in a normal germination time frame. These increases in rate and in percentage seed germination are of great value to the plant propagator.

It may be of real value to use this method to try and speed up the germination process or to increase the percentage of any seed which are slow to germinate, or have a low percentage germination. In addition, the method is simple and cheap.

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A BRIEF REVIEW OF ETHYLENE IN PROPAGATION

DAVID H. SIMONS

Department of Horticulture
Queensland Agricultural College
Lawes, Queensland 4343

Abstract. Ethylene is a gaseous plant hormone affecting a wide range of plant growth and development responses It is effective in minute concentrations and is extremely common in the environment It is difficult to avoid exposure of plants to ethylene

There is conflicting evidence of the effects of ethylene in plant propagation and minor changes in conditions appear to alter the response from promoting rooting to inhibiting it In some cases ethylene clearly promotes root initiation, or root elongation Ethylene effects in propagation can be tested by adding it, most conveniently as ethephon, or by removing it with ventilation Its action can be inhibited by silver thiosulphate.

INTRODUCTION

Ethylene is now generally recognized as a plant hormone. It is commonly known for its ability to stimulate fruit ripening and to induce senescence responses such as abscission or dropping of leaves and flowers but, like other plant hormones, its effects have been documented in relation to a very wide range of plant responses, including:—

Seed Germination — breaking dormancy
— stimulation and inhibition of seedling growth

Growth of Shoots— stimulation and inhibition
— change in nature of growth to short and fat
— a changed angle of growth

Induction of Root Initials — generally promotes induction

Growth of Roots — generally inhibits elongation
— very low concentrations can promote elongation
— promotes root hair formation

Induction of Flowering — in bromeliads, mango, etc.

Control of Sex Expression — promotes femaleness

Fruit Growth — promotes growth of fruit, such as figs

Fruit Ripening — stimulates ripening of climacteric fruits
— degreening of fruits is promoted

Senescense — leaf senescence promoted
— flower senescence promoted
— abscision of flowers, leaves, and stems promoted.

Like other hormones ethylene is effective at minute concentrations, in the part per billion to part per million range, not the percentage range — where it forms an explosive mixture with air.

Ethylene is extremely common in the environment. It arises as an air pollutant, especially from the internal combustion engine; from incomplete combustion of organic materials (i.e. from smoky fires); from the ballasts in fluorescent lights; from plants, particularly stressed plants, whether that be water stress, nutrient stress, physical pressure (e.g. wind, handling, packaging or transport); disease or wounding such as that associated with preparation of cuttings. Consequently it is difficult to avoid exposure of plants to ethylene during propagation or during growth and marketing.

ETHYLENE IN PROPAGATION

The first published report of ethylene stimulation of root formation was by Zimmerman and Hitchcock in 1933 (10). This was a year before auxin was shown to also stimulate rooting (9). There has been a continuing sequence of apparently contradictory reports about the effects of ethylene in propagation since that time. An excellent example of the confusion in the literature is the simultaneous publication of two articles on the effects of ethylene on root formation in 'Berken' mung bean. While there appears to be only minor differences in experimental technique one article (7) claimed that ethylene stimulated rooting, while the other (3) found a decrease in root initiation.

To me the real significance of this is that apparently minor differences in conditions and propagation technique can have a dramatic effect on whether ethylene promotes or inhibits root formation and/or growth. The only way to know how it works in your operations is to try it, and to remember that there are two approaches to use — adding ethylene and removing it.

Examples of ethylene-stimulated root formation are found in the work of Swanson (8) where four out of six species tested, *Prunus tomentosa, Amorpha fruticosa, Forestiera neomexicana*, and *Cotoneaster racemiflorus*, rooted better with ethephon alone than with ethephon and IBA combinations, or the untreated controls. *Juniperus scopulorum* and *Rhamnus cathartica* rooted best when treated with a combination of ethephon /IBA/NAA.

Maleike (5) showed that spraying coleus and pelargonium cuttings with ethephon promoted rooting. He suggests this as a technique for getting faster rooting and therefore more plants through the facility in a shorter time.

There is evidence of very low concentrations of ethylene promoting root elongation in some plants while higher concentrations inhibit elongation in the same roots (4). In rice, seminal root growth is stimulated by ethylene but crown roots are inhibited, while in barley the opposite applies (6,1). There are also many reports indicating that ethylene stimulates formation of root hairs and the initiation of adventitious roots, while inhibiting the elongation of such roots (6). Timing of exposure to ethylene may therefore be important in that its continued presence after roots have been initiated would be undesirable if it is inhibiting their elongation.

Other workers have suggested that primordia production is blocked by ethylene for the first 24 hours after taking cuttings, but after this phase ethylene promotes root formation (2).

I mentioned earlier that there are two aspects to control of ethylene in propagation — adding it and removing it. Ethylene exists as a gas and it is inconvenient to apply it as such unless the plants can be kept in a relatively sealed environment. It is soluble in water and can therefore be dissolved and applied as a spray. However a more convenient formulation is the commercially available ethephon, which breaks down to release ethylene when diluted or when its pH is raised.

Other ways of effectively applying ethylene are, firstly, to treat with auxin, the traditional root induction treatment. Auxins, particularly high concentrations of auxins, induce plant material to produce large quantities of ehtylene. Another traditional propagation technique that induces massive production of ethylene is wounding of tissue. Wounding is inevitably involved in any preparation of a cutting but the extent of wounding is commonly increased to increase the percentage strike. Increased ethylene production is associated with this treatment. Stress also induces increased ethylene production by the tissue itself whether that stress be water stress, nutrient stress, high or low temperature, or even flooding of tissue.

The simplest way to remove ethylene from a plant environment is by effective aeration. Ethylene can also be removed by a strong oxidising agent and the material commonly used is potassium permanganate, or Condies crystals. For this to be effective a very high exposure of saturated postassium permanganate is necessary.

It is also possible to inhibit the production of ethylene by the plant tissue and this can be achieved by low oxygen concentration. However plant growth would also be inhibited. It is also possible to inhibit the action of ethylene in the plant tissue. High concentrations of carbon dioxide can do this for some ethylene responses, but the most effective technique is to treat the tissue with the silver ion in the form of silver thiosulphate. This material is commonly used to extend the vase life of cut flowers and in treating certain other nursery lines such as *Zygocactus* plants to minimize the dropping of flowers.

Ethylene, like auxins, is one of several plant hormones and all are involved in the control of plant growth and development. So, too, are many other factors such as light, water, mineral nutrients, oxygen, and carbon dioxide. They are all in balance and closely interacting. Altering any one of these many factors alters the plants synthesis of and/or responses to the other factors. It is, therefore, possible to modify plant responses, e.g. initiation of roots, by altering factors other than hormones. We can put too much reliance on hormones as the controllers of plant responses instead of looking at all of the factors. A ten-fold increase in auxin or ethylene can have dramatic effects on a plant's growth response, but so too can a ten-fold change in water supply or carbon dioxide.

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MICROPROPAGATION OF 'NORTHERN SPY' APPLE ROOTSTOCK

JAMES F. HUTCHINSON

Department of Agriculture
Horticultural Research Institute
P.O. Box 174, Ferntree Gully 3156, Victoria

Abstract. The literature on the micropropagation of apple rootstocks is briefly reviewed. Detailed results are presented on factors affecting the establishment of cultures, shoot proliferation, adventitious root initiation, and growth and establishment in potting medium of the apple rootstock 'Northern Spy.'