

Research review paper

Controlling ethylene responses in flowers at the receptor level

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Abstract

For a vast number of ornamental species, blocking the plant's response to ethylene is an efficient strategy to enhance the longevity of the flowers. The most effective ways to conduct such interference will be reviewed in this paper.

A large number of chemical compounds have been evaluated for their effects on ethylene production and perception. Among these are a range of strained olefines. This has resulted in the discovery that cyclopropenes, among them 1-methylcyclopropene (1-MCP) and a number of other substituted cyclopropenes effectively block ethylene responses at the receptor level. A lot of testing remains to be done to uncover the full potential of these compounds, but they do offer promising new ways to extend the postharvest life of ornamentals.

Also genetic modification appears to be a very effective way in controlling of ethylene synthesis and perception. Attempts to use both a reduced endogenous ethylene production and a reduced sensitivity to ethylene will be reviewed. Among these the use of the mutant ethylene receptor gene, *etr1-1*, from *Arabidopsis* seems most promising, especially when it is expressed under the control of a flower specific promoter.

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Contents

1. Ethylene effects on ornamental crops	369
2. Ethylene action and methods for inhibiting ethylene responses.	370
3. Blocking ethylene perception	372
3.1. Environmental factors determine the plant's response to ethylene.	372
3.2. Chemical inhibition of ethylene perception	372
3.2.1. 2,5-Norbornadiene	372
3.2.2. Silver thiosulphate	372

Abbreviations: 1-MCP, 1-methylcyclopropene; ACC, 1-aminocyclopropane-1-carboxylic acid; ACO, ACC-oxidase; ACS, ACC-synthase; AOA, aminoxyacetic acid; AVG, aminoethoxyvinylglycine; DACP, diazocyclopentadiene; NBD, 2,5-norbornadiene; STS, Silver thiosulphate.

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3.2.3.	Diazocyclopentadiene	373
3.2.4.	1-Methylcyclopropene	374
3.2.5.	Other cyclopropenes	375
3.3.	Genetic manipulation	377
4.	Concluding remarks	378
	References	378

1. Ethylene effects on ornamental crops

Traditionally, flowers (like fruits) are categorised as being climacteric or non-climacteric. In climacteric or ethylene sensitive flowers such as carnations, *Gypsophila* and orchids, senescence is accompanied by a sudden, transient increase in ethylene production and respiration while treatment of non-senescent flowers with ethylene rapidly induces petal senescence. In non-climacteric flowers such as gladiolus, tulip and iris, generally, no increases in ethylene production and respiration are apparent during flower senescence, and exogenous ethylene has little or no effect on petal senescence. In these latter species, ethylene may, however, have severe effects on other plant parts such as bulbs or corms (Kamerbeek and De Munk, 1976). Knowledge about ethylene sensitivity of flower species is necessary to predict the effects of e.g. mixed storage and transport of flowers with fruit species, to predict the usefulness of anti-ethylene treatments and to direct breeding programs towards better flower vase life. With respect to petal senescence, sensitivity to ethylene was found to be roughly determined at the plant family level. High sensitivity is found in e.g. Campanulaceae, Caryophyllaceae, Geraniaceae, Labiatae, Malvaceae, Orchidaceae, Primulaceae, Ranunculaceae and Rosaceae species; low sensitivity is found in Compositae and Iridaceae species and in most of the Amaryllidaceae and Liliaceae species. Sensitivity of species within one plant family is generally comparable (Woltering and van Doorn, 1988). As a rule of thumb this classification is satisfactory, although there are notable exceptions (as discussed below).

In flowers where *petal senescence* is independent of ethylene (e.g. in many ephemeral flowers, in short lived flowers from e.g. Iridaceae and Liliaceae plant families and in long lived flowers of Compositae family) other aspects of flower development such as *flower opening*, *ovary development* or *pedicel elongation* may be responsive to ethylene. As an example, petal senescence in iris flowers is virtually insensitive to ethylene, however, treatment with very low concentrations of ethylene may seriously inhibit flower opening as a result of ethylene-induced growth inhibition of the flower pedicel.

Depending on the species, ethylene, either applied or endogenously produced, may induce various processes (Woltering and van Doorn, 1988). In many flowers ethylene hastens senescence of petals that initially stay attached to the flower. This type of senescence is found in e.g. Orchidaceae (*Cymbidium*, *Dendrobium*), Campanulaceae (*Campanula*, *Trachelium*) and Caryophyllaceae (*Dianthus*, *Gypsophila*). In other flowers, ethylene may induce abscission of fully turgescient, non-senescent petals or of whole corollas. This type of effect is found in e.g. Geraniaceae (*Geranium*), Ranunculaceae (*Aconitum*, *Delphinium*), Rosaceae (*Rosa*, *Potentilla*) and Scrophulariaceae (*Antirrhinum*, *Veronica*). In contrast to *petal senescence*, which is also found in ethylene insensitive species, ethylene insensitive *abscission of petals* seems extremely rare in plant kingdom (Sexton et al., 2000).

Apart from these effects of ethylene on *petal senescence* and *petal abscission*, ethylene may also stimulate abscission of whole flowers and flower buds such as in *Hibiscus*, *Begonia*, *Clerodendron*, *Fuchsia* and *Agapanthus*, or may stimulate abscission of whole inflorescences (*Beloperone*, *Pachystachus*) (Woltering, 1987).

Strikingly, especially in flowers with a relatively long life, ethylene has evolved as a trigger of senescence or abscission. In such flowers, pollination often triggers an increase in ethylene production and subsequent rapid senescence and it has been suggested that ethylene may have evolved as a mechanism to terminate flower life after successful pollination as a way to benefit survival of the species (van Doorn, 2001). In species with ephemeral and short lived flowers such a mechanism apparently is not beneficial as the life of individual flowers is short anyway. Similarly, in Compositae species, with numerous flowers in one flower head, continuous visits of pollinators are required to fertilise all individual flowers and the senescence of pollinated flowers would not be beneficial.

Although ethylene sensitivity is roughly fixed at the plant family level, still marked differences may exist between species and cultivars within one family. Several carnation cultivars (e.g. Chinera, Epomeo, Ginevra) derived from crosses involving a long life non-commercial breeding line (8367) have been described with reduced

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