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ETHYLENE AND SENESCENCE IN FLOWERS<sup>1</sup>

STABY - OSU

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Vase life of cut flowers, as well as blooming life of flowering pot plants, is a significant factor in the salability of the florists' product. Research is currently being conducted that will help increase the longevity of flower life. Many of these studies deal with the plant hormone ethylene.

Ethylene is widely recognized as an important ubiquitous plant hormone involved in many developmental processes including fruit ripening, abscission, senescence, growth, flowering and sex expression. However, the initial biochemical event triggered by ethylene which ultimately causes these diverse developmental stages is unknown.

During studies aimed at better understanding of this key event, silver ion (Ag(I)) was found to block ethylene action effectively. This property of Ag(I) surpasses that of the well known ethylene antagonist, CO<sub>2</sub>, and, therefore, should provide a new experimental tool for studying ethylene action and defining further its role in plant growth. Here, the author reports the ability of Ag(I) to block specifically the action of exogenously applied ethylene in such classical ethylene responses as abscission, senescence and growth retardation.

The general experimental approach in one study was to treat orchids with various concentrations of AgNO<sub>3</sub> and observe the protection afforded by such treatments following a given ethylene exposure. (Although silver nitrate was the preferred salt, because of its water solubility and immediate laboratory availability, other salts such as silver acetate and silver lactate have also been found to be effective.)

In this experiment, hybrid white cattleya orchids in 100 percent medium Douglas fir bark were treated with AgNO<sub>3</sub> for three days prior to flower scape emergence from the sheath. The amount of AgNO<sub>3</sub> was reduced each day. Then the fully opened plants were exposed to ethylene for 14 hours. Plants were then observed for effects. (It was necessary to expose the flowers to ethylene shortly after they had fully opened since three to five days later, flower hardening had occurred which greatly reduced their sensitivity to ethylene).

The ability of a substance to block specifically the action of a plant hormone in the intact plant to the extent reported in this experiment is unparalleled in plant biology. The most outstanding antiethylene properties of Ag(I) are its persistence, specificity and lack of phytotoxicity at effective concentrations. In addition to the responses reported here, Ag(I) has also been found to block ethylene action in tomato and cucumber plants.

How then does Ag(I) work? Although its exact mode of action is not known, one possibility is that it interferes directly with ethylene action at the ethylene receptor site. One theory of ethylene action proposes that ethylene is attached briefly to a metallic receptor site. The attachment process activates the receptor molecule thereby initiating important biochemical events which ultimately lead to the ethylene response. This process is instituted during the oxidation of ethylene to CO<sub>2</sub>.

Cut carnations were exposed to ultra high purity <sup>14</sup>C<sub>2</sub>H<sub>4</sub> during flower opening and senescence in another experiment to study its incorporation and metabolism. Cut carnations were examined in this study because they produce ethylene at substantial rates during senescence and are highly responsive to the gas, providing circumstantial evidence that the gas is a natural accelerator of senescence in these flowers.

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In the experiment,  $^{14}\text{C}_2\text{H}_4$  was injected into carnation stems and  $\text{CO}_2$  given off was collected for measurement. Carnations, cut in the tight bud stage and placed in water, open and senesce naturally although at an accelerated rate. At the tight bud stage, the petals already extend beyond the sepals but are held folded closely together by the sepal collar. When placed in water, the petals expand rapidly, reaching full bloom in five to eight days. Shortly thereafter the petals roll inward, wilt and within 24 to 48 hours become completely dried and shriveled. During the period of rapid petal expansion, the flower takes up water at a steady rate and the fresh weight increases 20 to 25 percent. Respiration, on the other hand, as measured by  $\text{CO}_2$  production, steadily declines, but then rises as senescence commences. Just at the onset of wilting, or slightly preceding it, a dramatic but short-lived surge in ethylene occurs, and ethylene increases 10 to 50 times in 24 hours. This surge is not restricted to the cut flower as it has also been found to occur at even higher rates in flowers still attached to the plant.

Undoubtedly the relatively large amount of ethylene produced by carnation flowers influences their further development since ethylene exposure induces premature senescence. As with many tissues, the degree of injury caused by a given concentration of ethylene is dependent on both the temperature and the duration of exposure and is reversible to a point. Furthermore,  $\text{CO}_2$ , a well known antagonist of ethylene action, will prolong the normal vase life of untreated flowers and block the senescence-inducing effects of added ethylene. Exogenous ethylene also stimulates respiration and dry matter accumulation of the ovary which are natural phenomena associated with endogenous ethylene production.

Based on the data obtained in this experiment, it would appear that ethylene may function as a natural regulator of floral development in carnations.

Morning Glory blooms were used in another experiment as a continuation of these studies. Prior to the study of the metabolism of carnations, and peas, it was not known that an active ethylene metabolic system oxidizes ethylene to  $\text{CO}_2$  and incorporates ethylene into water-soluble tissue metabolites.

Recently, several reports have appeared on the regulatory involvement of ethylene in the senescence of the morning glory flower. Since cut carnations actively metabolize ethylene during flower opening and senescence, it was of interest to see if morning glory flowers behave similarly.

The flowers were periodically evaluated for their ability to metabolize ethylene. This evaluation covered a 5-day period beginning three days before and ending two days after bloom. Data presented indicated that morning glories, like carnations, have the metabolic competency at certain stages of flower development to oxidize ethylene to  $\text{CO}_2$  and to incorporate ethylene into water-soluble tissue metabolites.

Kende and Baumgartner first studied the possible involvement of ethylene in the regulation of aging these flowers. Evidence suggesting such a link including a sharp increase in the rate of natural ethylene production coincident with petal senescence, the ability of added ethylene to induce ethylene production and premature senescence and the ability of the ethylene antagonist,  $\text{CO}_2$ , and an ethylene trap to delay senescence.

These and other data indicated that the ethylene-producing system develops as an integral part of the aging process in the morning glory and may not be the initial causative agent.

As in other studies, the capacity of the tissue to carry out ethylene metabolism was not always the same. In the case of ethylene oxidation, no activity was detected

until about 16 hours before flower opening. At this time the buds appeared to develop this capability and it rapidly increased with time reaching a peak just after flower opening. This peak activity was about 7 percent of that observed during peak activity in cut carnations.

In carnations, the peak in ethylene oxidation was more associated with the late stages of senescence and developmentally corresponded more with the second peak of ethylene oxidation in morning glories.

With regard to tissue incorporation of ethylene, the order of activity was petals, then reproductive parts, and then stems. This was in contrast to cut carnations, where the reproductive tissues were exceptionally active as compared to the other flower parts. However, in both flowers the peaks in ethylene oxidation occurred concomitantly with peaks in tissue incorporation.

Although ethylene metabolism has been examined critically in only a limited number of plant tissues, it appears that this metabolism is an integral part of the plant's ethylene biochemistry. Like ethylene sensitivity and biosynthesis, the ability of the plant tissues to metabolize ethylene changes during development.

Early work with  $^{14}\text{C}$ -labeled ethylene resulted in the general view that ethylene undergoes no permanent chemical change either before, during, or after it accomplishes its biological functions. More recent work with  $^{14}\text{C}_2\text{H}_4$  applied to plant tissue has made it necessary to change this view since an active ethylene metabolic system has been found in several plants. Based on this work, it was suggested that ethylene metabolism is an integral part of the ethylene action mechanism. Specifically, the constant metabolic turnover of ethylene in terms of oxidation and incorporation at a metallic receptor site was proposed as the initial biochemical event in the ethylene action sequence.

$\text{Ag(I)}$ , high  $\text{CO}_2$  and low  $\text{O}_2$  have all been reported to have antiethylene properties. Therefore, these treatments might also be expected to modify ethylene metabolism if, as proposed, metabolism is linked to ethylene action.

Regardless of the functional connection that may exist between ethylene action and metabolism, it is apparent from these studies that the ethylene metabolic system is relatively complex, consisting of not a single pathway but one involved in the incorporation of ethylene and another responsible for the oxidation of ethylene to  $\text{CO}_2$ .

EDITOR'S NOTE: *Elmer M. Beyer, Jr. is a researcher at E. I. du Pont de Nemours & Co. experimental station, Wilmington DE. This article is a compilation of studies done by Beyer. They include: "Effect of Silver Ion, Carbon Dioxide and Oxygen on Ethylene Action and Metabolism," Plant Physiology Vol. 63, 1970; " $^{14}\text{C}_2\text{H}_4$ : Its Incorporation and Oxidation to  $^{14}\text{CO}_2$  by Cut Carnations," Plant Physiology, Vol. 60, 1977; "A Potent Inhibitor of Ethylene Action in Plants," Plant Physiology, Vol. 58, 1976, and "Ethylene Antidote," HortScience, Vol. 11, No. 3, June 1976.*

<sup>1</sup>REPRINTED from Florists' Review, January 3, 1980.

NOTE: Gladiolus flowers are "put to sleep" by ethylene as some other flowers are. Flower buds stored with ripe or ripening fruit such as apples and bananas may not open their florets. Open flowers wilt in the presence of ethylene. (Ed.).