AN ABSTRACT OF THE THESIS OF

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Title: CHARACTERIZATION OF HARVESTABLE MATURITY DEVELOPMENT IN ROSES

Abstract Approved: Leslie H. Fuchigami

Physiological characteristics of stem tissue of rose nursery stock were evaluated as possible indices of harvestable maturity. The characteristics included ethylene production, water content, cold hardiness, and respiration. Ethylene production proved to be most promising in predicting harvestable maturity. Water content proved too variable and sensitive to post harvest desiccation to be useful as a maturity index. Cold hardiness increased with storageability, but the variation between and within plants was too great to provide an accurate prediction of harvestable maturity. Respiration showed the same pattern of variation as cold hardiness, with higher respiration rates in basal and acropetal tissues than medial tissue.

Sources of variation in these characteristics were then investigated to provide a basis for standardization of sampling procedures. Cold hardiness and respiration showed the same pattern of variation within individual canes. Hardiness was lowest in proximal and distal portions of the cane, with the medial portions showing the greatest cold hardiness. Respiration was greatest in proximal and distal portions, and lowest in medial

tissue. Water content and ethylene production increased acropetally and were highly correlated (r^2=.81). Tissue age proved to be a significant factor in the level of each of the four characteristics studied. Water content, ethylene production, and respiration declined with tissue age, while cold hardiness increased. A simple, accurate index of rose maturity may not be achievable due to the presence of canes of various ages on a single plant.

Characterization of Harvestable Maturity Development in Roses

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CHARACTERIZATION OF HARVESTABLE MATURITY DEVELOPMENT IN ROSES

INTRODUCTION

The rose nursery stock industry produces 30 million rose plants annually[1]. The Jackson and Perkins Company, the world's largest grower of rose nursery stock, accounts for 16 million. Early in October, employees begin digging the field-grown roses for bare root storage in large cold rooms at the storage facilities in Medford, Oregon. The plants are held there in large, polyethylene-lined boxes until they are distributed to retail nurseries the following spring.

It is during this storage period that problems begin to develop. Many plants exhibit cane dieback, fungal growth, or buds which have begun to grow (buds broken) while in storage. In addition, some varieties, when replanted in a suitable environment, display a delay in budbreak of up to two months. These problems result in plants which are unmarketable, or in customer dissatisfaction in the case of delayed budbreak. The potential gain involved in alleviating these storage problems has led Jackson and Perkins to fund research in this area. This thesis describes the work done, results obtained, and conclusions reached in this project.

[1] Fike, personal communication.

REVIEW OF THE LITERATURE

STORAGE PROBLEMS IN ROSES

The poor storageability of roses has long been known. Yerkes and Gardner reported problems of budbreak and desiccation in cold-stored roses in 1935 (57). In 1931 Tukey and Brase (53) proposed post harvest treatment prior to storage as the crucial problem. Hunter (29) found that plants defoliated with a low content of acid hydrolyzable material in the root tissue was associated with poor survival in cold storage, and poor regrowth in the spring.

Poor storageability is not inevitable, however. Janne and Chadwick (32) reported successful storage of rose plants as late as June 30th without injury. Solutions to these problems included paraffin waxing of canes to reduce water loss and respiration (52), subfreezing temperature storage, and humidity reduction (32). Several researchers (29,42,52) attributed "plant maturity" as the single most important factor in determining storage durability.

WINTER DORMANCY IN WOODY PLANTS

Deciduous woody plants tolerate bare root cold storage best when they are in a state of rest, or winter dormancy (28). This stage is considered an adaptation to cold by temperate plants

(16). It is usually characterized as a cessation of growth due to internal inhibiting factors within the bud itself (16). Plants in deep rest will not resume growth when placed in favorable environmental conditions, for as long as several months in the case of red-osier dogwood (21).

Natural defoliation in deciduous woody plants occurs while the plants are in the state of rest (28). However, it has been shown that the onset of rest takes place up to seven weeks before natural defoliation occurs (21). This is an important developmental stage for nurserymen, since it marks the earliest point at which the plant can be safely defoliated and dug bareroot (28). To take advantage of more favorable weather it is desirable for the nurseyman to begin defoliating and digging nursery stock as early as possible. Identification of the earliest stage of development (vegetative maturity) when roses may be safely dug would be of great value to nurserymen.

VEGETATIVE MATURITY

In red-osier dogwood, the onset of rest coincides with the developmental stage termed vegetative maturity (47). Plants defoliated at or after vegetative maturity overwinter with minimal injury, and produce normal spring growth. Plants defoliated before vegetative maturity is reached die or suffer varying degrees of tip dieback (21). In many deciduous woody plants this stage is temperature and photoperiodically induced (55); therefore, vegetative maturity can easily be predicted. A model of vegetative maturity development in red-osier dogwood has predicted this stage

within four days (41).

VEGETATIVE MATURITY VS HARVESTABLE MATURITY

Work by other researchers suggest that roses do not have a rest period and do not become vegetatively mature. Rosa species grown in the tropics exhibit continuous growth, unlike most temperate woody species, which go dormant even in the presence of favorable environmental conditions (16). Photoperiod studies with greenhouse-grown roses show that growth does not cease under short daylengths, as is the case in red-osier dogwood (47). Roses grown outdoors in the Pacific Northwest lose their leaves only after prolonged exposure to sub-freezing temperatures. This may be due to the mostly subtropical origin of most of the parents of today's rose varieties (49).

The absence of a stage of vegetative maturity in roses would suggest that defoliation and bare root digging for cold storage might result in dieback and poor regrowth, as has been observed in other plants which did not reach this stage (21). However, several researchers have noted that, even though growth does not cease, rose plants do achieve a type of maturity which permits successful bare root storage. Indeed, there are several studies which suggest that, in some ways, roses behave similarly to deciduous woody plants which do undergo a period of rest. Roses have been observed to acclimate to low temperatures (43); in red-osier dogwood vegetative maturity marks the onset of acclimation (37), and the rate of acclimation is greatest when rest is deepest (30). Rosa

setigera and R. multiflora have been shown to require chilling, a requirement for the completion of rest, before lateral buds will break (48). Roses subjected to 22 weeks of low temperatures displayed an increase in flower quality and basal budbreaks, and produced twice the number of flowers as plants not exposed to low temperatures (27). Hunter (29) found that storage durability, regrowth, and winter hardiness were correlated with time of defoliation. Roberts (44) noted an increase in sensitivity to chemical defoliants as rose plants mature. Sensitivity to defoliants has also been shown by Fuchigami to increase as red-osier dogwood approaches vegetative maturity (20).

It appears, then, that although the characteristic of growth cessation in not present in roses, the rose plant does develop some type of maturity and some characteristics of rest period in some species. Therefore, the physiological characteristics which change in hardy deciduous species at the time of vegetative maturity may be useful in detecting and predicting rose maturity. To avoid confusion with vegetative maturity this stage will be termed harvestable maturity. This is the stage at which the nursery stock can be defoliated, dug bare root, and placed in prolonged cold storage without detrimental side effects.

To be a useful maturity index any physiological characteristic should have four attributes: 1) It should change with development of the plant; 2) Variation among samples should be limited to permit its practical use; 3) It should correlate well with storage and replant performance; and 4) It should be simple and straightforward for nurserymen to use.

The four physiological parameters chosen for this study were ethylene production, cold hardiness, water content and respiration of cut stem segments. Each is relatively simple to measure and has been shown by other researchers to meet some of the requirements listed above for a useful maturity index. The goal of this research was to evaluate the potential usefulness of these parameters for predicting harvestable maturity and ultimately to determine the optimum time of harvest of rose nursery stock.

ETHYLENE PRODUCTION

Ethylene production in plant tissue can be divided into two categories: endogenous ethylene, and stress ethylene. Both have been shown to follow the same biochemical pathway (2), and to change with the development of the plant tissue. Hence, the production of ethylene seems an appropriate characteristic for study as a maturity index.

Endogenous ethylene production correlates well with the state of metabolic activity in plant tissue. Dormant seeds produce less ethylene than non-dormant seeds in a variety of species (1). In fruit the rise in production of ethylene precedes an increase in respiration during the climacteric phase of development; and has been used as an indicator of maturity or ripeness in that tissue (1). Rose cell cultures produce ethylene in proportion to growth. Ethylene production increased until the stationary growth phase was reached, then rapidly declined when cells ceased to divide (34).

The process of digging and transporting bare root plants imposes a great deal of stress on the nursery stock. Ethylene production has been shown to be proportional to stress induced by 2,4-D, salt (23), dehydration (33,31), and wounding (59). Since the development of maturity decreases the tissue's metabolic activity, and in turn increases tolerance to stress, one would expect ethylene production of stressed tissues to decline with development. This is exactly what Seibel found in cut stem segments of red-osier dogwood (46), where a reduction in ethylene production occured several weeks prior to vegetative maturity.

COLD HARDINESS

In red-osier dogwood vegetative maturity marks the onset of cold acclimation (37). An increase in cold hardiness might, therefore, be useful as an indicator that the plant has reached maturity. Burdett and Simpson (7) found this to be true in the case of white spruce and lodgepole pine seedlings. Their work showed a high correlation between cold hardiness and the storability of the seedlings at $-2^{o}C$. At least one nursery now uses hardiness as a guide to deciding when to begin digging their seedlings in the fall (42).

Although the cessation of growth associated with vegetative maturity appears to be necessary for maximum development of cold hardiness, roses and other plants which do not enter a state of rest do cold acclimate to some extent. Citrus, another woody plant which does not cease growth in the fall unless environmental

conditions are unfavorable, does acclimate to some extent (56,58).

Rajashekar (39) noted low temperature exotherms as low as - 42°C in Rosa acicularis. Sakai (45) reported a wide range of cold hardiness among the tissues of rose species and cultivars, with killing temperatures ranging from -15°C in the cortex tissue of the variety 'Christian Dior' to -70°C in R. acicularis and R. rugosa. In these hardy roses it appeared that a reduction in growth rate was correlated with acclimation. Carrier (9) observed that vigorous rose canes were less hardy than slow growing canes. Factors which promote growth, such as a long photoperiod, high nitrogen fertilization, and early defoliation have been shown to reduce cold hardiness (10,22), while exposure to cool temperatures (9,22), and water stress (11,14) enhanced acclimation.

WATER CONTENT

Associated with the development of vegetative maturity and cold acclimation is a decrease in tissue water content, even when soil moisture is maintained at field capacity. Nissila and Fuchigami (38) reported a decrease in stem tissue water content in red-osier dogwood as the plant reached vegetative maturity. Parsons (39) observed a decrease in stomatal resistance six days after induction of acclimation, resulting in a higher rate of water loss in acclimated plants during the first 30-40 days. McKenzie et al. (36) showed an increase in water permeability of phloem and cortical parenchyma during this time, while Timmis and Fuchigami (50) noted a significant decrease in stem water content between

non-dormant and dormant tissue of red-osier dogwood. In dormant buds of Populus balsamifera, Bachelard (3) reported water contents of 40-45%.

RESPIRATION

Respiration has been shown to be directly proportional to the level of ethylene production in many tissues (1,35), and inversely proportional to the level of cold hardiness (15). Gibbs (25) has shown that the major respiratory pathway shifts with age, from the Embden-Meyerhoff-Parnas pathway to the Direct Oxidation pathway. In most woody plant tissue, respiration decreases with age (4,24,26). Geronimo (24) proposes that this decrease is due to a decreased ability of the mitochondria to oxidize Krebs cycle intermediates. Respiration rate in dormant imbibed seeds of Avena fatua average 25% (9 ul/hr) of the rate in non-dormant imbibed seeds (36 ul/hr) (12).

In woody plants, respiration is an excellent indicator of tissue activity. Work by Brayman and Schaedle (5) with Populus tremuloides internodes showed a hyperbolic decline in respiration with increasing plastochron age, from 19-29 mg $CO_2/dm^2/hr$ to 10-15 mg $CO_2/dm^2/hr$. This age-related decline in respiration coincided with a cessation in internode elongation. Comparison of dormant and non-dormant internode stem tissue of the same species by Foote and Schaedle showed differences in respiration rates (0.24 mg $CO_2/dm^2/hr$ for dormant tissue; 7.4 mg $CO_2/dm^2/hr$ for non-dormant

tissue) (18), as well as Q_{10} values (1.5 between -12° and 10°C, 3.4 between 10° and 30°C for dormant tissue; 1.7 between 3° and 30°C for non-dormant tissue) (19).

Respiration has been shown to be an important factor in storageability. Tukey and Brase (53), working on the effects of paraffin wax, reported on increase in survival and overall growth by rose plants coated with wax before storage compared with unwaxed plants. This was later attributed to a decrease in respiration caused by the wax acting as a barrier to CO_2 and O_2 exchange (52). Another study in 1960 by Toy and Mahlstede (51) supported this finding by showing that "dormant" roses held in up to 80% CO_2 inhibited budbreak in storage without visible signs of damage. Harvesting the nursery stock at its lowest rate of respiration could conceivably accomplish similar beneficial effects.

SOURCES OF VARIATION

From the evidence presented, it would appear that development of an index of harvestable maturity for roses is possible. However, studies with roses and other deciduous woody plants indicate that at least two factors present obstacles in achieving this goal. First, is the problem of physiological age. Roses continually produce new growth from basal budbreaks. Many studies have been made to increase the number of basal budbreaks (17,60,61,62, 63,64). Ironically, successful efforts made over the past years to develop varieties which freely produce basal shoots may be contributing to the poor storageability of many modern varieties.

In addition to variations in age within an individual plant,

the position at which the sample is taken could have an effect on the magnitude of the maturity index. Carrier (9) has shown that both stem diameter and position affect cold hardiness. Large canes, basal and terminal portions were shown to be less hardy than smaller canes and medial tissue. High variation even among stems of similar diameter and position was also noted.

Water content and ethylene production also vary with position of the sample. In Rosa multiflora Tukey and Green (54) found a gradient of increasing water content from base to tip. McKenzie et al. (36) showed that the water content gradient in red-osier dogwood is steepest in non-acclimated tissue. Seibel noted the same pattern in ethylene production in red-osier dogwood (46).

Brayman and Schaedle (5) found a similar gradient in respiration of internodes of Populus balsamifera. Internodes respired fastest at the distal portion of the stem and decreased basipetally. Delong (15) found that respiration correlates well with cold hardiness in apple twigs. If this is true for roses, the data by Carrier (5) discussed earlier would indicate that respiraton would be greatest in basal and terminal portions, as opposed to what was found in Populus. It is evident that the pattern of respiration in roses must be established before it can be used as a maturity index.

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ETHYLENE PRODUCTION, COLD HARDINESS AND WATER CONTENT AS POSSIBLE INDICATORS OF HARVESTABLE MATURITY OF ROSE NURSERY STOCK

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Additional index words. Rosa hybrida

Abstract. Ethylene production, water content, and cold hardiness of rose stem tissue were examined as indices of harvestable maturity. Ethylene production decreased with later harvests and correlated well with each cultivar's ability to tolerate cold storage. Tissue water content also decreased at later harvests, but was too variable to be useful as a maturity index. Cold hardiness increased with later harvest dates and appeared to correlate with storageability, but large variation within and between plants was observed. Standardized sampling procedures are recommended to reduce variation.

INTRODUCTION

A major problem in the rose nursery industry has been the development of a test for determination of the earliest stage at which the nursery stock may be harvested. In red-osier dogwood, Cornus sericea L., and other woody plants (6) the earliest harvestable stage is called vegetative maturity. Vegetative maturity (VM) has been determined for many deciduous woody plants which exhibit classical winter dormancy (7). This distinct stage of physiological development coincides with the onset of winter dor-

mancy and the end of summer dormancy (18). Plants placed in cold storage following VM survive for long periods without injury (6).

Roses, however, do not appear to enter true winter dormancy (physiological rest). Rosa spp. grown in tropical regions grow continuously (2), as do hybrid tea plants in the greenhouse. Durkin (3) has reported that budbreak follows manual defoliation regardless of tissue age, suggesting that roses do not acquire rest. Therefore, to avoid confusion and differentiate maturity of roses from plants that develop rest, the term harvestable maturity (HM) is used to describe the stage of rose maturity where plants can be dug, stored, and transported without subsequent dieback. The objective of this study was to determine whether plant characteristics which can be used to predict VM and dormancy in other plants could be used to predict HM in roses. The characteristics studied were ethylene production, water content, and cold hardiness of stem tissue.

Hunter (8) has reported that a stage is reached in which roses will tolerate defoliation and cold storage. He showed a correlation between storage durability and overwintering ability, cold hardiness, and acid hydrolyzable carbohydrates in the roots.

Ethylene production declines with decreasing growth rate and metabolic activity in many plant tissues. Seibel (17) has shown that ethylene production of cut stem segments of red-osier dogwood decreases to a minimal level (3 nl/mg/hr) about two weeks before vegetative maturity is reached, and Kobayashi (9) and others (11,21) reported that the level of ethylene remains low throughout the dormant period. LaRue and Gamborg (11) found that rose cell

cultures produce ethylene in proportion to the growth rate.

Ethylene production is also a good indicator of stress in plants (20,26). Leopold et al. (12) reported that internal ethylene increased in white pine as a result of mechanical stress. Water stress and low temperatures produce similar responses (4,10). Since harvesting and cold storage of bare root plant material imposes stresses which rose nursery stock must tolerate, endogenous ethylene production may provide a useful indicator of that tolerance.

Cold hardiness has been linked to vegetative maturity in red-osier dogwood by Nissila (14). Resistance to cold increases dramatically after VM has been reached. Although rest has been shown to be necessary for maximum cold acclimation, plants which do not undergo rest can still attain a substantial level of hardiness. Citrus, which continues growing as long as temperature permits, changes in hardiness during the season which are related to cycles of growth and dormancy (23,25). Hunter (8) has shown that cold hardiness in roses changes seasonally, and correlates well with the plant's ability to withstand cold storage.

A decrease in water content is closely associated with cold hardiness development. Nissila et al. (15) and Hotze (7) showed that xylem water potential and tissue water content decline as plants become vegetatively mature. Dormant tissue of red-osier dogwood contains less water than actively growing tissue (18). Water content changes were studied because it is quickly and easily measured and known to change with plant maturation.

MATERIALS AND METHODS

The roses (Rosa hybrida) used in this study were obtained from the Jackson and Perkins Company at Wasco, California. Six cultivars were studied initially: Four hybrid teas - 'Medallion', 'Fascination', 'New Day', and 'Honor'; one flora-tea, 'Evening Star'; and one floribunda, 'Cherish'. These six cultivars represent a range of storage and regrowth abilities. 'New Day', 'Cherish', and 'Evening Star' are known as a good performers in storage and suffer little subsequent dieback. 'Fascination', 'Honor', and 'Medallion' are difficult to store, often have stem dieback, and are slow to break bud when replanted. Experimental plants were dug at random, packed bareroot in polyethylene-lined boxes, stored at the Jackson and Perkins storage facilities at approximately -1°C in Medford, Oregon and shipped to Oregon State University.

Storageability Tests

Fall 1982: The effect of harvest period and time in storage on the nursery stock's ability to survive cold storage was tested. Three harvest periods were examined: 11/1/82 - 11/15/82, 11/15/82 - 12/15/82, and 12/15/82 - 1/15/83. Duration of cold storage ranged from 0 to 7 months. Five plants of each cultivar were shipped at the appropriate monthly intervals for evaluation of

regrowth ability. Plant roots and stems were pruned to approximately 20 and 25 cm, respectively, just before replanting in a 25 cm diameter plastic pot containing a mixture of fir bark, pumice and soil (3:2:1 by vol.). The plants were grown in a greenhouse at 20 ^{o}C./15 ^{o}C. day/night temperatures. Days to budswell, percentage of stems with dieback and percentage of dead canes was recorded.

Fall 1983: Observation of repotted plants from the 1982 experiment revealed that the vegetative buds of some cultivars failed to elongate once budbreak had occurred. To reflect this, budbreak evaluation was modified. Ten plants of each of the four harvest dates and three cultivars, 'Fascination', 'Honor', and 'New Day', were shipped from Medford to Oregon Sate University at monthly intervals for replanting. The same procedure was used for potting the nursery stock as the previous year's study. This time, however, budbreak was evaluated using a rating system (table 1.1). In order to include the range of harvest dates that were under consideration by the rose nurserymen, the experiment was repeated with four harvest dates: 9/26/83, 10/24/83, 12/2/83, and 1/6/84. Three weeks after potting, the individual buds of each plant were rated, and an average rating for the entire plant was calculated.

Ethylene Production and Water Content

Fall 1982: A 3 x 6, harvest date x cultivar, factorial experiment with a completely randomized design was used to test differences in ethylene production and water content between the culti-

vars and harvest periods used in evaluating storageability. Five centimeter internode segments from three separate stems randomly selected from each of five plants were taken from each cultivar and fresh weights were recorded. Segments were then placed in 75 ml test tubes and sealed with serum stoppers. Following 24 hour dark incubation at 21 ^{o}C., 1 ml air samples were taken from the test tubes and injected into a Carle 210 analytical gas chromatograph with a 1.22m x 3.18 mm 80/100 mesh activated Alumina column and flame ionization detector. The segments were dried in a forced air oven at 60 ^{o}C. for 48 hours and reweighed. Ethylene production was expressed as nl/mg dry weight/hr, and water content as a percentage of fresh weight.

Fall 1983: Ethylene production was measured concurrently with arrival of plants for budbreak analysis, but only for those plants not held in cold storage. The number of replications was increased to ten, with three subsamples per replication. Three cultivars were studied: 'Fascination', 'Honor', and 'New Day'. In addition, samples included nodal tissue; preliminary tests showed larger differences could be detected by including nodes. Finally, a time course study indicated the rate of ethylene production to be greatest after 14 hours incubation; therefore, the ethylene measurements were taken after 14 hours dark incubation.

Cold Hardiness

Fall 1982: Cold hardiness of stem tissue as affected by harvest period and cultivar was tested in a 3 x 6 factorial in a completely randomized design. Freezing injury was determined by

measuring the electrolyte leakage from stem tissues subjected to -12 °C. This temperature was found in preliminary tests to mark the point at which significant cell damage occurred (figure 1.1).

Electrolyte leakage was measured as percentage conductivity as defined by Mecklenberg and Pridham (13). Two centimeter stem segments placed in Dewar flasks were placed in a Kelvinator Ultra Cold freezer at -60 °C. and allowed to cool to -12 °C. Tissue temperature was measured with copper-constantan thermocouples inserted into a stem segment placed among the samples in the flask, and monitored on a Leeds and Northrup multipoint recorder. At -12 °C the thermos was removed and allowed to warm slowly overnight in a 4 °C. walk-in cooler. The stems were then placed in scintillation vials containing 10 ml of distilled water. The closed vials were secured on a shaker and shaken for 24 hours at 21 °C. Conductivity in x 10^2 micromhos was then measured by a Markson ElectroMark pH/conductivity meter model 604. Samples were then frozen to -60 °C. to completely kill the tissue. After thawing, the vials were again shaken for 24 hours and conductivity measured as before. Percentage conductivity was calculated by comparing the ratio of the conductivity of the injured tissue to the conductivity of the killed tissue, expressed as a percent.

RESULTS AND DISCUSSION

Harvest date, storage period and varietal effects on survival and regrowth: Days to budswell tended to decrease with later harvest period, and was greatest without storage, and after four months in storage (figure 1.2). The delay in budswell could be taken as an indication that proper chilling had not been reached, as in plants which undergo a rest period. However, the delay in budswell after four months, when it would be reasonable to assume that rest would be broken, conflicts with this. Days to budswell in even the worst case, 'Fascination', was shorter than that of other woody plants which go dormant every fall. Red-osier dogwood has been shown to break bud as much as 180 days after being placed in a suitable environment (6). This suggests that rose plants do not undergo a period of rest, and that some other factor is responsible for the delay in budswell. Damage to the roots by desiccation during harvest and after prolonged storage may account for this delay.

Missing storage treatments made complete statistical analysis difficult. The data for four months storage, however, showed an interaction between time of harvest and cultivar. 'Honor' and 'New Day' showed a clear trend towards decreasing time to budswell, while 'Cherish' and 'Medallion' presented the opposite trend (table 1.2). 'Fascination' and 'Evening Star' fluctuated in no discernable pattern. These results suggest that days to budswell does not correlate well with storage durability.

Percentage of stems with dieback agreed well with observations made by the nurserymen on storageability, as exemplified by the data for four months storage in table 1.3. 'Fascination', 'Honor' and 'Medallion', the cultivars selected as the poor performers in storage, all had a higher percentage of stems with dieback than those considered good performers. Due to large variations between samples, only 'Honor', 'Cherish' and 'New Day' were significantly different from each other. Harvest date and time in storage had no consistent effect on the percentage of stems with dieback. Since dieback in storage is associated with immaturity in those species which are able to attain vegetative maturity, the fact that the cultivars under study did not vary significantly in response to later harvest period suggests that 1) All of the plants have not reached maturity, even in January, 2) There is another factor involved in the plant's ability to tolerate storage, or 3) Dieback is not a result of storage duration and harvest date, but possibly due to some factor(s) occurring prior to storage. In light of the facts presented earlier it would seem likely that there are other factors which affect storageability.

Percentage of dead stems was significantly different for both harvest dates and cultivars for four months storage (table 1.3). Again, 'Fascination', 'Honor' and 'Medallion' suffered the most injury in storage. Across all cultivars percentage of dead stems was lowest for the 11/15-12/15 harvest period. This suggests that differences in percentage of dead stems may be due to a factor other than maturity, such as environmental conditions at harvest.

During one month's sample preparation, some of the plants received were covered with mud. Although the cultivars, harvest periods, and storage times for these plants were not noted, it was later observed that these plants performed better after replanting. Weather data provided by Jackson and Perkins showed rainfall of 1.3 cm (0.5 inches) on 11/29/82 (table 1.4); since this date is within the harvest period in which the lowest overall stem dieback was recorded, it is possible that the high moisture conditions contributed to the lower dieback observed.

Differences between cultivars in the 1983 budbreak evaluation depended upon both harvest date and storage time (figure 1.3). Increased plant age (later harvest date) tended to increase the budbreak rating. This may indicate a process of maturation occurring, in agreement with Hunter (8). However, the high temperatures recorded for the two earliest harvest dates (table 1.4) make it equally likely that prestorage treatment of the plants played a significant role. Temperature differences of up to 17 ^{o}C (31^{o}F) between the earliest and latest harvest dates could definitely affect the condition of the plants prior to storage. 'New Day' tended to rate highest in each combination of harvest date and storage time, which may indicate a higher tolerance to prestorage environmental conditions rather than storage durability.

Ethylene Production: In 1982, there were significant differences in ethylene production between harvest periods (table 1.4). Ethylene production rose slightly during the second harvest period, then fell off sharply. Since ethylene is known to be a

good indicator of stress in woody plants (12), this large decrease between the later two harvest periods may show that as the rose plant matures it becomes more tolerant of stress.

In the 1983 tests, again there was a general decrease in ethylene production from the first to the last harvest dates (figure 1.4). However, there was an approximately two-fold increase in ethylene production between the 1982 and 1983 experiments. This fact can probably be attributed to the use of nodal tissue and a shorter incubation time in the second year. 'Fascination', the cultivar whose performance in cold storage is poorest among those tested, generally produced higher ethylene levels, but there was too much variability to show significance.

Water Content: Water content differed with harvest date, but the results were inconsistent (table 1.5). The 1982 study shows a rise in stem water content between the 11/1-11/15 and 11/15-12/15 harvest periods, followed by a drop between the 11/15-12/15 and 12/15-1/15 harvest periods. Comparison between ethylene production and water content in table 1.5 suggests a possible correlation between the two; this was found to be the case in another study (16). The 1983 study showed an interaction between harvest date and cultivar (figure 1.5). Water content generally declined with time for each cultivar, with 'Fascination' having slightly higher levels in most harvest dates. This also fits well with the concept that 'Fascination' is less mature than 'Honor' or 'New Day', if it is assumed that mature plants contain less water. A study of "immature" and "mature" canes of potted roses showed pronounced differences in stem water content as well as ethylene

production (16).

One possible source of the large variation in water content observed may be due to the way the roses were handled at and after harvest. Since the plants were dug bareroot and shipped to Corvallis, there was ample opportunity for water loss during harvesting, packing, storage and transit. This indicates that water content may still be an important characteristic to study in field-grown plants, but postharvest desiccation must be tightly controlled before significant changes with development can be detected. Studies done on greenhouse-grown roses showed significantly higher water content in the acropetal vs. distal portion of the stem and this was highly correlated with ethylene production (16). It is possible that the genetic contributions of various Rosa species to the cultivars cause differences in cuticle formation, stomatal resistance and number, and lenticel number. Differences in these characteristics would result in various degrees of resistance to desiccation, resulting in poor budbreak, or dieback.

Cold Hardiness: Injury due to freezing, as measured by electrolyte leakage, declines with later harvest period (table 1.6). Of the six cultivars studied,'Fascination' was the least hardy earlier in the season. Since it is known that actively growing tissue is less hardy than tissue in which growth has ceased (5), this finding may indicate 'Fascination' is still active and thus relatively immature at this time. At Wasco, California where the plants were produced, 'Fascination' continues to produce new shoots at the base of the graft union throughout the year. The

other cultivars, however, terminate shoot production earlier in the fall. This continuous production of shoots may be the cause of the variability observed in these studies; in other words, any given plant may have shoots of differing levels of development (e.g. maturity). This is brought out by the presence of large variations in electrolyte leakage between plants as well as within a single plant. Work done by Carrier has shown that stem diameter and position of the sample taken both influence hardiness (1). In this study, samples were taken at random and variation due to stem diameter or position were not taken into account.

CONCLUSION

From the data presented here it appears that the index of harvestable maturity may actually be indicating the plant's ability to withstand post harvest handling, which in turn affects its storage durability. Since the objective of this study was not to look at post harvest tolerance, no clear conclusions on this subject can be made. Further studies correlating storage ability with these characteristics on a plant by plant basis need to be made.

A major stumbling block to using any of these characteristics is the large variation inherent in their measurement. Decreasing the variation involved would require standardization of sampling with respect to position on the stem, post harvest desiccation, stem diameter and stem age. Such standardizations may enable the establishment of actual threshold values for an index of harvestable maturity.

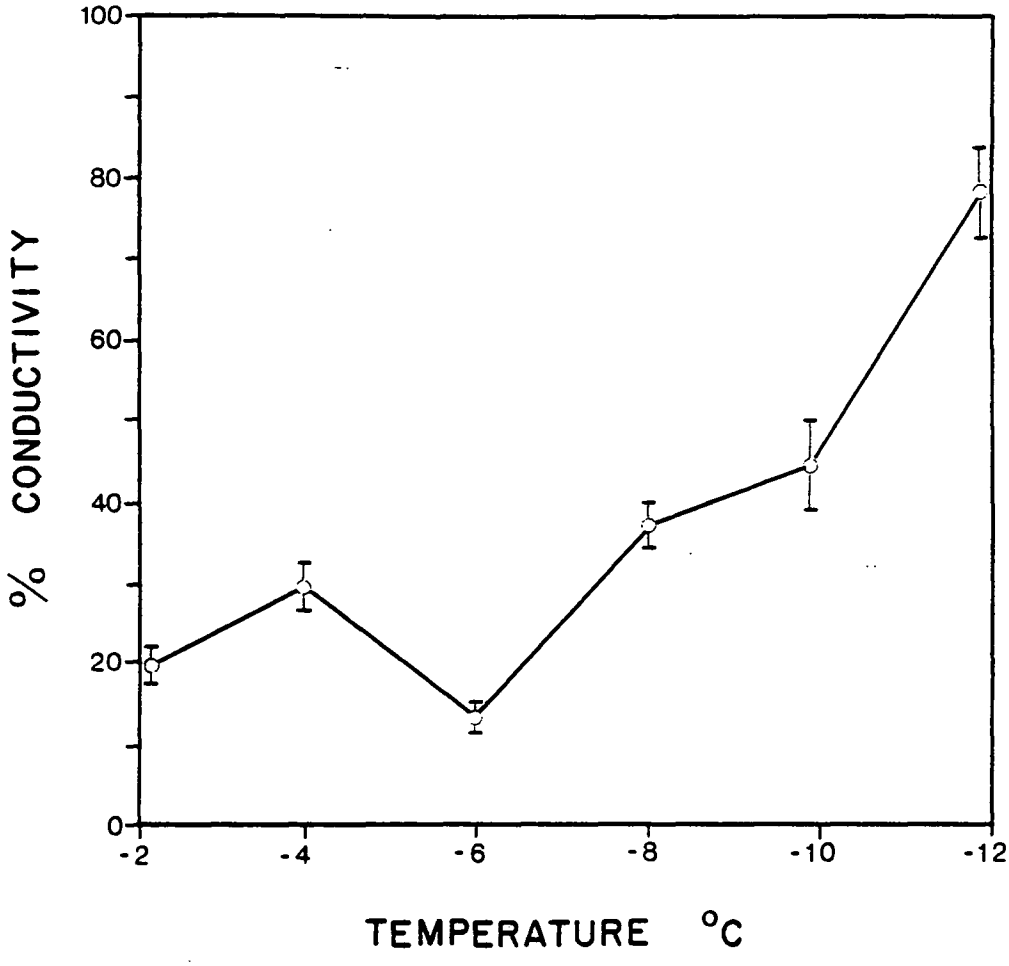

Figure 1.1. Mean percent conductivity of solution containing rose stem tissue subjected to various temperatures.

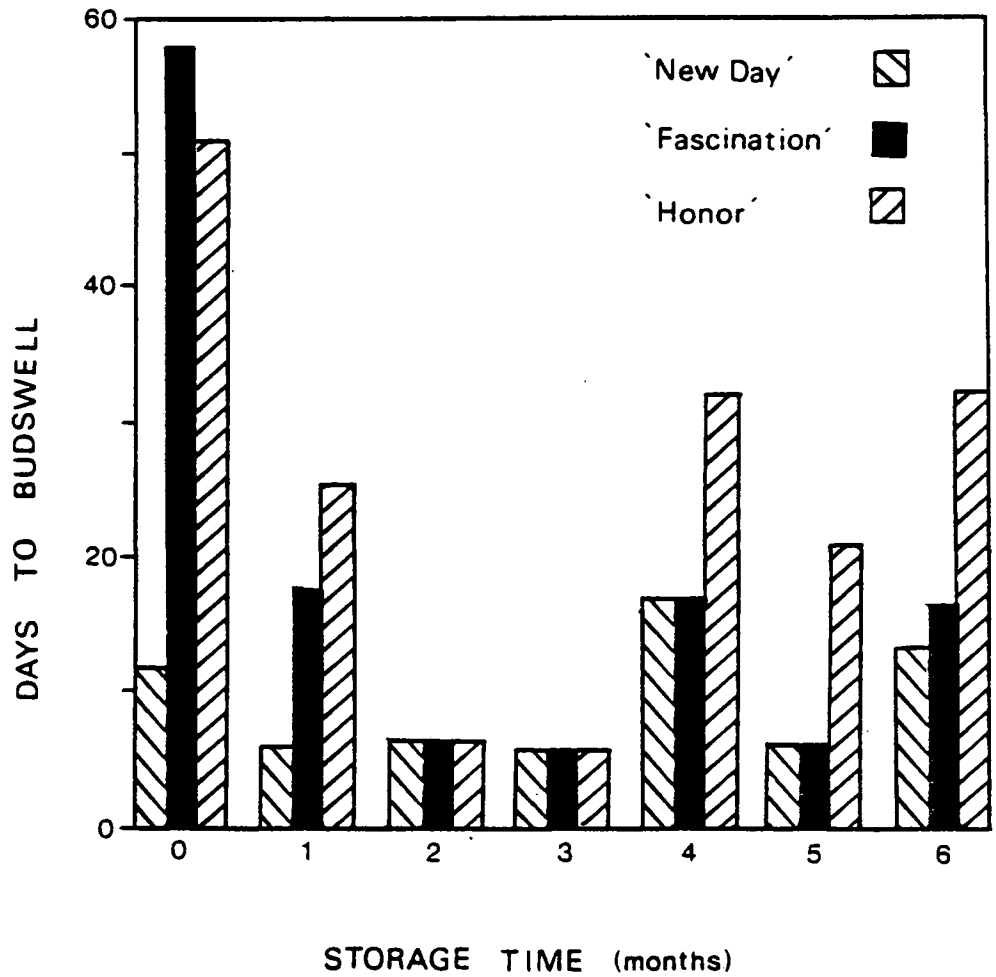

Figure 1.2. Mean days to budswell as affected by storage time for three harvest periods in fall 1982.

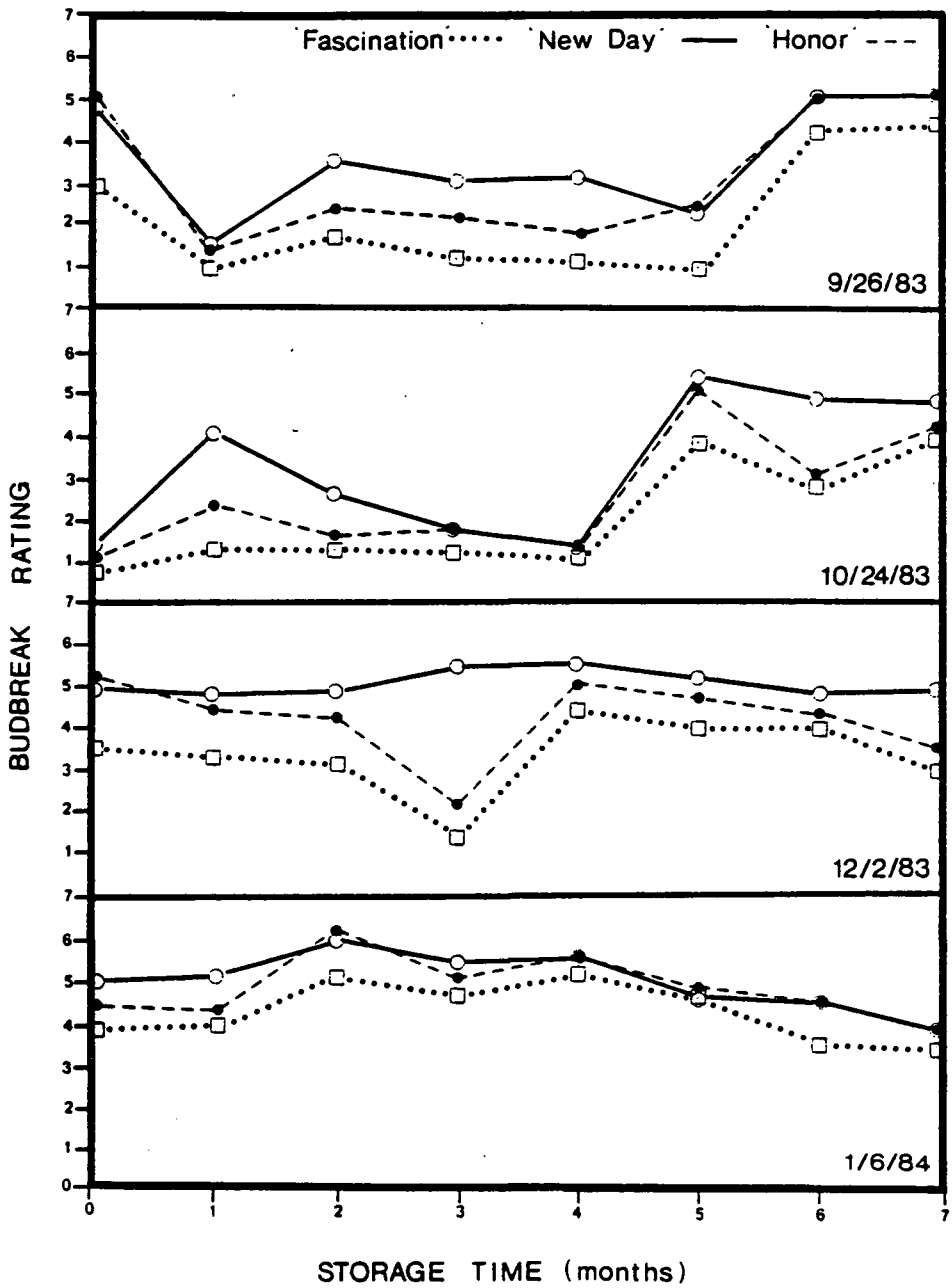

Figure 1.3. Mean budbreak rating as affected by time in cold storage, for harvest dates 9/26/83, 10/24/83, 12/2/83, and 1/6/84.

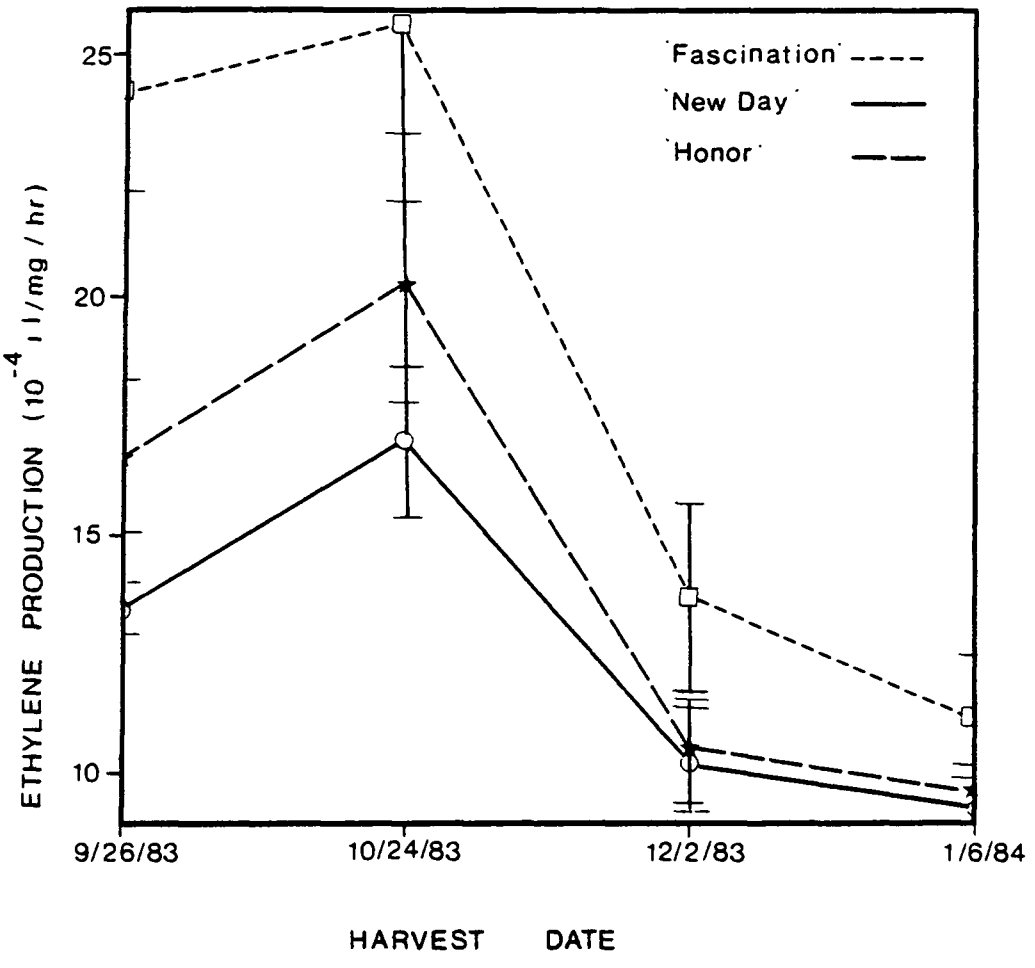

Figure 1.4. Mean ethylene production of cut stem segments as affected by harvest date. Fall 1983.

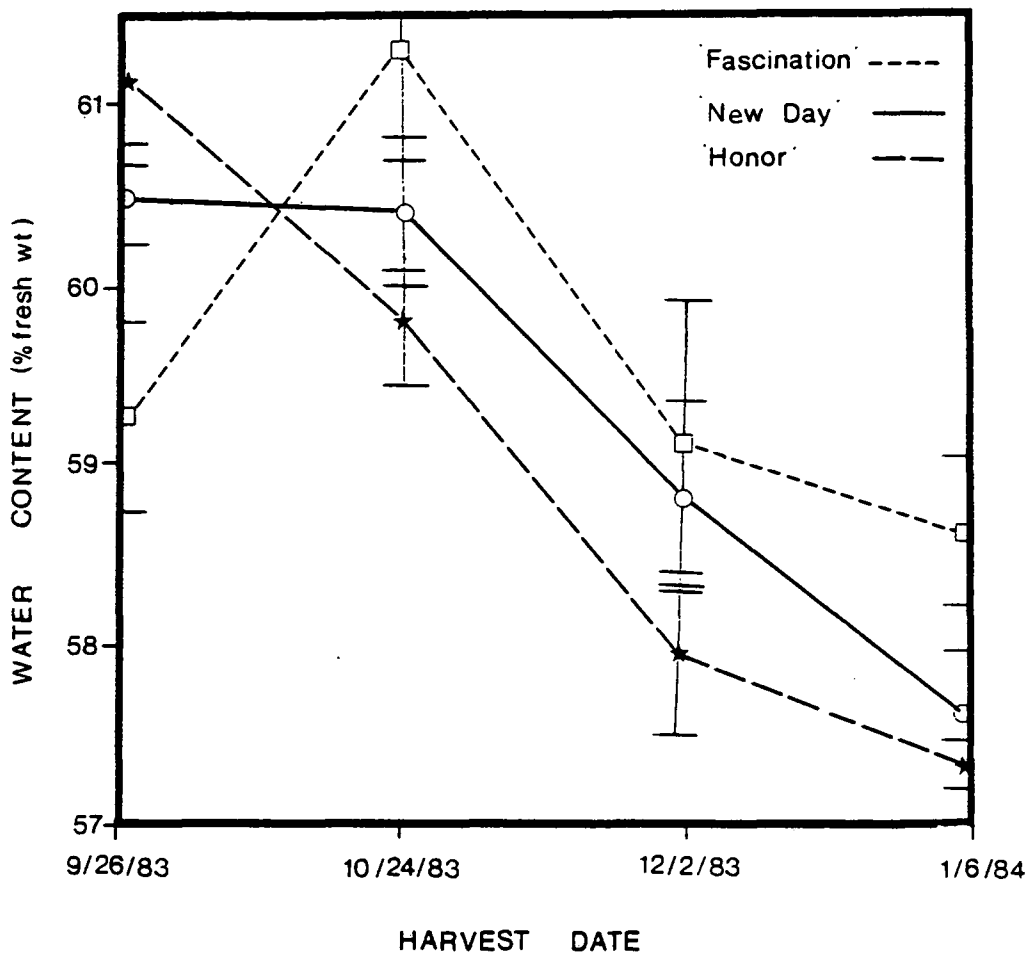

Figure 1.5. Mean water content of cut stem segments as affected by harvest date. Fall 1983.

Rating	Description
0	Bud appears to be dead.
1	Bud healthy but no indication of growth activity.
2	Bud swollen.
3	Signs of stem elongation; no fully expanded leaves.
4	First leaves expanded.
5	Stem 1 to 2 inches long.
6	Stem 2 to 4 inches long.
7	Stem 4 to 6 inches long.
8	Stem 6 to 8 inches long.
9	Stem longer than 8 inches.

Table 1.1. Rating criteria for evaluation of budbreak.

Variety	Harvest Period 11/1/82-11/15/82	11/15/82-12/15/82	12/15/82-1/15/83
'Fascination'	17.0 bc	20.4 ab	14.8 ab
'New Day'	17.0 bc	12.4 b	13.0 b
'Honor'	32.0 a	22.8 a	17.6 ab
'Cherish'	3.4 d	12.4 b	16.6 ab
'Medallion'	11.4 cd	12.4 b	17.8 ab
'Evening Star'	20.0 b	16.8 ab	23.2 a
MSE = 20.9			

Table 1.2. Mean days to budswell of roses replanted after four months of cold storage, as affected by harvest period. Means in columns followed by the same letter are not significantly different at the 5% level, using Tukey's HSD. Fall 1982.

Variety	stems with dieback percent of total	dead stems percent of total
'Honor'	52.7 a	43.3 a
'Fascination'	44.5 ab	23.7 ab
'Medallion'	30.3 b	24.9 ab
'Evening Star'	24.4 b	6.8 b
'Cherish'	10.5 b	13.9 b
'New Day'	9.6 b	9.0 b
Harvest Period		
11/1/82-11/15/82	33.3 a	29.1 a
11/15/82-12/15/82	22.3 b	11.4 b
12/15/82-1/15/83	30.4 a	20.3 ab
MSE	423	477

Table 1.3. Mean percent of stems with dieback, mean percent dead stems when replanted after four months of cold storage, as affected by cultivar and harvest period. Means within columns followed by the same letter are not significantly different at the 5% level using Tukey's HSD. Fall 1982.

Harvest Date	Temperatures (°F)		R.H. at noon	Precipitation (inches)
	Low	High		
11/2/82	51	79	87	0
11/4/82	42	74	69	0
11/8/82	46	68	56	0
11/9/82	42	55	80	0.3
11/10/82	47	64	60	0
11/15/82	39	48	86	0
11/18/82	46	69	74	trace
11/24/82	49	53	88	0
11/26/82	39	56	86	0
11/29/82	52	67	71	0.5
12/10/82	40	72	60	0
12/22/82	--	66	--	0.1
1/3/83	--	41	81	0
1/11/83	32	40	84	0
1/12/83	36	45	86	0
1/14/83	36	45	88	0
1/17/83	44	54	88	0.2
9/26/83	60	82	63	0
10/24/83	55	81	62	0
12/2/83	42	60	72	0
1/6/84	--	51	82	0

Table 1.4. Weather data for propagation fields in Wasco, California, for harvest dates of the 1982-83 and 1983-84 seasons, provided by Jackson and Perkins.

Harvest Period	Ethylene Production 10E-4 nl/mg/hr	Water Content percent of fresh weight
11/1/82-11/15/82	8.09 b	59.9 b
11/15/82-12/15/82	10.14 a	61.4 a
12/15/82-1/15/83	4.74 c	58.6 c
MSE	6.96	735

Table 1.5. Mean ethylene production and water content of cut stem segments as affected by harvest period. Means within columns followed by the same letter are not significantly different at the 5% level, using Fisher's Protected LSD. Fall 1982.

	Variety		
	'Fascination'	'New Day'	'Honor'
Harvest Period			
11/1/82-11/15/82	63.8 a	52.8 a	56.9 a
11/15/82-12/15/82	43.0 ab	49.3 a	46.7 a
12/15/82-1/15/83	33.2 b	31.5 a	42.5 a
MSE = 238			

Table 1.6. Mean percent conductivity of stems subjected to -12°C. as affected by cultivar and harvest period. Means within the columns followed by the same letter are not significantly different at the 5% level, using Tukey's HSD. Fall 1982.

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FACTORS AFFECTING COLD HARDINESS, RESPIRATION, WATER CONTENT AND ETHYLENE PRODUCTION IN ROSE STEM TISSUE

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Additional index words. Rosa hybrida

Abstract. Three factors affecting the level of cold hardiness, respiration, and ethylene production of rose stems were studied. Varieties which performed poorly in cold storage showed higher levels of respiration and ethylene production. Medial stem tissue was hardier and respired less than distal or acropetal tissue. Ethylene production and water content increased acropetally. Hardiness increased with age, while respiration and ethylene production decreased. Interactions of the three factors are discussed.

INTRODUCTION

Cold hardiness and ethylene production of cut stem segments have recently been proposed as indices of harvestable maturity for rose nurserystock (10), and studies on respiration in maple suggest that the decrease in respiration with the onset of rest may also be a practical index (9). The purpose of the index is to determine the earliest possible time in the fall when nursery stock can be defoliated and dug bareroot without damage in storage. This stage will be referred to as harvestable maturity. In addition, respiration has been reported to decrease with the onset of rest in maple (9), suggesting its potential use as a maturity

index. Development of a maturity index for roses is very important; many of the roses placed in cold storage yearly do not maintain a saleable quality[1]. However, a major problem in the development of a reliable index is consistency; there is great variation involved in random sampling of the physiological characteristics listed above which makes the assignment of threshold values difficult. The purpose of this study was to determine the importance of two factors, tissue age and position on the cane, on cold hardiness, ethylene production, water content, and respiration in an attempt to remove these sources of variation when sampling tissue for maturity.

Tissue age has been shown to affect a wide variety of physiological characteristics. Photosynthesis declines with leaf age in roses (1,2). Respiration of leaf tissue is similarly affected (5,7). Tissue age also affects rooting ability and flowering (11). Observation of rose plants in the greenhouse and the field reveals occasional sprouting of basal shoots, resulting in a plant that is a composite of various aged shoots. Sampling from such a plant without knowledge of the stem's age could result in a high degree of variability. Some varieties, e.g. 'Fascination', continue to sprout new shoots throughout the year while others cease sprouting at various times between late summer and fall. Often

[1]Fike, unpublished data.

these basal shoots are large and vigorous; canes with these characteristics have been shown to be less cold hardy than other canes (3).

Many characteristics have been reported to change with the position of the stem tissue. Work by Tukey and Green (12) has shown gradients in chemical composition to occur in Rosa multiflora. Water content, mineral nutrients and nitrogen increased acropetally, while starch decreased. In red-osier dogwood, basal portions of the stem were reported to produce less ethylene than acropetal portions (12). According to Carrier (3), cold hardiness of roses varies with position, with the basal and terminal portions of the stem tissue being less hardy than intermediate portions.

MATERIALS AND METHODS

Cold Hardiness: The material used for determining the effect of age and position on cold hardiness were individual segments selected by employees at the Jackson and Perkins Company, Wasco, California, and shipped in pre-moistened polyethylene-lined boxes to the lab in Corvallis. Ten canes were chosen for each of three varieties: 'Samantha', 'Fascination', and 'Madras'. Half of the canes were selected as being "mature"; these were canes in which growth had ceased at the apex. The other half, with actively growing apical meristems, were designated as "immature". A 2 cm segment from the basal, medial, and terminal portions of each cane was taken for each of six temperatures: -2,-4,-6,-8,-10, and

-12°C., in a completely randomized factorial design.

Viability of the frozen sections was measured as percent electrolyte leakage from the stem segments in a method similar to that used by Mecklenberg and Pridham (8). The segments were placed in six Dewar flasks and allowed to cool gradually in a Kelvinator Ultra Cold freezer set at -60°C. Tissue temperature was measured by copper-constantan thermocouples inserted into a stem segment in each flask and monitored on a Leeds and Northrup multipoint recorder. At the designated temperatures one flask was removed and warmed slowly in a 4°C. walk-in cooler overnight. The stems were then placed in scintillation vials containing 10 ml of distilled water. The vials were secured on a shaker and shaken for 24 hours at 21°C. Conductivity in 10^2 micromhos was then measured by a Markson ElectroMark pH/conductivity meter model 604. The samples were then frozen to -60°C. to kill the tissue. After thawing, the vials were again shaken for 24 hours and conductivity measured as before. Percentage conductivity was calculated by taking the ratio of the conductivity of the injured tissue to the conductivity of the dead tissue, expressed as a percent.

Ethylene Production, Water Content, and Respiration: The plants used in these studies were those used in an earlier study for budbreak evaluation (10). Varieties included were 'Fascination', 'Honor', and 'New Day'. 'Fascination' and 'Honor' were considered difficult to store, while 'New Day' did well in storage. The plants were potted at roughly monthly intervals from February through July, 1984. This provided plant stem material of

various physiological ages when the experiments were conducted in November. In all three experiments, a 3x3x7, variety x position x age factorial with 2 replications was used in a completely randomized design. As with the cold hardiness experiment, the three portions used were basal, medial, and acropetal. Age was determined by calculating days from budbreak to date of experiment. Ages included were 269, 250, 215, 188, 160, 130, and 106 days.

Ethylene production and water content were measured by methods previously described (10). Five centimeter nodal segments were taken at random from material of the appropriate ages, varieties and positions, weighed, and placed in 75 ml test tubes sealed with serum stoppers. Following 8 hours dark incubation at 21°C., 1 ml air samples were taken from the test tubes and injected into a Carle 210 analytical gas chromatograph with a 1.22 m x 3.18 mm 80/100 mesh activated Alumina column and flame ionization detector. The segments were then dried in a forced air oven at 60°C. for 48 hours and reweighed. Ethylene production was expressed as nl/mg dry weight/hour and water content as a percentage of the fresh weight.

Respiration was measured by a Gilson Respirometer using 1 cm nodal segments again randomly selected from material of the appropriate ages, varieties, and positions. Respiration rate was calculated by measuring oxygen consumption at 26.7°C.(80°F). at ten minute intervals for two hours and calculating the slope of the regression line of time vs. oxygen consumed. The fresh weights were then recorded and respiration rate expressed as nl O_2 consumed /mg fresh weight/hour.

RESULTS AND DISCUSSION

Cold Hardiness: Electrolyte leakage increases abruptly between -10 and -12°C. in both "mature" and "immature" tissue (figure 2.1). However, the immature tissue displays significantly greater injury below -8°C., as shown in figure 2.1. These results would tend to suggest that, even though roses do not undergo a period of rest, which is known to be essential for maximum development of cold hardiness (6), there is still some degree of acclimation with age.

Maturity x variety and maturity x position interactions were significant for electrolyte leakage (table 2.1). In immature tissue, 'Madras' was the least hardy, whereas 'Samantha' proved to be least hardy in the mature tissue. This would tend to indicate that the acclimation process differs with variety. The hardiness of the stem positions is also influenced by tissue maturity. In the immature tissue, hardiness increased acropetally, while in older tissue hardiness followed a pattern similar to that found by Carrier (3); proximal and distal portions of the cane were more sensitive to cold than medial portions.

In addition to the interactions described above, the temperature x position interaction was significant (figure 2.2). Differences in electrolyte leakage between the three positions was most pronounced at the lowest temperatures.

Respiration: The rate at which respiration declines with age differs with variety (figure 2.3). All varieties respired less as tissue aged, but 'Honor' decreased at a faster rate. 'New Day' showed the slowest decrease. This may reflect the fact that 'New Day' could be harvested and stored earlier in the fall without damage.

Respiration rate of medial portions of canes was significantly lower than the basal and acropetal portions (table 2.2). It is interesting to note that respiration levels follow the same pattern as cold hardiness. This relationship has also been noted in 1930 by Delong et al. in apple twigs (4).

Ethylene Production: Tissue age and positional effects on ethylene production differs among varieties. In a preliminary study accompanying the cold hardiness tests, the maturity of the plant played a significant role in the amount of ethylene produced (table 2.3). 'Madras' produced the highest levels of ethylene in "immature" tissue, while its "mature" tissue produced the lowest levels. As figure 2.4 shows, ethylene production was greatest in young tissue and decreased with age in all three varieties. In general,'Fascination', the variety considered the poorest performer in cold storage, produced ethylene at a higher rate than either 'New Day' or 'Honor'. In contrast, the variety chosen as the best performer in storage, New Day, produced the lowest levels of ethylene at all ages. Ethylene production in all varieties at all ages increased acropetally (table 2.4). This has also been reported in red osier dogwood by Seibel (12). The increase in ethylene production from basal to acropetal tissue was greatest in

'Fascination'.

The position of the tissue also influenced the rate at which ethylene decreased. In general, the rate of decline in production with age was greatest in acropetal tissue.

Water Content: Water content was also measured in the preliminary ethylene study involving the cultivars 'Fascination', 'Madras', and 'Samantha' (table 2.3). Water content between "mature" and "immature" tissues showed a marked difference, with "mature" tissues averaging 9-22% less water than "immature" tissues. Overall, water content correlated well with ethylene (r^2=.68); "immature" canes of 'Samantha', however, were an exception. This cultivar produced ethylene at its lowest rate when the water content was at its highest. The reason for this difference is unknown. In the age x position x variety study, water content followed the same pattern as ethylene (table 2.5); in fact, water content correlated very well with ethylene (figure 2.5). The water content of stems from greenhouse plants also fell within the same range as those plants dug bare root, stored, and shipped to Corvallis in a previous study (10). It must be pointed out that none of the plants in this study were under water stress when the samples were taken; in such a case ethylene would be expected to increase with decreasing water content. Instead, this high correlation indicates the similarity of patterns of variation seen in both characteristics.

CONCLUSION

In conclusion, the results showed that the physiological age of the stem and the position on a stem influence their respiration rates, ethylene production, hardiness and water content. Therefore, any physiological characteristic used for an index of maturity must carefully consider the age and position of the stem.

In addition, these studies suggest that varieties which continue to sprout basal shoots throughout the year may be difficult to develop a standard maturity index for the entire plant. In fact this may not be possible as these results suggest that the maturity of each shoot on a plant may differ. This could explain the varying degrees of dieback of individual canes on a given plant. Varieties such as 'Fascination', which continue to produce basal sprouts late in the season also suffer greater stem dieback (10).

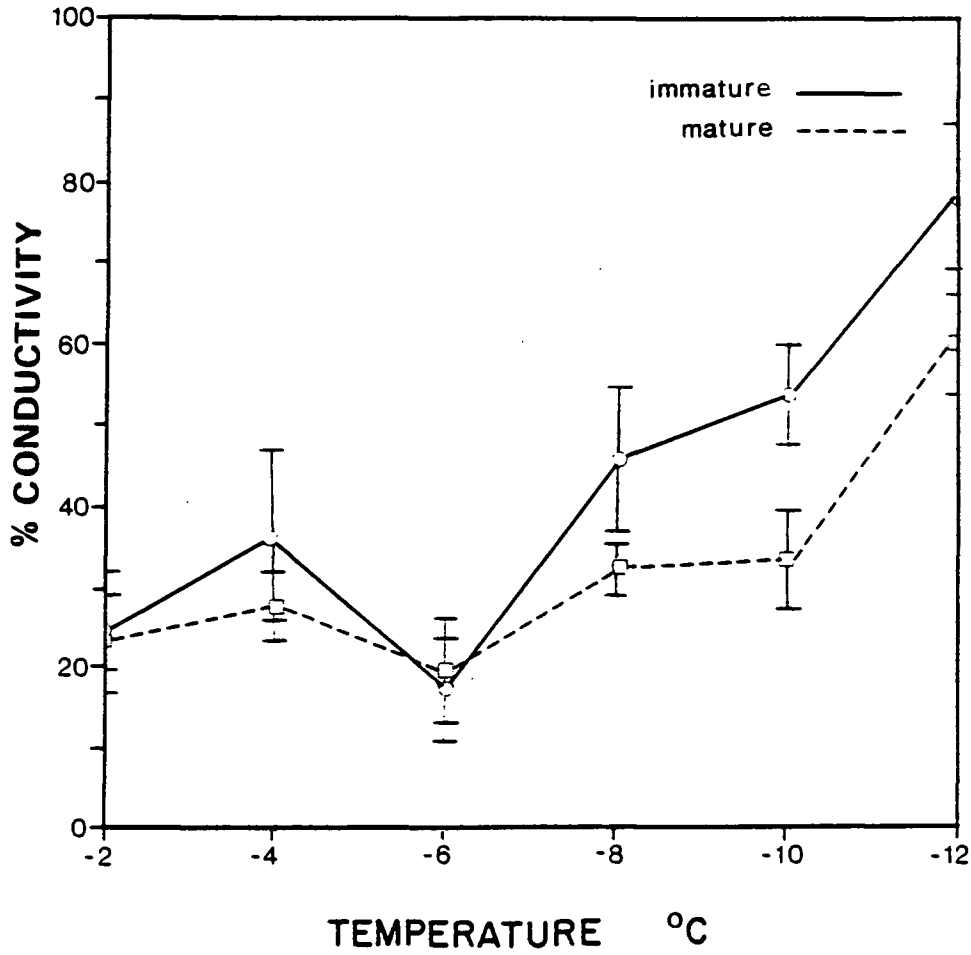

Figure 2.1. Mean percent conductivity as affected by temperature for "mature" and "immature" tissue.

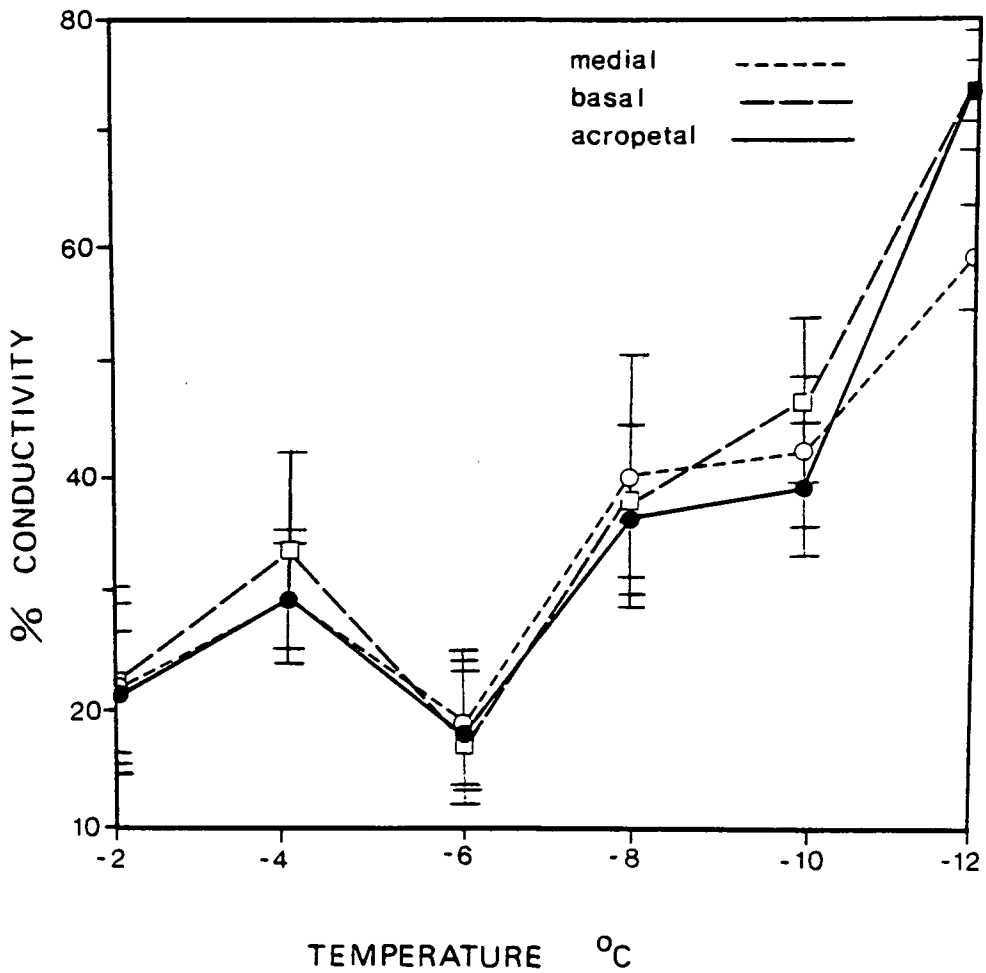

Figure 2.2. Mean percent conductivity as affected by temperature for basal, medial, and acropetal tissue, pooled across cultivars and maturity.

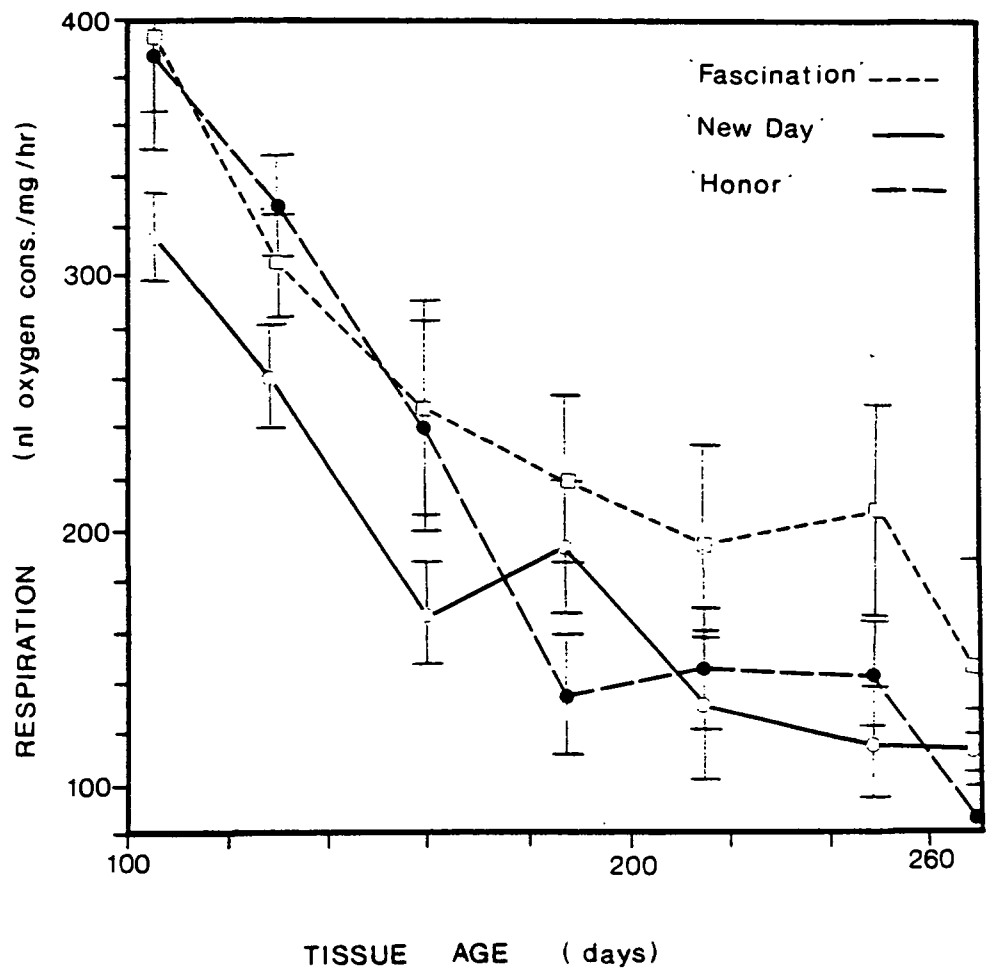

Figure 2.3. Mean respiration rate as affected by tissue age for the varieties 'Fascination', 'New Day', and 'Honor', across all positions.

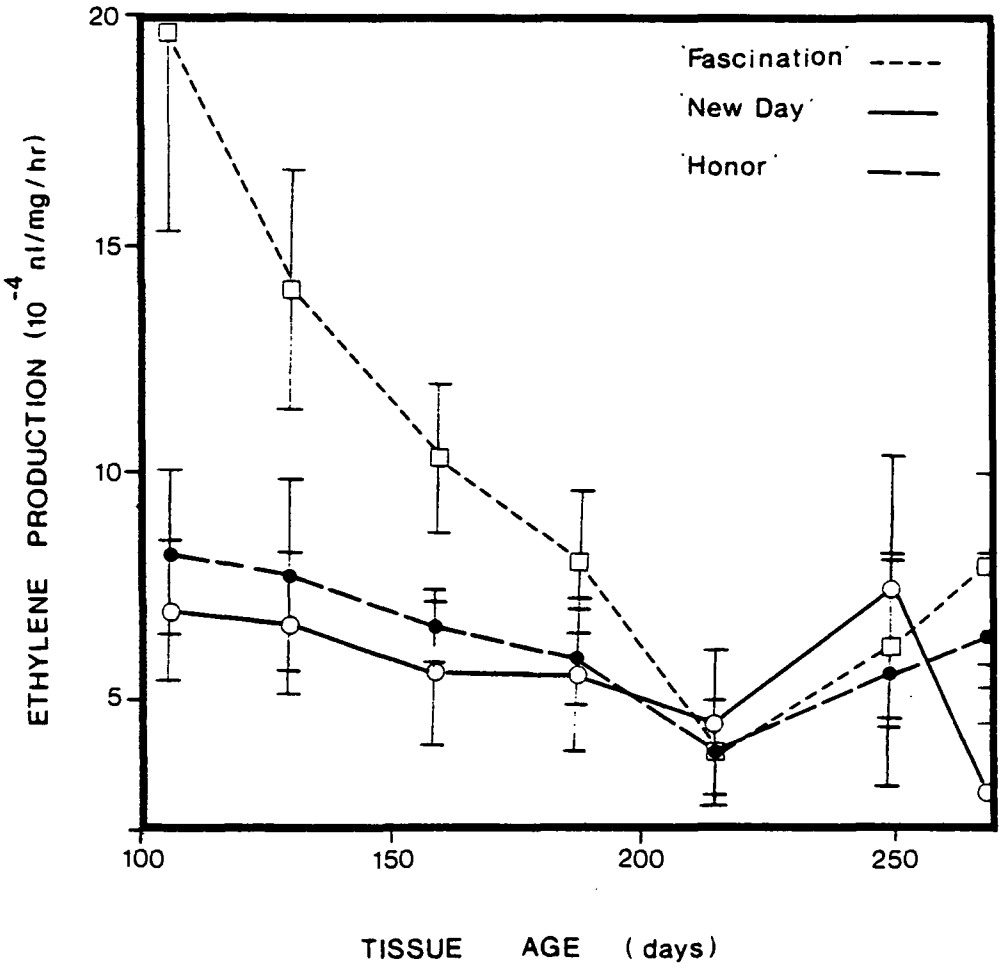

Figure 2.4. Mean ethylene production as affected by tissue age for the varieties 'Fascination', 'New Day', and 'Honor', across all positions.

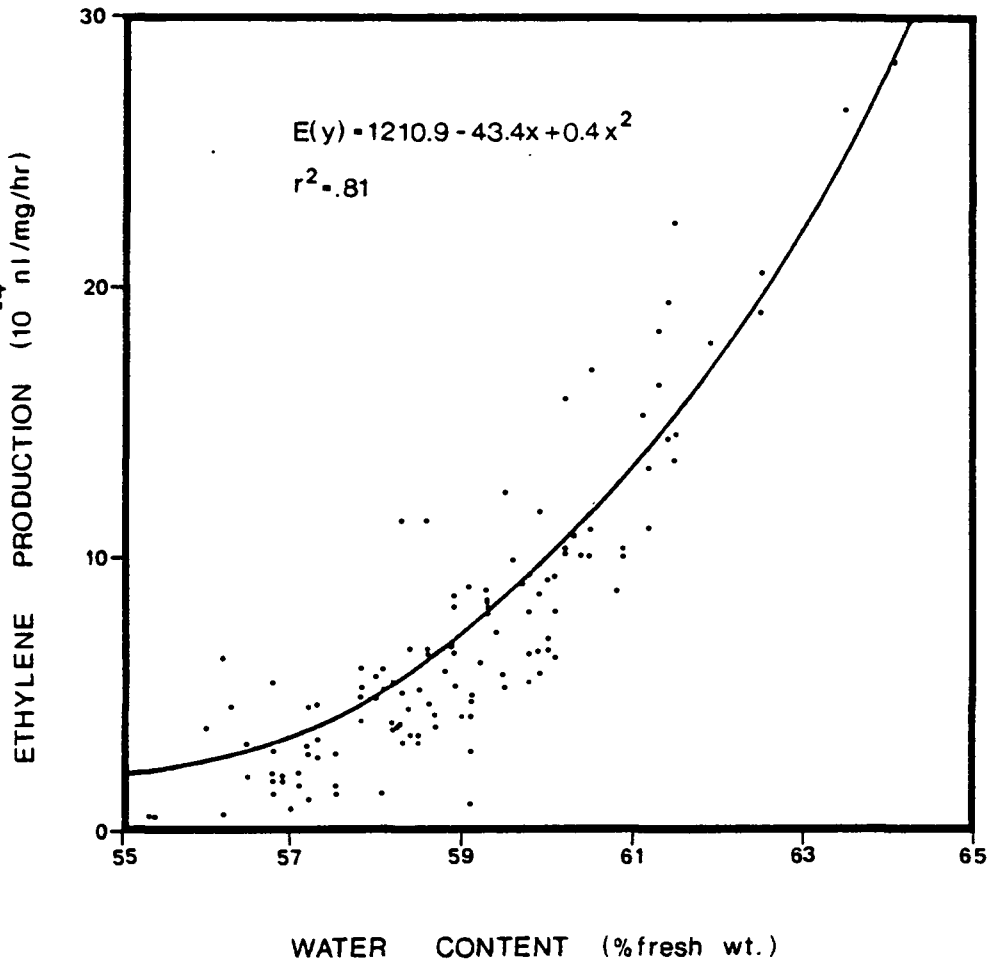

Figure 2.5. Ethylene production as a function of water content.

	% Conductivity	
	"immature"	"mature"
Variety		
'Fascination'	37.1	27.1
'Madras'	46.6	30.4
'Samantha'	43.3	39.8
Position		
Basal	46.2	32.3
Medial	41.2	30.3
Acropetal	39.6	34.8
MSE = 146		

Table 2.1. Mean percent conductivity of "mature" and "immature" tissue across all temperatures, as affected by variety and position. Means in columns were not significantly different at the 5% level using Tukey's HSD.

Position	O_2 consumed/mg/hr
Basal	220 a
Medial	189 b
Acropetal	229 a
MSE = 1449	

Table 2.2. Mean respiration rate of stem tissue as affected by position on the cane, pooled across varieties and ages. Means with same letter are not significantly different at the 5% level using Tukey's HSD.

Varieties	Ethylene Production (10^{-4} nl/mg/hr) "Immature"	"Mature"
'Fascination'	16.8	7.4
'Madras'	24.7	6.7
'Samantha'	15.1	8.6
	Water Content (% fresh wt)	
'Fascination'	67.9	55.5
'Madras'	69.6	54.0
'Samantha'	71.8	65.0

Table 2.3. Preliminary studies on the effect of maturity and variety on the stem tissue ethylene production and water content. Means within rows are significantly different at the 1 % level using Tukey's HSD.

	Variety		
Position	'Fascination'	'New Day'	'Honor'
Acropetal	14.71 a	8.31 a	9.08 a
Medial	8.59 b	4.67 b	5.48 b
Basal	5.08 c	3.81 b	4.37 b
MSE = 9.54			

Table 2.4. Mean ethylene production ($x10^{-4}$ nl/mg/hr) as affected by position for the varieties 'Fascination', 'New Day', and 'Honor' pooled across all ages. Means in columns followed by the same letter are not significantly different at the 5% level, using Tukey's HSD.

Tissue Age (days)	Water Content (% fresh wt) 'Fascination'	'New Day'	'Honor'
106	62.5 a	58.7 a	59.0 a
130	61.0 ab	58.6 a	59.1 a
160	60.1 bc	58.6 a	58.7 ab
188	60.1 bc	58.6 a	58.8 ab
215	58.5 c	58.7 a	58.4 ab
250	58.6 c	58.8 a	58.5 ab
269	58.8 c	56.8 b	57.3 b

MSE = 0.93

Table 2.5. Water content vs tissue age for the cultivars 'Fascination', 'New Day', and 'Honor'. Numbers within columns followed by the same letter are not significantly different at the 5% level, using Tukey's HSD.

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APPENDIX

Appendix 1

Water Content and Ethylene Production vs. Harvest Date and Storage Time

'Fascination'

Harvest Date:11/2/82

Storage Time (months)	Water Content (%)	Ethylene Production (1.0E-04 nl/mg/hr)
0	59.9	10.3
1	----	----
2	60.5	8.3
3	60.5	16.2
4	58.9	22.8
5	57.0	20.8
6	58.1	16.6
7	61.4	18.5

Harvest Date:11/26/82

0	60.1	9.7
1	57.9	7.0
2	59.7	22.3
3	57.6	11.3
4	55.8	22.3
5	57.4	13.8
6	58.9	16.7

Harvest Date:12/22/82

0	----	----
1	57.9	23.4
2	57.1	17.3
3	58.8	16.1
4	56.7	10.5
5	57.5	18.6

Appendix 1 (cont.)

Water Content and Ethylene Production
vs. Harvest Date and Storage Time

'Evening Star'

Harvest Date:11/10/82

Storage Time (months)	Water Content (%)	Ethylene Production (1.0E-04 nl/mg/hr)
0	56.2	10.3
1	----	----
2	56.5	10.6
3	57.4	13.1
4	57.9	7.7
5	56.8	13.0
6	54.3	13.0
7	56.8	18.2

Harvest Date:11/18/82

0	----	----
1	57.9	8.6
2	56.2	11.2
3	57.5	10.2
4	56.5	12.2
5	54.9	9.6
6	58.8	14.0

Harvest Date:1/11/83

0	----	----
1	60.3	8.2
2	60.2	14.6
3	59.2	12.5
4	57.5	15.7
5	59.1	13.7

Appendix 1 (cont.)

Water Content and Ethylene Production
vs. Harvest Date and Storage Time

'New Day'

Harvest Date:11/15/82

Storage Time (months)	Water Content (%)	Ethylene Production (1.0E-04 nl/mg/hr)
0	59.1	6.2
1	----	----
2	59.9	5.0
3	58.7	9.2
4	59.1	5.6
5	61.7	10.1
6	58.3	8.1
7	58.4	15.5

Harvest Date:11/24/82

0	62.2	10.6
1	57.8	3.4
2	58.6	9.3
3	60.2	9.8
4	61.1	17.4
5	58.2	16.5
6	59.4	----

Harvest Date:1/17/83

0	----	----
1	60.3	24.6
2	60.2	13.5
3	57.2	15.4
4	59.5	8.1
5	58.5	9.4

Appendix 1 (cont.)

Water Content and Ethylene Production
vs. Harvest Date and Storage Time

'Honor'

Harvest Date:11/9/82

Storage Time (months)	Water Content (%)	Ethylene Production (1.0E-04 nl/mg/hr)
0	60.6	7.7
1	----	----
2	59.9	4.8
3	63.5	12.1
4	60.5	8.5
5	59.6	13.1
6	58.5	12.4
7	57.9	21.3

Harvest Date:11/29/82

0	61.0	9.5
1	59.9	3.8
2	61.2	12.2
3	60.3	6.5
4	55.2	12.9
5	60.7	8.5
6	59.3	10.3

Harvest Date:1/12/83

0	----	----
1	62.0	10.3
2	62.6	4.3
3	58.3	5.1
4	57.9	5.3
5	58.8	12.2

Appendix 1 (cont.)

Water Content and Ethylene Production
vs. Harvest Date and Storage Time

'Cherish'

Harvest Date:11/8/82

Storage Time (months)	Water Content (%)	Ethylene Production (1.0E-04 nl/mg/hr)
0	56.9	4.9
1	----	----
2	54.0	3.4
3	53.9	5.5
4	54.7	6.5
5	53.0	7.2
6	55.1	4.6
7	55.1	9.4

Harvest Date:11/24/82

0	----	----
1	59.5	10.4
2	57.8	5.2
3	56.3	4.6
4	55.2	9.1
5	53.5	4.3
6	56.9	6.1

Harvest Date:1/14/83

0	----	----
1	57.7	5.6
2	58.5	5.5
3	56.1	9.7
4	55.5	3.0
5	55.7	8.9

Appendix 1 (cont.)

Water Content and Ethylene Production
vs. Harvest Date and Storage Time

'Medallion'

Harvest Date:11/4/82

Storage Time (months)	Water Content (%)	Ethylene Production (1.0E-04 nl/mg/hr)
0	61.7	5.4
1	----	----
2	61.1	8.0
3	59.4	14.8
4	63.9	10.1
5	62.9	18.2
6	58.8	14.8
7	57.4	16.2

Harvest Date:12/10/82

0	----	----
1	56.3	5.6
2	55.5	8.5
3	54.6	11.2
4	55.5	12.0
5	54.8	9.1
6	56.4	18.0

Harvest Date:1/3/83

0	----	----
1	61.1	7.9
2	61.4	20.3
3	58.9	14.4
4	58.1	17.5
5	60.1	24.5

Appendix 2

Cold Hardiness vs. Harvest Date and Storage Time

'Fascination'

Harvest Date	Temp (°C)	Storage Time (months) 0	1	2	3	4	5	6
11/2/82	0	13.38	-----	-----	-----	6.11	10.76	12.05
	-6	-----	-----	-----	-----	34.46	43.86	49.21
	-6.5	14.33	-----	-----	-----	-----	-----	-----
	-7	16.45	-----	-----	-----	-----	-----	-----
	-8	-----	-----	-----	-----	37.94	44.86	75.63
	-10	27.25	-----	-----	-----	30.73	65.24	64.47
	-12	63.80	-----	-----	-----	42.53	65.46	69.67
	-14	-----	-----	-----	-----	50.25	71.90	91.38
11/26/82	0	-----	-----	-----	10.91	8.81	11.11	-----
	-2	12.38	-----	-----	-----	-----	-----	-----
	-4	16.46	-----	-----	-----	-----	-----	-----
	-6	15.55	-----	-----	14.02	46.84	45.86	-----
	-8	18.47	-----	-----	16.44	38.06	58.64	-----
	-10	21.64	-----	-----	35.60	47.88	46.83	-----
	-12	42.95	-----	-----	38.56	61.80	55.33	-----
	-14	-----	-----	-----	38.33	65.51	73.78	-----
12/22/82	0	-----	10.50	9.04	14.81	13.74	-----	-----
	-6	-----	16.81	29.93	31.13	34.35	-----	-----
	-8	-----	22.39	25.92	54.68	19.24	-----	-----
	-10	-----	29.26	46.77	42.52	55.43	-----	-----
	-12	-----	33.21	47.48	55.06	59.47	-----	-----
	-14	-----	54.00	60.36	60.83	43.67	-----	-----

Appendix 2 (cont.)

Cold Hardiness vs. Harvest Date and Storage Time
(Mean % conductivity)

'Evening Star'

Harvest Date	Temp (°C)	Storage Time (months) 0	1	2	3	4	5	6
11/10/82	0	12.82	-----	-----	-----	5.70	8.02	10.70
	-6	-----	-----	-----	-----	30.95	54.01	55.57
	-6.5	19.67	-----	-----	-----	-----	-----	-----
	-7	23.84	-----	-----	-----	-----	-----	-----
	-8	-----	-----	-----	-----	30.18	60.86	73.04
	-10	26.36	-----	-----	-----	45.78	58.29	50.16
	-12	49.00	-----	-----	-----	57.29	70.68	69.26
	-14	-----	-----	-----	-----	64.25	67.76	79.57
11/18/82	0	-----	9.30	-----	8.16	10.51	11.83	-----
	-2	-----	-----	-----	-----	-----	-----	-----
	-4	-----	-----	-----	-----	-----	-----	-----
	-6	-----	26.68	-----	39.09	26.43	34.81	-----
	-8	-----	36.69	-----	13.82	20.87	45.01	-----
	-10	-----	23.97	-----	26.91	41.50	42.80	-----
	-12	-----	58.68	-----	46.41	51.60	58.61	-----
	-14	-----	56.40	-----	66.11	49.45	58.75	-----
1/11/83	0	-----	7.16	6.28	8.61	11.00	-----	-----
	-6	-----	14.43	19.12	51.85	30.33	-----	-----
	-8	-----	16.14	41.67	43.20	52.40	-----	-----
	-10	-----	22.93	32.17	57.31	40.39	-----	-----
	-12	-----	19.11	38.37	70.33	38.98	-----	-----
	-14	-----	43.00	58.59	71.82	67.62	-----	-----

Appendix 2 (cont.)

Cold Hardiness vs. Harvest Date and Storage Time
(Mean % conductivity)

'Cherish'

Harvest Date	Temp (°C)	Storage Time (months) 0	1	2	3	4	5	6
11/10/82	0	10.40	-----	-----	-----	9.42	12.59	11.30
	-6	-----	-----	-----	-----	25.95	33.06	41.12
	-6.5	18.00	-----	-----	-----	-----	-----	-----
	-7	29.53	-----	-----	-----	-----	-----	-----
	-8	-----	-----	-----	-----	24.59	31.42	48.69
	-10	29.53	-----	-----	-----	29.50	50.85	45.98
	-12	44.90	-----	-----	-----	38.54	48.10	57.87
	-14	-----	-----	-----	-----	49.29	51.15	59.98
11/24/82	0	-----	8.90	-----	8.68	8.31	14.53	-----
	-2	-----	-----	-----	-----	-----	-----	-----
	-4	-----	-----	-----	-----	-----	-----	-----
	-6	-----	27.14	-----	31.95	44.47	29.73	-----
	-8	-----	19.95	-----	16.73	25.39	32.74	-----
	-10	-----	21.30	-----	16.38	36.84	47.03	-----
	-12	-----	48.33	-----	41.23	41.94	46.77	-----
	-14	-----	45.88	-----	29.41	63.94	48.66	-----
12/22/82	0	-----	8.05	7.75	10.63	10.96	-----	-----
	-6	-----	11.00	12.91	29.03	33.00	-----	-----
	-8	-----	16.32	16.27	-----	27.10	-----	-----
	-10	-----	19.17	36.84	32.54	31.80	-----	-----
	-12	-----	29.72	22.08	33.67	37.95	-----	-----
	-14	-----	50.50	55.06	42.50	50.30	-----	-----

Appendix 2 (cont.)

Cold Hardiness vs. Harvest Date and Storage Time
(Mean % conductivity)

'Honor'

Harvest Date	Temp (°C)	Storage Time (months) 0	1	2	3	4	5	6
11/9/82	0	-----	-----	-----	-----	10.20	10.03	12.98
	-1	9.53	-----	-----	-----	-----	-----	-----
	-6	-----	-----	-----	-----	31.62	37.88	71.00
	-6.5	9.19	-----	-----	-----	-----	-----	-----
	-7	14.96	-----	-----	-----	-----	-----	-----
	-8	-----	-----	-----	-----	43.44	47.04	60.55
	-10	13.23	-----	-----	-----	40.84	52.05	66.03
	-12	54.22	-----	-----	-----	61.77	62.06	67.62
	-14	-----	-----	-----	-----	53.99	73.47	89.46
11/29/82	0	-----	-----	-----	7.08	8.37	8.46	-----
	-2	11.99	-----	-----	-----	-----	-----	-----
	-4	11.01	-----	-----	-----	-----	-----	-----
	-6	16.68	-----	-----	14.27	27.55	48.44	-----
	-8	17.24	-----	-----	15.20	38.15	81.25	-----
	-10	-----	-----	-----	25.49	61.78	55.50	-----
	-12	46.74	-----	-----	32.40	66.34	53.90	-----
	-14	-----	-----	-----	40.39	68.33	77.75	-----
1/12/83	0	-----	8.98	8.04	11.50	10.17	-----	-----
	-6	-----	16.09	23.48	23.99	39.40	-----	-----
	-8	-----	20.89	31.46	27.77	33.58	-----	-----
	-10	-----	24.26	35.47	43.58	35.27	-----	-----
	-12	-----	42.49	53.46	54.76	47.20	-----	-----
	-14	-----	60.65	56.91	57.95	54.72	-----	-----

Appendix 2 (cont.)

Cold Hardiness vs. Harvest Date and Storage Time
(Mean % conductivity)

'New Day'

Harvest Date	Temp (°C)	Storage Time (months) 0	1	2	3	4	5	6
11/15/82	0	-----	-----	-----	-----	8.36	7.45	11.78
	-1	9.55	-----	-----	-----	-----	-----	-----
	-6	-----	-----	-----	-----	17.93	57.35	67.64
	-6.5	11.74	-----	-----	-----	-----	-----	-----
	-7	29.53	-----	-----	-----	-----	-----	-----
	-8	-----	-----	-----	-----	42.66	51.03	76.08
	-10	20.80	-----	-----	-----	39.53	58.61	69.47
	-12	44.90	-----	-----	-----	52.36	71.36	74.02
	-14	-----	-----	-----	-----	52.30	77.07	83.46
11/24/82	0	-----	-----	-----	8.57	10.85	12.35	-----
	-2	15.14	-----	-----	-----	-----	-----	-----
	-4	12.04	-----	-----	-----	-----	-----	-----
	-6	14.86	-----	-----	19.23	47.47	41.49	-----
	-8	18.92	-----	-----	30.98	38.35	59.93	-----
	-10	27.14	-----	-----	41.44	62.90	56.26	-----
	-12	48.47	-----	-----	51.13	76.00	54.23	-----
	-14	-----	-----	-----	61.89	77.59	68.68	-----
12/22/82	0	-----	8.74	7.58	8.46	11.39	-----	-----
	-6	-----	11.39	29.93	31.21	43.33	-----	-----
	-8	-----	19.47	25.92	28.98	42.98	-----	-----
	-10	-----	24.76	46.77	52.42	57.12	-----	-----
	-12	-----	31.49	47.48	54.56	58.73	-----	-----
	-14	-----	53.13	60.36	63.89	49.61	-----	-----

Appendix 2 (cont.)

Cold Hardiness vs. Harvest Date and Storage Time
(Mean % conductivity)

'Medallion'

Harvest Date	Temp (°C)	Storage Time (months) 0	1	2	3	4	5	6
11/4/82	0	-----	-----	-----	-----	6.40	9.26	11.33
	-1	10.45	-----	-----	-----	-----	-----	-----
	-6	-----	-----	-----	-----	14.87	53.00	37.88
	-6.5	10.22	-----	-----	-----	-----	-----	-----
	-7	12.87	-----	-----	-----	-----	-----	-----
	-8	-----	-----	-----	-----	47.59	50.05	63.55
	-10	16.71	-----	-----	-----	30.33	57.38	51.45
	-12	49.01	-----	-----	-----	47.60	76.91	69.67
	-14	-----	-----	-----	-----	59.68	80.86	78.00
12/10/82	0	-----	12.03	-----	14.41	14.03	14.20	-----
	-2	-----	-----	-----	-----	-----	-----	-----
	-4	-----	-----	-----	-----	-----	-----	-----
	-6	-----	26.68	-----	26.77	10.52	31.51	-----
	-8	-----	36.39	-----	22.19	8.88	39.55	-----
	-10	-----	23.97	-----	23.42	12.16	35.69	-----
	-12	-----	58.68	-----	41.01	10.93	56.33	-----
	-14	-----	56.40	-----	30.51	10.87	58.05	-----
1/3/83	0	-----	7.10	7.75	8.74	10.76	-----	-----
	-6	-----	11.39	29.93	31.21	43.33	-----	-----
	-8	-----	19.47	25.92	28.98	42.98	-----	-----
	-10	-----	24.76	46.77	52.42	57.12	-----	-----
	-12	-----	31.49	47.48	54.56	58.73	-----	-----
	-14	-----	53.13	60.36	63.89	49.61	-----	-----