	0.0885 $\pm$ 0.0146	0.05	2.48
3	10	- 0.34	- 9.5	4	0.0425 $\pm$ 0.0016	20.46	- 10.8	3	0.0949 $\pm$ 0.0196	0.01	2.23

TABLE 2

EFFECT OF REMOVAL OF STRESSING CONDITIONS ON ETHYLENE PRODUCTION AFTER 5 DAYS' STRESS  
 $\mu\text{l/kg/hr}$ 

Day	Unstressed		Stressed	
	Weight Loss (%)	Water Potential (atm.)	Weight Loss (%)	Water Potential (atm.)
	0.71	- 8.0	11.63	- 12.0
1 .. .. .	0.0483 $\pm$ 0.0037		0.1061 $\pm$ 0.0100	
2 .. .. .	0.0464 $\pm$ 0.0066		0.0812 $\pm$ 0.0060	
3 .. .. .	0.0422 $\pm$ 0.0060		0.0626 $\pm$ 0.0042	
Significance differences	of	Not significant	Days 1 and 3; $P < 0.01$ Days 2 and 3; $P < 0.05$	

Inspection of the ethylene production curve of stressed fruit over a larger time period indicates that the points closely fit an exponential curve (of the form  $y = a + bc^x$ , where  $y$  is ethylene ( $\mu\text{l/kg/hr}$ ),  $x$  is time in days, and  $a$ ,  $b$  and  $c$  are constants). The line of best fit for this relationship was  $y = 0.03971 + 0.06677(0.6071)^x$ , and real and computed values are shown in Figure 1.

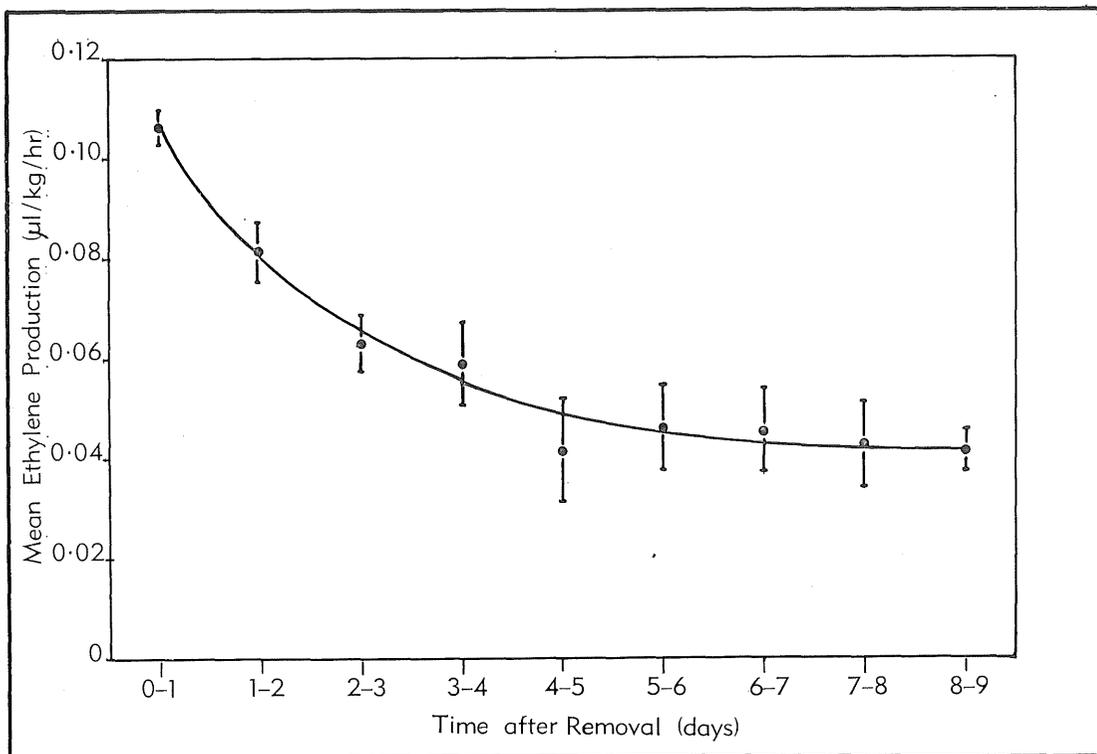


Fig. 1.—Ethylene production, with time, of fruit removed from stressing conditions calculated from each accumulation period of approximately 1 day.

The experiments were performed a number of times, and on occasions some stressed fruit had commenced to ripen when ethylene determinations were begun. However, this was not the case in any of the figures quoted. The ethylene levels fell exponentially to a low level until the ethylene increase associated with fruit ripening occurred.

The steady state level which was approached was usually greater than that of the unstressed fruit. However, this was not always the case, and an understanding of the relationships involved would require further work.

#### IV. DISCUSSION

The results establish that ethylene production of banana fruit is stimulated by water stress to levels which fall only when stressing conditions are removed.

A similarity in the response of ethylene production of fruit tissue to decreasing water potential exists between these results and those of Burg and Thimann (1960). These authors showed that apple and pear tissues soaked in water developed an inhibition of ethylene synthesis, reversible by increasing the tonicity of the bathing solution, and which was seemingly controlled by some critical solute concentration within the tissue. However, the appreciable leakage of solutes reported by these authors and others (Baur and Workman 1964; Ben-Yehoshua 1964) and the well-documented differences between the biochemistry of water-bathed tissue slices and that of the parent organ from which they were taken (Latic 1963, 1967; ap Rees 1966) indicate the care required when comparing effects found in whole organs and in water-bathed tissues.

The most commonly discussed notions concerning the relationship between ethylene concentration and the ripening response of fruit are that endogenous ethylene increases until a stimulatory concentration occurs (Burg 1962; Pratt and Goeschl 1969) and that fruit change in sensitivity to ethylene (Kidd and West 1945; Burg and Burg 1965). In either case it seems likely that the effect of a higher concentration in fruit tissue would result in earlier ripening. It is therefore proposed that ethylene is a common mediator for the reduced green-life found in climacteric-type fruit and for the augmented respiration rate found in stressed preclimacteric banana fruit.

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