cuttings were stuck). The plant did not require pinching or the application to plant growth regulators to control height. Final plant height was approximately 10.5".

Some preliminary results indicate that a Florel application at sticking (when flower buds have been initiated) acts as a chemical pinch. This may eliminate the need for hand pinching in pot mum production. MN 83-267-3 does not require disbudding which eliminates another labor intensive practice of pot mum production.

This new day neutral, heat delay insensitive plant and those which may subsequently arise from crosses made using this plant as a parent should lead to reduced production cost for pot mum growers which may mean higher profits in the future.

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REVIEW OF FACTORS WHICH

AFFECT BLIND SHOOT

DEVELOPMENT IN FLOWERING

CROPS

John Erwin

Introduction

Failure of a plant to flower can be attributed to either failed flower initiation or failed flower development after initiation. Failed flower develoment is a common problem in rose and gerbera. The physiological disorder in which a flower fails to develop following initiation is often referred to as flower bud abortion or 'blind shoot' development (Hubbell, 1934, Zieslin and Halevy, 1975). Typically, blind shoot development occurs prior to differentiation of the sepals and petals during flower development (Hubbell, 1934; Moe, 1971). Blind shoots have thinner stems, and bear fewer leaves which have a lower chlorophyll content than leaves on flowering shoots (Zieslin and Halevy, 1975, Moe, 1971).

The basis for the failure of a shoot to develop a flower is unclear. Research on bulb crops and roses has given some insight as to what factors may cause the development of blind shoots. This review will concentrate on what physiological factors cause blind shoot formation in flowering crops.

Endogenous, or internal carbohydrates or sugars supply the energy for growth. Carbohydrate status at the developing meristem is the primary factor effecting blind shoot development (Moe, 1979; Mor and Halevy, 1980). The meristem is the actively growing shoot tip. The carbohydrate status at an active meristem is affected by total endogenous plant carbohydrate and the ability of the meristem to attract carbohydrates (meristematic sink strength) (Patrick, 1987).

I. Factors Effecting Total Plant Carbohydrate Content

The Effect Of Temperature On Carbohydrate Status: Temperature effects total plant carbohydrate, and carbohydrate movement within a plant (translocation). Temperature has its greatest impact on the carbohydrate status of a plant through differential effects on photosynthesis and respiration (Wardlaw, 1968). Photosynthesis provides the energy needed for plant growth and maintenance through formation of carbohydrates. Photosynthesis has a maximum rate in most plants

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between 20° - 25°C. In contrast, respiration is the use of those carbohydrates for growth. Repiration increases exponentiality as temperature increases until approximately 40°C. Therefore, high temperatures (> 25) may limit plant carbohydrate content and result in blind shoot development in <u>Rosa</u> by significantly increasing dark respiration and decreasing photosynthesis. Above 40° protein denaturation often occurs which results in plant death (Salisbury and Ross, 1979).

Excessively low temperatures may limit total plant photosynthesis which can also result in blind shoot formation. For example, rose plants often show excessive blind shoot development when temperatures are below 12°C (Moe and Kristoffersen, 1969; Zieslena and Halevy, 1975).

The Effect Of Light Intensity On Total Plant Carbohydrate: Low light levels can result in blind shoot development in a number of plant species (Zieslin and Halevy, 1975; May, 1965; Moe and Bonk, 1975). Low light levels result in a lower photosynthetic rate which reduces the amount of available carbohydrate in the developing meristem (Sweet, 1973). Plants appear to be most sensitive to reduced light intensity when flower buds are differentiating anthers (Zieslin and Halevy, 1976; Munk, 1973; Kamerbeek and Durieux, 1971). Blind shoot formation increases greatly when low light intensity is given in combination with low temperatures (Moe and Kristoffersen, 1969; Moe, 1972).

When only young shoots are shaded the percentage of blind shoots in <u>Rosa</u> was greatly increased. This occurred even though the proportion of total carbohydrates within the plant which are produced in the young shoots is relatively small. Removal of leaves from stems increases blind shoot number (Zieslin and Halevy, 1976). Blind shoot production was greatest when mature leaves are removed as opposed to young leaves, Zieslin suggested that the mature leaves produce photosynthates, whereas, young leaves produce growth regulators which attract assimilates

from a reserve source, i.e. from the leaves to the developing flower bud (Zieslin and Halevy, 1976).

The Effect Of Over And Under Watering On Total Plant Carbohydrate: Water stress can cause blind shoot development. Water stress stimulates both ethylene and abscisic acid (ABA) biosynthesis (Yang, 1978; Zeevaart, 1977). Both ABA and ethylene reduce translocation of carbohydrates and nutrients to the meristem (Simpson, 1981). In addition, ABA induces stomatal closure which ultimately results in a reduction in available assimilates, or carbohydrates, necessary for growth in the meristem (Simpson, 1981). Therefore, under watering can induce blind shoot formation through both reduction of translocation of carbohydrates and reduction in total plant carbohydrate via stomatal closure.

Overwatering can also cause blind shoot development. In contrast to water stress, overwatering produces anaerobiosis in roots which results in the transport of an ethylene precursor (ACC) from the roots to the shoots where ethylene is formed. Ethylene subsequently inhibits transport of carbohydrates to the meristem which ultimately can induce blind shoot formation.

II. Factors Effecting Meristem Sink Strength

The Effect Of Temperature On Sink Strength: The ability of a growing tip or meristem to attract photoassimilates is referred to as 'sink strength'. Sink strength is greatly influenced by temperature. Determinants of meristematic sink strength are: 1) the ability of the meristem to metabolize sucrose, 2) the presence of specific plant growth hormones in the meristem, and 3) the degree of differentiation of the vascular system leading to a meristem. Cool night temperatures, i.e. a condition which promotes blind shoot development in <u>Rosa</u>, results in an increase in starch and sucrose content of <u>Rosa</u> leaves relative to the meristematic region. This difference in carbohydrate between the meristem and leaf content suggests that cool night temperatures reduce meristematic sink strength in <u>Rosa</u> through

inhibiting sucrose transport and/or metabolism (Khayat and Zieslin, 1986; Clensen et al, 1985).

Sink strength can be accessed by determining the activity of enzymes which are involved in sucrose metabolism and transport (Hawker, 1985; Kursanov, 1984). Total endogenous levels of 3 primary enzymes involved in sucrose metabolism decrease when Rosa plants are grown with 12°C (54°F) night temperatures (Khayat and Zieslin, 1987).

The Effect Of Hormones On Sink Strength: Sink strength may also be affected by the presence of specific growth hormones (Wardlaw, 1968). Flowering shoots have greater levels of auxins, gibberellins, and cytokinins than blind shoots (Zieslin and Halevy, 1976b). This is presumably due to developing plant organs producing growth hormones which attract assimilates to the floral meristem.

Exogenous applications of gibberellins and cytokinins increase the ability of a meristematic region to attract assimilates (Moe, 1979, Zieslin and Halevy, 1976). Often this results in more flowers and larger flowers (Carpenter and Carlson, 1970). It is interesting to note at this point that application of cycocel, a gibberellin synthesis inhibitor (Cross, 1968), also markedly reduces the amount of blind shoot development on plants. (Zieslin and Halevy, 1976). Cycocel has, however, been shown to increase gibberellin levels in some plant species (Van Bragt, 1969; Halevy, and Shilo, 1970).

In contrast to the effects of gibberellin and cytokinin on meristematic sink strength, ethylene decreases the sink strength of a meristem. Injection of 2-chloroethylphosphonic acid (CEPA), an ethylene source, reduces translocation of ^{14}C-sucrose from bulb scales to developing flower shoots of Tulipa (Moe, 1979). A result of the decrease in translocation is the formation of blind shoots. Tulipa is most sensitive to ethylene when another development is occurring (Munk, 1973). Similarly, Lilium and Rosa flower bud abortion are

also most sensitive to ethylene anther development (Kamerbeek and Durieux, 1971; Hubbell, 1934).

Therefore, either high levels of ethylene and/or low concentrations of gibberellins in a bulb will cause 'blasting' of flower buds in Tulipa due to limitation of carbohydrates to the sink or developing flower bud, especially if problems occur during anther development.

Gibberellin and cytokinin counteract the inhibitory effect of ethylene on carbohydrate translocation, i.e. normal flower formation occurs following exogenous application of these hormones (Moe, 1979; Scott and Leopold, 1967; Stewart et al, 1974).

The Effect Of Vascular Differentiation On Sink Strength: An additional factor influencing sink strength is the degree of differentiation of the vascular system in the meristematic region. The meristem itself produces relatively small quantities of assimilates. The meristem must, therefore, import most photoassimilates. To support rapid growth the meristem requires a well differentiated vascular system as well as have rapid loading and unloading from the vascular system.

Auxin increases the degree of vascular differentiation. In addition, recent evidence suggests that auxin may regulate phloem loading and unloading (Moe, 1971; Patrick, 1987). Similarly, gibberellin and cytokinins also play an important role in unloading carbohydrates from the vascular system.

Ways To Possibly Reduce Blind Shoot Formation: Based on the information presented above, a number of possible methods, or hypothesis to reduce blind shoot development can be put forth. Some of the possibilities include:

1) Application of silver thiosulfate (STS) to plants which have the potential for blind shoot development due to ethylene synthesis. Examples

of such situations where ethylene is synthesized include over and under watering.

2) Grow plants with as much light as possible. The higher the light levels the higher the endogenous levels of photoassimilates and the lower the possibility of blind shoot development. This is especially important during the early stages of flower development. This was effective in a recent experiment conducted to reduce blind shoot development in gerbera (Moe, Heins and Erwin, personal communication).

3) Do not grow plants at excessively low or high air temperatures which may limit the rate of photosynthesis.

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