Auxin-Induced Ethylene Formation: Its Relation to Flowering in the Pineapple

Abstract. *Within 1 day after pineapple plants are treated with naphthalene acetic acid they begin producing ethylene. It is suggested that applied auxins mimic the action of ethylene by stimulating ethylene formation, and that ethylene, not auxin, causes pineapples to flower.*

Pineapple plants are induced to flower by application of auxin (*1*). Hence accumulation of auxin in the stem apex might be responsible for the flowering of these plants under natural conditions. This concept is supported by the observation that geotropically stimulated pineapple plants flower prematurely (*2*), presumably because auxin is concentrated in the lower side of the stem apex. In opposition to this theory it has been pointed out that unsaturated gases such as ethylene and acetylene induce formation of flowers in pineapples and other bromeliads (*3, 4*) without increasing the auxin content (*5*); ethylene usually lowers the concentration of diffusible auxin in plants (*6*). The explanation for these apparently conflicting observations becomes clear when consideration is given to the effect which auxin has on the rate of formation of ethylene. Auxins induce ethylene formation in a variety of plants (*7–9*), and it has been demonstrated that the resultant ethylene causes epinasty (*7*), inhibition of growth, swelling, and ageotropism (*9*). In every case the same symptoms are evoked by auxin or ethylene because ethylene is the causative agent and auxin induces ethylene formation. We now present evidence suggesting that initiation of flowering in the pineapple is controlled by ethylene rather than auxin, the latter functioning indirectly to stimulate flowering by inducing ethylene formation.

Potted pineapple plants (*Ananas sativus* var. Pernambuco), 8 months old, were obtained from a local nursery. They were sealed in 40-liter glass chambers and illuminated with Sylvania Grolights which provided light of intensity 300 μw/cm^2 at the leaf surface. At 1- or 2-day intervals 5-ml samples of air were withdrawn with a gas-tight hypodermic syringe through a rubber port in the top of the container, and the ethylene content of the samples was determined by a gas chromatographic procedure (*10*) capable of detecting as little as 40 nl of ethylene produced per plant (1 part of ethylene in 10^9). The containers were aerated for 1 hour every 3 to 4 days; under these conditions it was not possible to measure any ethylene formation by control plants during a 2-week period. However, within 1 day after 5 ml of naphthalene acetic acid (NAA) was poured into the center of the plants, ethylene emanation began (Table 1). The concentration of acid was such (100 mg/liter) that each plant received 0.5 mg of the auxin, an amount maximally effective in inducing flower formation in other varieties of pineapple (*2, 11*) and able to bring this variety into flower in about 6 weeks. In six experiments the ethylene formation was sustained for about 1 week, but in one instance (experiment 2) it was of shorter duration. Since the flowering of pineapples is hastened when smoke or ethylene is applied for only 12 to 24 hours (*3*), and since the variety Pernambuco consistently flowers within 6 weeks after such treatment, it is clear that the auxin-induced ethylene formation noted in Table 1 is of sufficient duration to account for the flower-initiating ability of applied NAA. Each plant used (except for that in experiment 2) evolved between 15 and 60 μl of ethylene per kilogram fresh weight during a 24-hour period at some time after NAA was applied. If the ethylene were produced equally throughout the root and shoot systems, the average concentration of the gas within the plant would be not less than 0.1 part per million and perhaps as high as 4 ppm (*12*). However, in the region of the presumptive flower bud where NAA was applied, ethylene must be formed most rapidly and its content ought to be considerably higher than these average values would indicate. In the bud the concentration might easily exceed 1 ppm, an amount maximally effective in promoting most responses to the gas (*13*). Therefore the evidence favors the view that enough ethylene is produced after NAA is applied to pineapple plants to account for their subsequent transition to the flowering state.

Table 1. Stimulation of ethylene formation in pineapple plants treated with NAA. Five milliliters of naphthalene acetic acid (100 mg/lit.) was poured into the center of each plant. For 7 days before this treatment the plants produced no detectable ethylene. Control plants which did not recieve NAA failed to produce measurable ethylene for at least 2 weeks.

Days after treatment	Ethylene production (milliliters per plant)						
	Exp. 1	Exp. 2	Exp. 3	Exp. 4	Exp. 5	Exp. 6	Exp. 7
1				1.0	1.4	1.1	1.0
2	1.2	1.8	3.8	13.0	16.4	4.3	5.9
3		2.1				15.7	12.5
4		2.1	11.5				
5	6.2	2.2		30.6	43.2	29.3	14.9
6						34.7	13.1
7	13.4		17.0	31.6	48.1	34.9	

STANLEY P. BURG
ELLEN A. BURG
Program in Cellular and Molecular Biology, University of Miami School of Medicine, Miami, Florida 33136

References and Notes

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12. These values refer to the partial pressure of ethylene in the gas phase with which the tissue has equilibrated. The low estimate is derived from studies with sections of pea stem (*9*); these studies show that the tissue grows as though it had been exposed to 1 ppm of ethylene when it evolves the gas at a rate of about 5 μl/kg (fresh wt.) per hour. A similar relationship between internal concentration of ethylene and rate of ethylene production was derived from experiments with sunflower stem sections (Burg and Burg, unpublished data). The high estimate is based on studies with different varieties of fruits (*10*) in which it was found that at least 2 ppm of ethylene is contained in the air spaces within the tissue when the gas is produced at a rate of 1 μl/kg (fresh wt.) per hour.
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