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DEVELOPMENT OF THE INFLORESCENCE IN 'MONTMORENCY' SOUR CHERRY (PRUNUS CERASUS L.) AND EFFECTS OF COMPETITION BETWEEN AND WITHIN FLOWER CLUSTERS ON FRUIT SET AND ABSCISSION

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Daniel Humberto Diaz

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Frank G. Dennis Jr.
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DEVELOPMENT OF THE INFLORESCENCE IN 'MONTMORENCY' SOUR CHERRY (*PRUNUS CERASUS* L.) AND EFFECTS OF COMPETITION BETWEEN AND WITHIN FLOWER CLUSTERS ON FRUIT SET AND ABSCISSION

By

Daniel Humberto Diaz

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ABSTRACT

DEVELOPMENT OF THE INFLORESCENCE IN 'MONTMORENCY' SOUR CHERRY (PRUNUS CERASUS L.) AND EFFECTS OF COMPETITION BETWEEN AND WITHIN FLOWER CLUSTERS ON FRUIT SET AND ABSCISSION

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Field plots were established in a commercial Michigan sour cherry orchard to investigate some of the factors which might affect fruit set, including competition among flowers and fruits, nitrogen applications and growth regulators. Flower differentiation was also monitored using scanning electron microscopy.

No correlation could be established between percent of sour cherry pistils killed by freezes and percent set of the surviving flowers. Reduced flower density following freeze injury was associated with reduced fruit set. Regardless of flower density approximately 25% of the flowers which survived freezes yielded mature fruit. Hand removal of two-thirds of the flower buds at bud swell did not alter percent set significantly. Competition between flower clusters is therefore not a factor controlling fruit set. Removal of two-thirds of the flower buds for two or three consecutive years did not affect set as compared to

control; thus fruit load does not appear to affect subsequent percent fruit set. Abscission of flowers and immature fruits was not affected by flower bud thinning at bud swell or by removal of two-thirds of the fruits or leaves 2 weeks after bloom.

Within clusters fruit set of flowers that opened early was greater (25-36%) than that of flowers which opened late (19-27%). This was not affected by selective hand removal of flowers within clusters; thus fruit set is not affected by competition among flowers within clusters. Within flower buds tetrad formation in anthers of flowers which opened early occurred 1-2 days earlier than in those which opened late, and embryo sacs in the early opening flowers were less subject to degeneration than were those in the late-opening flowers.

Critical point dried axillary buds of 'Montmorency' sour cherry were viewed in the scanning electron microscope to determine the morphological changes which occur during flower formation. The first evidence of change from the vegetative to the reproductive stage occurred as a flattening of the apex five weeks after full bloom. Sepal primordia were evident 45 days after the first signs of initiation and 2 weeks later petal and stamen primordia developed. Pistil initiation occurred about 3-4 weeks later. Up to the time of anther and probably pistil initiation, flowers within a bud differ in stages of development and these differences probably play a role in the setting potential of such flowers.

To my parents, Raul and Celia, for

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Guidance Committee:

The journal-article format was adopted for this dissertation in accordance with departmental and university requirements. Two sections were prepared and styled for publication in the Journal of the American Society for Horticultural Science.

INTRODUCTION

Michigan produces about 60-70% of the national tonnage of sour cherries. Almost the entire crop is frozen or canned, and one cultivar, 'Montmorency', accounts for all but a few tons.

One of the most important problems of the cherry industry is fluctuating yearly yields, caused primarily by spring frosts which kill some of the flowers. Also, the shedding of flowers or immature fruits is so heavy in some years that the crop is greatly reduced.

To avoid freeze injury, attempts have been made to delay bloom of fruit trees using either growth regulators (14, 41) or evaporative cooling (8, 51, 57). Response to growth regulators has not been encouraging and side effects make their use questionable (14). Evaporative cooling is more effective in arid (1) than in humid (Dennis, personal communication) regions, delays of up to 2 to 3 weeks having been achieved under arid conditions as compared to 6 to 7 days in humid areas.

For many years researchers have tried to establish what controls fruit set and abscission in order to be able to manipulate production. If this were possible, one might compensate for moderate frost injury by increasing the percentage set of the remaining flowers. Many factors control fruit set and abscission, and most appear to be critical at one or more stages of development. For sour cherry, competition between individual blossoms or fruits (3, 4), and early embryo sac degeneration (4, 37) may reduce fruit set.

The objectives in this research were (a) to determine the effect of position of flowers within the cluster on egg cell normality, and the effects of flower position and density on fruit set and abscission, and (b) to describe the morphological and anatomical development of the flowers from initiation in early summer until just prior to bud swell the following spring.

LITERATURE REVIEW

Sour Cherry Production

Michigan ranks first among the United States in production of sour cherry. Within the state in 1977, an average year, sour cherries accounted for 22% of the acreage, 20% of the total production and 39% of the total value of fruit crops (55). Within the last 10 years the total production of sour cherries in the United States has varied between 90 and 220 million pounds, mainly because of fluctuations in yield in Michigan. These fluctuations have caused the same effects on price of cherries to the producers with a range of 15 to 50 cents per pound with consequent major problems in marketing. By 1985 sour cherry production in Michigan is expected to be 224 million pounds, or 39% above the average for 1973-1978 (46). Observers (46) predict an 8% increase in acreage plus an increase in yield per acre. The industry must find a way to reduce fluctuations in production from year to year in order to maintain a uniform market that would economically benefit growers.

Origin of 'Montmorency'

The cultivar Montmorency accounts for most of the sour cherry production. It is believed to have originated in the Montmorency Valley in France around the seventeenth century, probably as a seedling of 'Cerise Hative' or 'Cerise Commune'. It was first mentioned by Duhamel in 1768 and in America in 1832 by William Prince (40).

Flower Bud Formation

In most deciduous fruit trees, flowers are initiated and differentiate the summer before they open. Goff (32) in 1899 was the first to report on the origin and development of flowers in stone and pome fruits. Other workers have provided additional information (20, 33, 36, 76). Depending on the location, condition of the tree and the cultivar under study, initiation (visual morphological change in apex) occurs in sour cherry about 5 to 6 weeks after full bloom and differentiation of most flower parts is complete 8 to 10 weeks later. The first noticeable change in the apex is a flattening-out. As the season progresses the apex becomes concave, and sepal, petal and stamen primordia develop acropetally (36). Gibberellin inhibits flower differentiation in peach (9) and cherry (10, 45), while SADH hastens it (58). Fully developed reproductive buds contain 2 to 4 flowers in an inflorescence that Goff (32) classified as a corymb. He noted that the proximal flower was slightly more advanced than the others.

Fruit Set and Abscission of Fruits

Deciduous fruit species normally produce many more flowers than will set fruit. Continuous shedding of flowers shortly after bloom and of immature fruits throughout the fruit maturity season results in a low percentage of flowers developing into mature fruits. Peach normally sets 30% of its flowers (38), almond, 30% (48), and sour cherry, 25% (4). As important as knowing what percentage of flowers will produce mature fruits is knowing what percentage must set in order to yield a commercial crop. Fletcher (25) reported that for plum and apricot a 13% set assured a good crop when no frost occurred, while Roberts reported 25% for sour cherry (68).

The abscission patterns of flowers and immature fruits have been established for most of the stone fruits. Those of the peach (16, 38, 90), almond (48), plum (17) and sour cherry (3, 37) are very similar. Three periods of fruit drop occur; the first takes place during bloom or shortly thereafter and appears to consist largely of defective flowers which drop without appreciable enlargement of the ovary. Their pedicels are often shorter than normal and the style and calyx cup do not abscise (4, 38, 48). The time of the second drop varies with species, occurring about a month after bloom in almond and peach (2, 38, 48), and about a week after the end of the first drop in sour cherry (3, 37). Sour cherry fruits falling in this drop are primarily 5-7 mm long. The calyx cup and style have abscised and the ovary is slightly yellow and has a dull surface appearance in comparison with developing fruits (4). The third drop occurs about three weeks after the second in sour cherry (3, 37) and about six to seven weeks after full bloom in almond and peach (38, 48). The fruits in this drop are large (9-10 mm long) with an ovate shape as compared to the globoid shape of persisting fruits (4, 38, 48).

The proportion of fruits which fail to develop to maturity varies from year to year. A range of 50 to 75 percent drop of the total number of blossoms has been reported for sour cherry in various years (4). Distribution of the drops also varies among years. In almond no first drop occurred one year (48), while in sour cherry an inverse relationship often exists between the intensities of the first and second drops (4, 37). The proportion of fruits falling in the third drop is generally low relative to the total number of abscising fruits.

Internal Factors Affecting Fruit Set

a) Compatibility. Some tree fruit cultivars are receptive to their own pollen (self-compatible), some are not (self-incompatible). In the latter pollen must be supplied by another cultivar (cross-pollination). Most apple and pear cultivars require cross-pollination while most peach cultivars are self-compatible. Most of the self-incompatible peach cultivars have been eliminated from the market because of their need for interplanting and insect pollination (54). Most sweet cherry cultivars are self-incompatible. Three of the most important cultivars--Bing, Lambert, and Napoleon--are inter-incompatible (27, 81), and therefore interplanting is essential. The need for insect pollinators is especially important for any species in which some cultivars are self-incompatible.

Some sour cherry cultivars are reportedly both self- and inter-compatible (4, 89) but others are self-incompatible (61). Roberts (67) stated that blossoms of 'Montmorency' were self-compatible and that insect pollinators were not needed. Marshall et al. (52) found that hand pollination with 'Montmorency' pollen increased set of 'Montmorency' (24%) in comparison with open pollinated flowers (7.5%). Similar results were reported by Hootman (42), Shoemaker (71) and Wocior (87).

Fruit set of 'Montmorency' trees which were caged with bees was 31% in comparison with 11% for the controls (71). Similar results have been reported by Drescher (19). Roberts (67) observed that the use of other cultivars, such as 'Early Richmond', as a source of pollen increased set of 'Montmorency'. Marshall et al. (52) confirmed this and suggested that higher viability of 'Early Richmond' pollen might be responsible for the difference.

Therefore, although most of the sour cherry cultivars are self-fruitful, insect pollination seems to be essential and cross-pollination may be beneficial.

Wocior (88) collected pollen from sour cherry flowers opening before, after, or at full bloom; maximum germination and tube growth occurred in that collected at full bloom.

b) Pollination, fertilization and embryo-sac viability. Following pollination several processes must occur before fertilization is accomplished, including pollen germination and tube growth. Flowers of 'Pandy' sour cherry are open an average of 80 hours. Their pistils become receptive 12 to 13 hours after anthesis and remain so for 48 to 130 hours, while the anthers dehisce 13 to 44 hours after anthesis (62). Following deposition of the pollen grain on the stigma, the grain swells and its coat cracks allowing the pollen tube to grow into the style. The time required for the tube to reach the micropyle varies with species and with environmental conditions. It varies from one (37) to 4 days (69) in sour cherry and 1 (78) to 5 days in sweet cherry (22), while for peach 4 days are required (38). Once the pollen tube reaches the micropyle and enters the embryo-sac, it discharges its two male gametes, one of which unites with the egg cell to form the zygote, while the other fuses with the polar nuclei to form the endosperm (29).

Bradbury (4) indicated that neither lack of pollination nor failure of pollen tubes to reach the ovary were important factors controlling fruit drop in sour cherry. She found pollen tubes in the ovarian cavities of both aborting and developing fruits 4 to 5 days after full bloom. Thus slow pollen tube growth was not responsible for lack of fertilization in first drop fruits. Ninety-one percent of abscising fruits sampled 12 days after full bloom contained two shriveled ovules, while all of the developing ones contained at least one plump ovule. Only 6% of third drop fruits did not contain an embryo. She concluded that abnormalities occur in the embryo-sac at least as early as full bloom. The degeneration observed in some flowers a day or two before blossoms opened support her conclusion. If her data are pooled, as much as 50% of the total abscission can be attributed to early embryo-sac degeneration.

Similar events occur in apricot (24), sweet cherry (21), plum (17), apple (18) and peach (38). Eaton (21) recorded the rate of embryo-sac degeneration in unpollinated 'Windsor' sweet cherry flowers following anthesis. At anthesis almost all embryo-sacs had reached the 8-nucleate stage; 2 days after anthesis over half of the flowers collected had degenerate egg cells; 4 days after anthesis 80% of the embryo-sacs showed some irregularity and by 6 days after anthesis no functional egg cells could be found. Eaton and Jamont (24) reported that only 22% of apricot ovules sampled between anthesis and petal fall contained functional egg cells. Eaton (21) stresses the importance of pollination immediately after anthesis to insure fertilization and fruit set.

In the sour cherry cultivar 'Korosi' the egg cells are still viable 48 hours after anthesis, but they have degenerated after 96 hours (65). Fruit set was highest when flowers were hand pollinated within the first 24 hours after anthesis; no fruit set occurred when pollination was delayed more than 72 hours. In 'Lambert' sweet cherry, mutant clones with a high pollen fertility had 62% normal egg cells while those with low fertility had only 46% (23).

What triggers embryo-sac degeneration is unknown. Harrold (38) observed shrinking of the nucellus at the chalazal end of peach seeds while the embryo-sac was apparently normal, indicating a possible disruption of the vascular system supplying the ovule. This in turn might cause egg cell degeneration. Similar observations have been made in plum (17).

Reports as to the cause of abscission of apparently normal fruits in the second and third drop are contradictory. Dorsey (17) suggested that the second drop of plum results from a lack of fertilization, while Bradbury (4) found some fruits with embryos in cherry. Even less is known as to the cause of the third drop. Abscising peach fruits do not exhibit any apparent differences in structure in comparison with developing fruits (38), embryo size being the only observable difference. Simons and Chu (7) suggested that the amount of placental tissue was important in apple and that formation of an abscission layer through the funiculus at the suspensor cell may be the first phase of embryo abortion and fruit drop. Weinbaum and Simons (84), comparing persistent versus potential drop fruits of apple, showed that at the time a fruit stops growing (an indication that it will abscise), no evidence of degeneration or functional change was evident in the embryo or the endosperm. Plum (17) and peach (38) fruits from the second and third drops contain seeds in which the integuments have begun to turn brown at the chalazal end. Browning extends towards the micropylar end as degeneration proceeds. All of these observations suggest that in the course of embryo abortion, the initial disorder occurs elsewhere than in the embryo itself. Therefore, embryo abortion probably is a result rather than the cause of fruit abscission.

c) Diseases. Various fungi, bacteria, viruses and other microorganisms can reduce production potential of sour cherry (26, 35). While most can be controlled by spray programs, some, including necrotic ring spot virus and yellows virus, cannot. Their effect on growth and yield has been reported (12, 49, 64). Tree to tree transmission of viruses can occur through the pollen (6, 30, 49, 64). Pollen from virus-infected trees is less effective in setting fruit than that from healthy trees (80, 82). Total sterility of sour cherry flowers may occur in trees infected with necrotic ring spot virus (80).

d) Competition between flowers. Numerous reports suggest that competition between flowers or fruits controls set (4, 17, 70, 85). Therefore a freeze which reduces flower density should reduce competition and increase set of the remaining non-injured flowers. Sax (70) noted that a larger percentage of apple flowers set fruit when blossoms were thinned prior to hand pollination. Bradbury (3, 4) reported that percentage fruit set of sour cherry was greater in years when bloom density was reduced by winter injury. However, using data published by Gardner (28), I have calculated the correlation coefficient (r) between percent survival following freezes versus percent set of surviving flowers. The value $r = 0.438$ is non-significant at $p = 0.05$ for these observations. Thus competition cannot explain all observations and other factors must also be involved.

Competition among flowers within buds has been reported. Bradbury (4) noted that early thinning to one blossom per bud increased percent set of sour cherry. Howlett (43) increased fruit set of apple flowers from 3% (untreated) to 50% by removing all flowers but one on each cluster. The terminal flower set better than did laterals and its presence reduced the set of the laterals. Srivastava (74) found no differences between setting potential of terminal versus lateral pear flowers; however, those in the central part of the inflorescence set best. In grape the highest percent set occurred in flowers opening the first day (66). When whole clusters were considered, about 70% of the berries developed from flowers opening the first 2 days. Selective removal of flowers opening the first, second or third day did not increase set; therefore competition was not a factor.

Thinning of the fruits is a commercial practice to increase size and/or color of fruits. Little is known as to its effect on fruit retention because it is usually done after "June" drop, that is, after most of the drop has occurred. Howlett (44) thinned apple fruit clusters to 1 to 4 lateral fruits about a month before June drop. As the number of fruits left per cluster increased the percentage of fruits remaining after June drop decreased. He concluded that reducing fruit competition early in the season largely eliminated June drop. Zucconi (90) removed two-thirds of the 1-year-old branches and one-third of 2-and 3-year-old branches on peach trees before anthesis, as well as two-thirds of the fruits set 2 weeks after bloom. Only 23 to 31% of the fruits left on these trees abscised, while 77 to 99% of the fruits on control trees, in which no branches or fruits were removed, abscised. Therefore, reducing fruit load early in the season reduces subsequent fruit drop in apple and peach.

e) Competition between fruit set versus current season vegetative growth. Fruit set occurs at the same time as shoot growth, and the two processes supposedly compete. However, Goff (34) showed that growth of the terminal bud on fruit spurs did not prevent setting of sour cherry fruits, as spurs that made more than 2.5 cm growth during the fruit setting period set fruit as well as did those with less than 2.5 cm growth.

f) Fruit set and flower bud position. Buds on sour cherry may occur on one-year-old shoots or on spurs on older wood. Flower bud production on spurs accounts for about 60% of total yield (67, 68, 77); however, relative setting ability of flowers on spurs versus those on one-year wood has not been evaluated. Roberts (68) mentioned that flowers on sour cherry shoots did not set as well as those on spurs, but no data were presented. Diaz (unpublished data) observed that 25-31% of flowers on shoots set fruit while those on spurs of 2, 3- and 4-year-old wood set 19-25%.

External Factors Affecting Set

a) Temperature. This is the main environmental factor controlling fruit set in fruit trees, and it exerts its effects in various ways. After rest is broken, microsporogenesis of sour cherry begins when daily temperatures exceed 5 to 6°C (56). Sour cherry pollen germinates well at 20° but is retarded by temperatures below 10° (34). Pollen germinates freely at 9° and the tube rapidly grows through the style. In sunny warm weather (15 to 22° and 9 to 12 hours of sunshine) the longevity of the sour cherry ovule is 2 to 3 days, while during cool overcast weather (4 to 12°) longevity may be 4 to 6 days (60). Thompson and Liu (75) observed that both initial fruit set and ovule longevity in plum were inversely correlated with post bloom temperature. Although ovule longevity is prolonged when temperatures are low, pollen tube growth is retarded, offsetting any beneficial effect on set. Similar observations have been made in bean (63).

The main adverse effect of temperature on sour cherry production is spring freeze injury to the flowers. The temperature at which 50% of the flowers are killed increases rapidly as the buds swell, reaching -5°C prior to bud scale separation and -3° at full bloom (15). Not all blossoms on a tree are at the same stage of development at any given time, and the amount of injury depends to a considerable extent on the percentage of opened versus unopened flowers.

b) Light. Several reports show that shading sour cherry trees, so as to reduce light intensity up to 50% for 2 to 3 weeks beginning at bloom, has no effect on pollen germination or tube growth (37, 69). However, the effect on fruit set has been contradictory, Gray (37) observing no effect while Lengord (50) and Roberts (68) noted a reduction in set.

c) Cultural practices. Nutrition plays a key role in tree yield and is closely related to tree vigor. Nitrogen application increases yield of sour cherry (5, 11, 77) but this may reflect an effect on vegetative growth, increasing the number of nodes where flowers can occur, rather than an actual increase in fruit set. In 'Schattenmorelle' sour cherry nitrogen applications increased both the total number of flowers per tree and the number of flowers per inflorescence (53). Wierszyllowski (86) reported that sour cherry trees treated in the fall with N-P-K and some minor elements dropped less fruit the following year. Fall applications of boron are effective on increasing set in Italian prune (7) and sweet cherry in Oregon (Westwood, personal communication).

Pruning can affect tree size, spur and flower bud formation, leaf area and fruit size, depending on severity and timing (29). Sour cherry orchards in Michigan are often left unpruned after initial training. Recently, Kesner et al. (47) reported that hedging of sour cherry trees before bloom increased both percent fruit set and yield in the year of treatment.

Although chemicals are effective in increasing set of some fruits (73, 83), no significant or consistent results have been obtained in stone fruits (13, 39). Some positive effects have been reported with self-incompatible sour cherry cultivars following application of auxin and/or gibberellins (59, 79).

Summary

Sour cherry production is erratic due to various factors of which the most important is freeze injury to the flowers. Considering that a relatively small percentage of the surviving flowers yield mature fruit, there is a need to evaluate more critically what controls fruit set, and to find methods to increase it.

Efficient pollination is essential for rapid fertilization of the egg cell, as the longevity of the ovule after anthesis is limited. This can be achieved by introducing bees and possibly by interplanting pollinizers. The cause of rapid ovule degeneration is unknown. Although nutritional status of the tree has been implicated as a possible cause, little evidence is available to support this hypothesis. Competition between flowers and/or fruits may also reduce set, but available data are contradictory.

Some critical work needs to be done to establish the relationship between nutrition and set, as well as the importance of environmental factors. Such studies should include evaluations of flower formation and ovule longevity as well as all other processes involved in fruit development.

In the work to be described, experiments were designed to provide additional information on some of the factors that are reported to affect fruit set including competition, nutrition, growth regulators and flower bud formation. The hypothesis that fruit set is predetermined at or near bloom was also evaluated.

LITERATURE CITED

1. Anderson, J. L., G. L. Ashcroft, R. E. Griffin, E. A. Richardson, S. D. Seeley, D. R. Walker, R. W. Hill, and J. F. Alfaro. 1976. Final report to four corners regional commission on reducing fruit losses by low spring temperature. Utah Agr. Expt. Sta.

2. Blake, M. A. 1925. The growth of the fruit of the Elberta peach from blossom bud to maturity. Proc. Amer. Soc. Hort. Sci. 22:29-39.

3. Bradbury, D. 1925. Notes on the dropping of immature sour cherry fruits. Proc. Amer. Soc. Hort. Sci. 22:105-110.

4. ________. 1929. A comparative study of the developing and aborting fruits of *Prunus cerasus*. Amer. J. Bot. 16:525-542.

5. Bryant, L. R., and R. Gardner. 1937. Fertilizer trials with sour cherry under limited irrigation. Proc. Amer. Soc. Hort. Sci. 35:347-351.

6. Cameron, H. R., J. A. Milbrath, and L. A. Tate. 1973. Pollen transmission of *Prunus* ringspot virus in prune and sour cherry orchards. Plant Dis. Rept. 57:241-243.

7. Chaplin, M. H., R. L. Stebbins, and M. N. Westwood. 1977. Effects of fall-applied boron sprays on fruit set and yield of 'Italian' prune. HortScience 12:500-501.

8. Collins, M. D., P. B. Lombard, and J. W. Wolfe. 1978. Effects of evaporative cooling for bloom delay on 'Bartlett' and 'Bosc' pear tree performance. J. Amer. Soc. Hort. Sci. 103:185-187.

9. Corgan, J. N., and F. B. Widmoyer. 1971. The effects of giberrellic acid on flower differentiation, date of bloom and flower hardiness of peach. J. Amer. Soc. Hort. Sci. 96:54-57.

10. Coston, D. C. 1976. The use of gibberellic acid sprays in altering flowering and fruiting of the sour cherry (Prunus cerasus L. cv 'Montmorency'). Ph.D. Dissertation, Michigan State University.

11. Crocker, T. F. 1971. The effect of nitrogen, potassium and SADH on yield, quality and vegetative growth of sour cherry (Prunus cerasus L., var. Montmorency). Ph.D. Dissertation, Michigan State University.

12. Davidson, T. R., and J. A. George. 1965. Effects of necrotic ring spot and sour cherry yellows on the growth and yield of young sour cherry trees. Can. J. Plant Sci. 45:525-535.

13. Dennis, F. G., Jr. 1972. Physiological control of fruit set and development with growth regulators. Acta Hort. 34:251-259.

14. ________. 1976. Trials with ethephon and other growth regulators for delaying bloom in tree fruits. J. Amer. Soc. Hort. Sci. 101:241-245.

15. ________, W. S. Carpenter, and W. J. Maclean. 1975. Cold hardiness of 'Montmorency' sour cherry flower buds during spring development. Hort-Science 10:529-31.

16. Detjen, L. R. 1926. Physiological dropping of fruits. Delaware Agr. Expt. Sta. Bul. 143.

17. Dorsey, M. J. 1919. A study of sterility in the plum. Genetics 4:417-488.

18. ________. 1929. The relation between embryo sac development and the set of fruit in the apple. Proc. Amer. Soc. Hort. Sci. 26:56-61.

19. Drescher, W., and G. Engel. 1976. Einfluss der Bestaubung von Schattenmorellen durch die Honigbiene auf den Ertrag. Erwerbsobstbau 18:19-20. (Hort. Abst. 46:9051).

20. Drinkard, A. W., Jr. 1909. Fruit-bud formation and development. Annu. Rept. Virginia Agr. Expt. Sta. pp. 159-205.

21. Eaton, G. W. 1959. A study of the megagametophyte in Prunus avium and its relation to fruit setting. Can. J. Plant Sci. 39:466-476.

22. ________. 1962. Further studies on sweet cherry embryo sacs in relation to fruit setting. Rept. Ontario Hort. Expt. Sta. and Prod. Lab. pp. 26-38.

23. ________. 1968. Embryo sac development in relation to pollen fertility in radiation induced Lambert cherry mutants. Rad. Bot. 8:515-517.

24. ________, and A. M. Jamont. 1965. Embryo sac development in the apricot, Prunus armeniaca L. cv. Constant. Proc. Amer. Soc. Hort. Sci. 86: 95-101.

25. Fletcher, S. W. 1900. Pollination in orchards. Cornell Univ. Agr. Expt. Sta. Bul. 181.

26. Freeman, J. A., H. A. Daubeny, and R. Stace. 1969. Increased pollen abortion caused by viruses in four red raspberry cultivars. Can. J. Plant Sci. 49:373-374.

27. Gardner, V. R. 1913. A preliminary report on the pollination of sweet cherry. Oregon Agr. Expt. Sta. Bul. 116.

28. ________. 1936. Factors influencing the yields of Montmorency cherry orchards in Michigan. Michigan Agr. Expt. Sta. Special Bul. 275.

29. ________, F. C. Bradford, and H. D. Hooker. 1939. Fundamentals of fruit production. McGraw Hill Book Co., Inc. 788 pp.

30. Gilmer, R. M. 1965. Additional evidence of tree-to-tree transmission of sour cherry yellow virus by pollen. Phytopathology 55:482-483.

31. ________, and R. D. Way. 1960. Pollen transmission of necrotic ring spot and prune dwarf virus in sour cherry. Phytopathology 50:624-625.

32. Goff, E. S. 1399. The origin and early development of the flower in the cherry, plum, apple and pear. 16th Annu. Rept. Wisconsin Agr. Expt. Sta. pp. 289-303.

33. ________. 1900. Investigation of flower buds. 17th Annu. Rept. Wisconsin Agr. Expt. Sta. pp. 266-285.

34. ________. 1901. A study of certain conditions affecting the setting of fruits. 18th Annu. Rept. Wisconsin Agr. Expt. Sta., pp. 289-303.

35. Gourley, J. H., and F. S. Howlett. 1941. Modern fruit production. The Macmillan Co. 579 pp.

36. Gracza, P., and M. Gergely. 1973. Some questions of flower organization in sour cherry. Acta Agron. 22:366-375.

37. Gray, G. F. 1933. Relation of light intensity to fruit setting in the sour cherry. Michigan Agr. Expt. Sta. Tech. Bul. 136.

38. Harrold, T. J. 1935. Comparative study of the developing and aborting fruits of *Prunus persica*. Bot. Gaz. 96:505-520.

39. Hartmann, H. T. 1950. Tests with growth-regulating chemicals for increasing fruit set and yield in olives. Proc. Amer. Soc. Hort. Sci. 55:181-189.

40. Hedrick, U. P. 1915. The cherries of New York. 22nd Annu. Rept. State of New York, Dept. Agr. Vol. 2, Part II.

41. Hitchcock, A. E., and P. W. Zimmerman. 1943. Summer sprays with potassium α-naphthaleneacetate retard opening of buds on fruit trees. Proc. Amer. Soc. Hort. Sci. 42:141-145.

42. Hootman, H. D. 1930. Recent discoveries in pollination methods and practices and their influence upon greater yields of desirable fruits. Proc. Maryland State Hort. Soc. 33:24-36.

43. Howlett, F. S. 1928. Fruit setting in the Delicious apple. Proc. Amer. Soc. Hort. Sci. 25:143-148.

44. ________. 1931. Effect of thinning before the June drop upon fruit production. Proc. Amer. Soc. Hort. Sci. 28:605-609.

45. Hull, J., Jr., and L. N. Lewis. 1959. Response of one-year-old cherry and mature bearing cherry, peach and apple trees to gibberellin. Proc. Amer. Soc. Hort. Sci. 74:93-100.

46. ________, D. Ricks, D. Smith, E. McManus, J. Lincoln, F. Klackle, W. Maclean, H. Better, and G. Antle. 1973. Fruit, vegetables, bees and pollination now and in 1985. Michigan Agr. Expt. Sta. and Coop. Ext. Serv. Research Rept. 188.

47. Kesner, C. D., C. H. Hansen, and S. B. Fouch. 1978. Mechanical summer tipping as a method of controlling sour cherry tree size: a preliminary report. Fruit Var. J. 32:26-28.

48. Kester, D. E., and W. H. Griggs. 1959. Fruit setting in the almond: the pattern of flower and fruit drop. Proc. Amer. Soc. Hort. Sci. 74:214-219.

49. Klos, E. J., and K. G. Parker. 1960. Yields of sour cherry affected by ring spot and yellow viruses. Phytopathology 50:412-415.

50. Lengord, L. R. 1935. Seasonal influences upon the effect of shading in regards to setting of sour cherry fruits. Proc. Amer. Soc. Hort. Sci. 33: 234-236.

51. Lipe, W. N., O. Wilke, and O. Newton. 1977. Freeze protection of peaches by evaporative cooling in the post rest, pre-bloom period. J. Amer. Soc. Hort. Sci. 102:370-372.

52. Marshall, R. E., S. Johnston, H. D. Hootman, and H. M. Wells. 1929. Pollination of orchard fruits in Michigan. Michigan Agr. Expt. Sta. Bul. 188.

53. Matzner, F. 1971. Einfluss steingender Stickstoffgaben auf die Zahl der gebildeten Blutenstade und Bluten beider 'Schattenmorelle' in Grossgefassen. Erwerbsobstbau 13:73-77. (Hort. Abst. 42:461).

54. McGregor, S. E. 1976. Insect pollination of cultivated crop plants. U.S.D.A. Agric. Handbook 496. 411 pp.

55. Michigan Crop Reporting Service. 1978. Michigan agricultural statistics, 1978. U.S. Dept. Agric. and Mich. Dept. Agric. CRSB-78-02.

56. Mikhailov, T., and S. Topchiiski. 1975. Studies on the date of microsporogenesis in some fruit species. Sweet and sour cherry. Gradinarska i Lozarska Nauka 12(8):19-27. (Hort. Abst. 47:1212).

57. Miller, M. B. 1977. Comparison of models for predicting end of rest of flower buds and use of evaporative cooling to delay bloom in sweet cherry (Prunus avium L.). M.S. Thesis, Michigan State University.

58. Modlibowska, I. 1972. Effect of growth regulators on plum and cherry trees. Acta Hort. 34:203-205.

59. Nyeki, J. 1973. Fruit set promoted by chemical induction in Pandy sour cherry. Acta Agron. 22: 207-209.

60. ________. 1974. Megyfajtak viragai termoinek es porzoinak ivarerettsege I. Kerteszti Egyetem Kozlemenyei 38(6):135-145. (Hort. Abst. 45:8152).

61. ________, and M. Soltesz. 1977. Effect of the distance and proportion of the pollen donor variety on fruit setting and fruit yield in Pandy sour cherry. Acta Agron. 26:87-89.

62. Nyujto, F., and B. Banai. 1974. A Pandy meggy viragzasmenetenek "mikrofenologiaja". Gyumolcstermesztes 1:175-189. (Hort. Abst. 46:891).

63. Ormrod, D. P., C. J. Woolley, G. W. Eaton, and L. H. Stobbe. 1967. Effect of temperature on embryo sac development in *Phaseolus vulgaris* L. Can. J. Bot. 45:948-950.

64. Parker, K. G., K. D. Brase, G. Schmid, T. H. Barksdale, and W. R. Allen. 1959. Influence of ring spot virus on growth and yield of sour cherry. Plant Dis. Rept. 43:380-385.

65. Pejkic, B. 1972. Vitalnost zenskog gametofita u visnje kereske (*P. cerasus* L.). Jugoslovensko vocarstvo 5(17/18):391-403. (Hort. Abst. 43:3448).

66. Pratt, C. 1973. Reproductive system of 'Concord' and two sports (*Vitis labrusca* Bailey). J. Amer. Soc. Hort. Sci. 98:489-496.

67. Roberts, R. H. 1922. Better cherry yields. Wisconsin Agr. Expt. Sta. Bul. 344.

68. ________. 1930. Sour cherry fruiting. Wisconsin Agr. Expt. Sta. Bul. 415.

69. Sandsten, E. P. 1909. Some conditions which influence the germination and fertility of pollen. Wisconsin Agr. Expt. Sta. Res. Bul. 4.

70. Sax, K. 1921. Studies in orchard management. II. Factors influencing fruit development in the apple. 37th Annu. Rept. Maine Agr. Expt. Sta. Bul. 298. pp. 53-84.

71. Shoemaker, J. S. 1928. Cherry pollination studies. Ohio Agr. Expt. Sta. Bul. 422.

72. Simons, R. K., and M. C. Chu. 1968. Ovule development in the apple as related to morphological and anatomical variation in supporting tissues. Proc. Amer. Soc. Hort. Sci. 92:37-49.

73. Soost, R. K. 1958. Gibberellic acid on mandarin. Calif. Agric. 12(5):5.

74. Srivastava, D. N. 1938. Studies in the non-setting of pears. I. Fruit drop and the effect of ringing, dehorning and branch bending. J. Pom. and Hort. Sci. 16:39-62.

75. Thompson, M. M., and L. J. Liu. 1973. Temperature, fruit set and embryo sac development in 'Italian' prune. J. Amer. Soc. Hort. Sci. 98:193-197.

76. Tufts, W. P., and E. B. Morrow. 1925. Fruit-bud differentiation in deciduous trees. Hilgardia 1: 1-14.

77. Tukey, H. B. 1927. Response of the sour cherry to fertilizers and to pruning in the Hudson River Valley. New York State Agr. Expt. Sta. Bul. 541.

78. ________. 1933. Embryo abortion in early-ripening varieties of Prunus avium. Bot. Gaz. 94:433-468.

79. Ugolik, M. 1975. Regulatory wzrostu w procesach zawiazywania i rozwijv owocow wisni. Roczniki Akademii Rolniczej w Poznaniu No. 56. 50 pp. (Hort. Abst. 47:5290).

80. Vertesy, J., K. Gyorgy, and J. Nyeki. 1974. A gyurusfoltossag virusok hatasa a Montmorency es Pandy meggyfajtak generativ ciklusara. Gyumolestermesztes 1:191-201. (Hort. Abst. 45:9224).

81. Way, R. D. 1968. Pollen incompatibility groups of sweet cherry clones. Proc. Amer. Soc. Hort. Sci. 92:119-123.

82. ________, and R. M. Gilmer. 1963. Reductions in fruit set on cherry trees pollinated with pollen from trees with sour cherry yellows. Phytopathology 53:399-401.

83. Weaver, R. J., and W. D. Williams. 1950. Response of flowers of Black Corinth and Thompson Seedless grapes to applications of plant growth regulators. Bot. Gaz. 111:477-485.

84. Weinbaum, S. A., and R. K. Simons. 1974. An ultrastructural evaluation of the relationship of embryo/endosperm abortion to apple fruit abscission during the post-bloom period. J. Amer. Soc. Hort. Sci. 99:311-314.

85. ________, and R. K. Simons. 1976. Relationship of seed number to fruit set in apple--an alternative hypothesis. Fruit Var. J. 30(3):82-84.

86. Wierszyllowski, J. 1977. Wplyw preparatu Wuxal na wzrost i owocowamie wisni Nefris. Referatrvhyi Zhurnal 7.55.1030. (Hort. Abst. 48:1140).

87. Wocior, S. 1976. Badania biologii pylku wytwarzanego przez kwiatz wisni zakwitajace w roznych fazach kwitnienia. Acta Agrob. 29(1):69-84. (Hort. Abst. 47:1213).

88. ________. 1976. Badania nad wybranymi zagadnieniami biologii kwitnienia i owocowania wisni. Cz. III. Niektore czynniki wplywajace na zapylenie wisni. Roczniki Nauk Rolniczych, A 101(4):63-77. (Hort. Abst. 47:5289).

89. ________, T. Mitrut, Z. Opiat, and J. Woloszyn. 1976. Badania kwitnienia i owocowania wisni. Roczniki Nauk Rolniczych, A 101(4):63-77. (Hort. Abst. 47:5289).

90. Zucconi, F. 1975. Reassessment of the relationship between hormonal and developmental changes during abscission with particular reference to peach (Prunus persica L. Batsch) fruit. Ph.D. Dissertation, Michigan State University.

SECTION I

EFFECT OF FLOWER AND FRUIT DENSITY ON FRUIT SET AND ABSCISSION OF SOUR CHERRY (*PRUNUS CERASUS* L. CV. MONTMORENCY)

EFFECT OF FLOWER AND FRUIT DENSITY ON FRUIT SET AND ABSCISSION OF SOUR CHERRY (*PRUNUS CERASUS* L. CV. MONTMORENCY)

Abstract

No correlation was established between percentage of sour cherry (*Prunus cerasus* L. 'Montmorency') pistils killed by freezes and percent fruit set of the surviving flowers. Random removal of two-thirds of the flower buds to simulate frost injury had no significant effect on final percentage fruit set in 3 consecutive years. Approximately 25% of the flowers which survived freezes yielded mature fruits regardless of flower density. The abscission patterns of flowers and immature fruits were not altered by flower bud thinning. Neither fruit thinning nor defoliation 2 weeks after bloom affected abscission of fruits. Competition between flowers and/or fruits is therefore not a factor in fruit set of 'Montmorency' sour cherry. Within clusters, flowers which opened early set better than those which opened late. Selective removal of flowers within clusters according to their opening sequence did not increase the fruit setting potential of those which remained, indicating that competition within clusters also is not a factor in sour cherry fruit set.

Nonuniform annual cropping is common in the Michigan sour cherry industry, mainly because of spring freezes. In addition, shedding of flowers or immature fruits could be so heavy some years that yield would be low even in the absence of damaging freezes.

Uniform cropping might be achieved by either a) delaying bloom to avoid freeze or b) controlling the fruit setting process. Bloom delay has been achieved both by using growth regulators (4, 9) and by evaporative cooling with overtree sprinklers (3, 13, 14). Although both methods have reduced the probability of freeze injury, side effects often reduce the potential of flowers to set fruit. The causes of fruit set are still obscure, but competition between flowers and/or fruits has been suggested as one controlling factor (2, 6, 7, 10, 11, 19). Bradbury (2) reported a higher fruit set in sour cherry in years when winter injury reduced bloom density. She also found that removal of flowers within clusters at bloom increased set. However, Gardner's (7) data show no correlation between extent of freeze injury and percent fruit set of surviving flowers. The effect of competition between flowers within clusters has been evaluated in apple. Leaving one apple flower per cluster at bloom results in much higher percent set than does leaving two, three or more flowers (10). Also the terminal apple flower, which opens first, sets better than lateral flowers, and its presence reduces the setting potential of laterals. The flowers in the middle part of the pear cluster set better than those either more apical or more basal (18). The highest percent set in grape flowers occurs in those opening on the first day, later flowers setting half as well (15).

Thinning apple (11) and peach (20) flowers and/or fruits early in the season reduces abscission of the remaining fruits, suggesting that competition is a factor in fruit set.

This work was designed to determine the effect of flower and fruit density on fruit set and to establish the relative setting ability of flowers within clusters.

Materials and Methods

The 'Montmorency' trees used for treatments were in a commercial orchard at Mears, Oceana County, Michigan, and were 16 years old in 1976. Terminal vegetative growth was 20-35 cm in length.

Effect of Freeze Injury on Set of Surviving Flowers

To establish the relationship between extent of freeze injury and set of surviving flowers, one limb with a base diameter between 0.75-1.25 cm and length of about 40-60 cm was selected on each of ten uniform trees in the spring of 1977 and eight in 1978. Two hundred flower buds per limb were counted beginning at the apex of the limb. In both years freezes (-3° to -6°C) occurred before bloom.

Two days after full bloom, the number of both injured and surviving flowers were recorded. At harvest, persisting fruits on each limb were counted and percent set determined.

Effect of Flower or Fruit Density and Defoliation on Fruit Set

In order to determine if flower or fruit density or defoliation had any effect on set either in the same or in subsequent seasons, three plots, each with 4 trees of uniform growth, vigor and yield were established in the summer of 1975 and one limb was selected on the north, south, east and west sides of each tree. Treatments applied to branches the following year were as follows: a) control--no treatment; b) two-thirds of the flower buds removed at bud swell; c) two-thirds of the leaves removed 2 weeks after full bloom; d) two-thirds of the fruits removed 2 weeks after full bloom. Each treatment was applied to one limb on each tree, using a Latin Square design, and 200 flower buds were counted on each limb. The number of flowers injured by freezes were recorded at bloom, and all results were expressed on the basis of living flowers. Limbs were shaken gently every 2 to 3 days following full bloom to dislodge abscising flowers and fruits, and persisting fruits were counted. Treatments were continued on the same limb on 1 plot in 1977, and on another plot in 1978 (Table 1); each year the number of buds, flowers and fruits were counted. In order to

Table 1. Experimental Arrangement of Treatments to Evaluate the Effect of Flower and Fruit Density and Defoliation Within Limbs on Fruit Set.

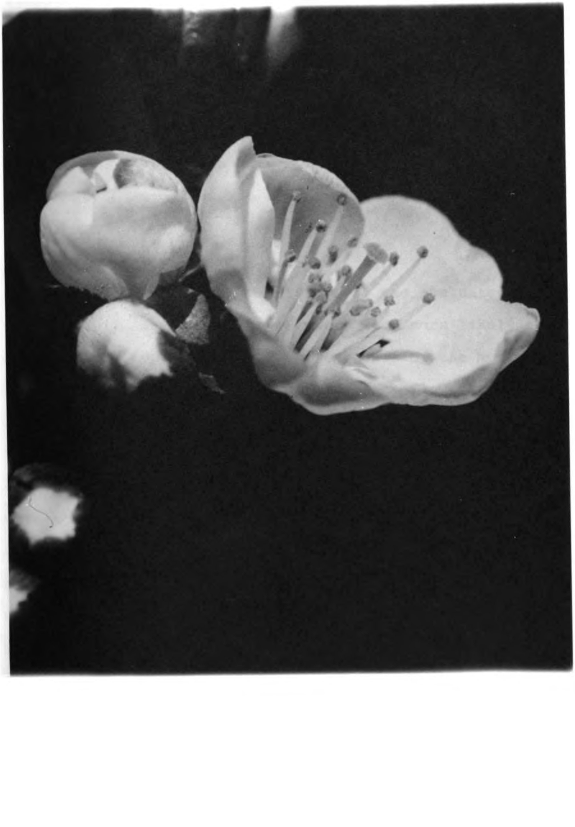
Plot	Year(s) of Treatments	Year Data Collected	Total No. Trees
I	1976 only	1976	4
II	1976 and 1977	1977	4
III	1976, 1977 and 1978	1978	4

verify the drop pattern of flowers and fruits, sheets were placed one one side of the tree (North, South, East or West) on the ground under four 7-year-old trees on an adjacent plot and abscised fruits were collected at 2 to 4 day intervals from bloom until harvest without shaking the limbs.

Effect of Flower Density and Position Within Clusters on Fruit Set

Sour cherry flowers open in sequence within clusters (Figure 1). Comparisons were therefore made of the fruit-setting ability of flowers in relation to time of opening. Flowers were classified as: A, first to open; B, second to open; and C, third to open within a cluster. In 1977 and 1978, flower clusters on 4 trees were selected and their flowers color coded with adhesive tape so as to classify their fruiting performance according to the sequence of flower opening. Also, during the spring of 1977 uniform 17-year-old trees were selected and assigned

Figure 1. Differential opening of flowers within a cluster.



to a randomized block design with 4 replications (trees) and 7 treatments, using only clusters with 3 flowers. To evaluate the effect of flower density and position on fruit set, the following treatments were applied to individual limbs: no flowers removed, C removed, B removed, A removed, A and B removed, B and C removed, A and C removed. The same design was used in 1978 with seven 7-year-old trees (replicates). Fruit set was evaluated several times during the early summer and again at harvest.

Embryo-Sac Development Within Clusters

In 1978 embryo-sac development was evaluated to determine if late developing flowers were more likely to contain non-functional sacs. At anthesis of the most advanced flower within each cluster, each flower was color labeled according to its opening sequence and samples were taken at intervals thereafter. Flowers were fixed in FAA as described by Johansen (12) and stored at 7°C. Pistils were then dehydrated using tertiary butyl alcohol (12), embedded in paraffin, and cut serially at 12 microns thickness. The ribbon was affixed to the slide with Weaver's solution (16). Sections were stained in Safranin-Fast green (12) and later examined with a light microscope. Embryo-sacs were classified according to whether the egg cell was a) differentiated, or b) irregular or degenerate. Nine to 12 flowers of each type (A, B, and C) were examined on each sampling date.

Tetrad Formation in Anthers of Flowers Within Clusters

To evaluate the time of microsporogenesis in relation to flower position within the bud, flower buds were collected at bud swell in 1978 and processed as described above. Anthers were examined with a light microscope and flowers were classified as to whether tetrads were present or not.

Results and Discussion

Freeze Injury

In both 1977 and 1978, percentage fruit set of flowers which survived freezes decreased as the proportion of flowers killed increased (Figure 2). However, correlation coefficients were nonsignificant in both years. As data were available for only 8 to 10 limbs, significant values might have been obtained with more replications. This relationship might be expected if sub-lethal frost injury occurred, and internal tissues such as the ovules were damaged without injury to the pistil itself.

Flower Cluster Density

Removal of two-thirds of the flower buds did not affect final percent fruit set (Table 2). Although all treatments reduced fruit set slightly, in no case were differences significant at 5%. These data do not agree with those of Bradbury (2) who found that low flower density increased set of sour cherry. Removal of

Figure 2. Freeze injury to flowers vs fruit set at harvest in 'Montmorency' sour cherry, 1977 and 1978.

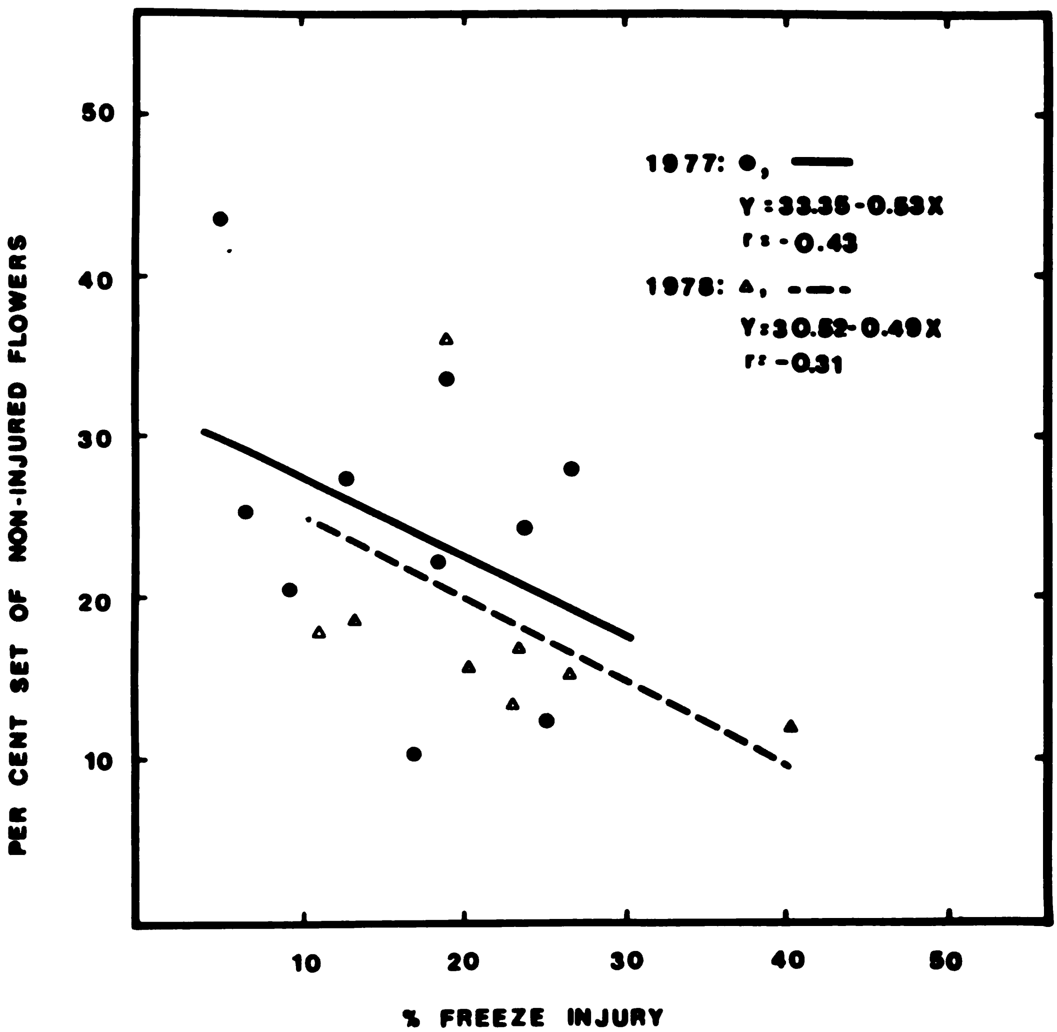

1977: ●,
Y=33.35-0.53X
r=-0.43
1978: △,
Y=30.52-0.49X
r=-0.31
50
40
30
20
10
10
20
30
40
50
PER CENT SET OF NON-INJURED FLOWERS
% FREEZE INJURY

Table 2. Effect of Removal of Two-Thirds of the Flower Buds Before Bloom, or Two-Thirds of the Fruits or Leaves 2 Weeks after Bloom on Subsequent Percentage Fruit Set of 'Montmorency' Sour Cherry. Data Corrected for Freeze Injury.[z] One Limb Bearing 200 Flower Buds on Each of 4 Trees Per Treatment.

Treatment	Years of Treatment					
	1976		1976, 1977		1976, 1977, 1978	
	No. Living Flowers[y]	% Set	No. Living Flowers	% Set	No. Living Flowers	% Set
None	2084	30.0	1926	29.2	2120	31.0
Flower buds thinned	1058	26.6	575	26.7	1050	28.8
Fruits thinned	2210	27.0	1986	26.0	2218	28.0
Defoliated	1953	27.2	1865	26.1	1760	24.0

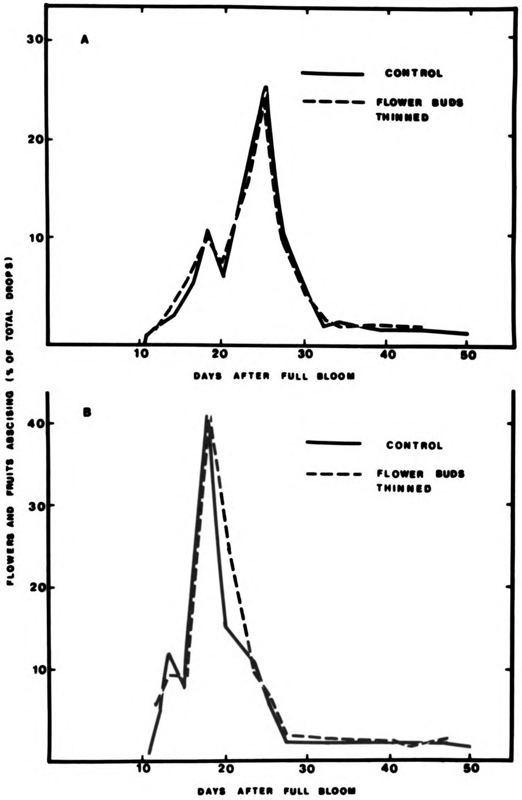
[z]Within years, no differences between treatments were significant at 5% level.

[y]Total for 4 limbs.

buds in 1976 only did not alter percentage fruit set significantly, even though the number of flowers per limb was reduced by half. Competition between clusters is therefore not a factor in controlling fruit set, and any injury to flowers will reduce potential yield. When flower buds were thinned 2 or 3 years in succession, fruit set was again similar to that of the control. Therefore, fruit load does not appear to affect fruit set the following year. Fruit thinning or partial defoliation 2 weeks after full bloom did not affect fruit set (Table 2), so competition between fruits does not appear to be a critical factor for a fruit to persist. Considering the pattern of fruit drop (see below), induction of abscission probably had already occurred 2 weeks after full bloom.

The abscission pattern of flowers and immature fruits for 1976 was similar to that reported by Gray (8) (Figure 3A). The first wave of abscission of flowers began 12 days after full bloom and comprised 20% of the total flowers and fruits abscised. The second wave began at 20 days, lasted for 12 days, and accounted for about 75% of the total drops. No definite third wave was observed, but a few fruits continued to fall from 32 days after full bloom until harvest. The pattern was similar in 1977, but the peaks were earlier (Figure 3B). Temperature following bloom may affect the pattern, as temperatures were higher in 1977 than in 1976. Flower thinning did not affect the pattern of abscission (Figures 3A, 3B). Abscission of

Figure 3. Effect of flower bud thinning on flower and fruit drop pattern, 1976 (A) and 1977 (B). Data based on number of persisting fruits.


A
CONTROL
FLOWER BUDS THINNED
30
20
10
10
20
30
40
50
DAYS AFTER FULL BLOOM
FLOWERS AND FRUITS ABSCISING (% OF TOTAL DROPS)
B
CONTROL
FLOWER BUDS THINNED
40
30
20
10
10
20
30
40
50
DAYS AFTER FULL BLOOM

sour cherry flowers and fruits has been attributed to early embryo-sac degeneration (2) and/or to embryo abortion (2). Whatever the cause, competition between flowers or fruits does not appear to be involved.

The drop pattern obtained by collecting flowers or fruits from sheets beneath the trees did not differ appreciably from that based on persisting flowers and fruits on tagged limbs (Figure 4).

Flower Density Within Clusters

Clusters with all three flowers present (no treatment) in 1977 and 1978, were classified as to fruiting performance according to the sequence of flower opening (Table 3). More than one-third of the clusters set no fruit, while only 4% set all flowers. When only one flower set per cluster, flowers A or B were twice as likely to be retained as was C. If 2 flowers set fruit, A plus B were retained more often than were A plus C or B plus C. Combining data for all flowers, flowers A and B set equally well, but C was less likely to set fruit.

Hand removal of flowers yielded similar data (Table 4) indicating again that flower C had a lower potential to set whether other flowers are left on the cluster or not. Thus fruit-setting potential is not affected by competition with other flowers in the cluster. Differences in set between treatments were not significant in 1978.

Figure 1. Scanning electron micrographs of critical point dried apices of sour cherry (Prunus cerasus L. cv 'Montmorency') showing developmental changes during flower initiation. A. Initial phase of change from vegetative to reproductive stage by rounding of the apex, with bract primordium (BP), June 10. x600. B. Flattening of the apex, June 15. x440. C. Floral primordia (FP) developing in the axil of each bract primordium, June 28. x510. D. Floral primordia evident in 3 bracts and a 4th beginning to form, June 30. x410. E. Ovate stage of flower primordia, July 3. x320. F. Round stage of flower primordia, July 10. x300.

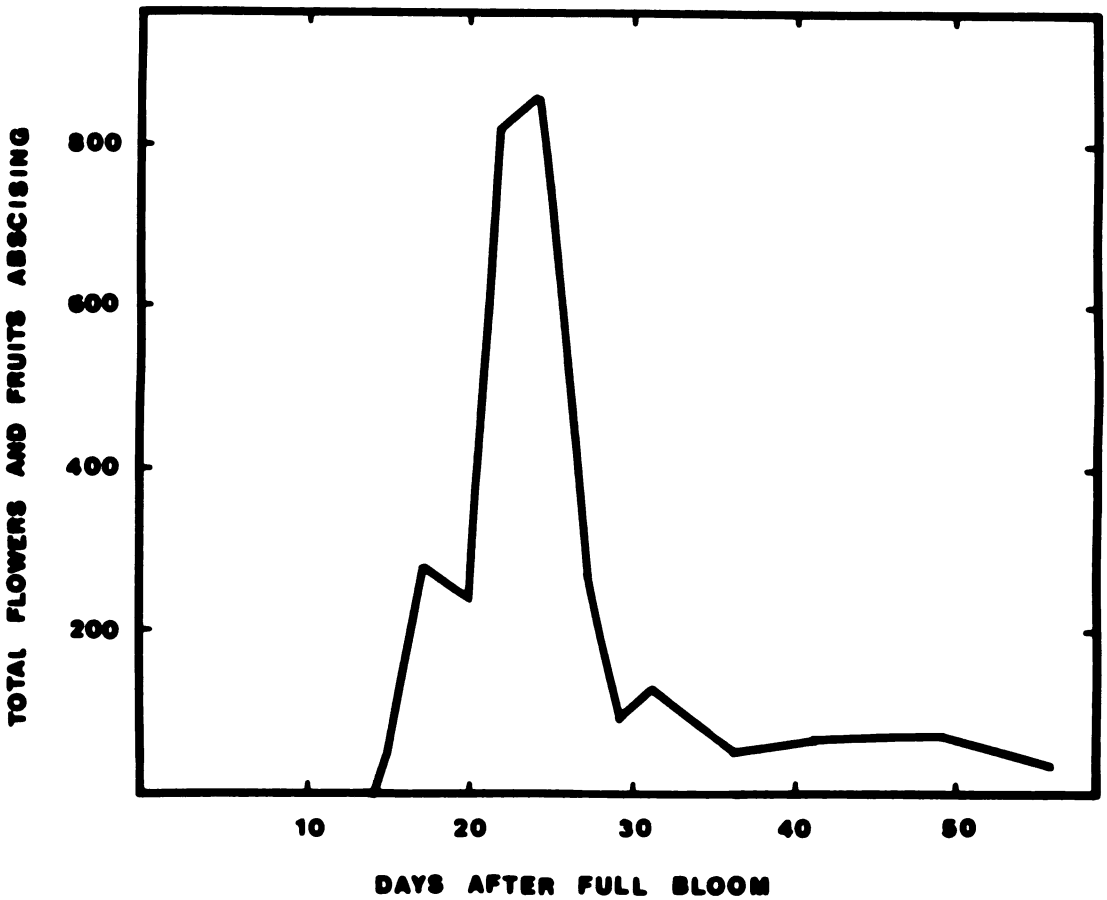

TOTAL FLOWERS AND FRUITS ABSCISING
800
600
400
200
10
20
30
40
50
DAYS AFTER FULL BLOOM

Table 3. Classification of Flower Clusters by Fruiting Performance According to Sequence of Flower Opening.

Cluster with	Percent of Clusters[z] 1977	Percent of Clusters[z] 1978
No mature fruit	38.5	37.4
A[y] only	13.8	13.0
B only	12.3	10.2
C only	6.2	6.8
A and B	15.4	12.2
A and C	4.2	7.5
B and C	4.2	8.8
A, B, and C	4.2	4.1
Means for:		
All A's	37.0	36.7
All B's	35.6	35.4
All C's	18.0	27.2

[z] Data collected from 65 (1977) and 147 (1978) labeled flower clusters.

[y] A, B, and C: 1st, 2nd, and 3rd flower to open within a cluster.

Table 4. Effect of Flower Removal Within Clusters upon Set of Remaining Flowers.

Flowers Remaining[y]	% Set[z]							
	1977				1978			
	A	B	C	Mean	A	B	C	Mean
A, B, and C	22.5	24.9	15.5	21.4ab[x]	30.7	32.9	31.6	31.7a
A and B	38.0	34.4	--	36.2a	44.8	35.1	--	33.5a
A and C	39.7	--	31.8	35.5a	36.7	--	27.6	32.2a
B and C	--	25.4	14.4	19.7ab	--	32.8	23.9	29.7a
A only	25.2	--	--	25.2ab	34.9	--	--	34.9a
B only	--	27.2	--	27.2ab	--	33.3	--	33.3a
C only	--	--	14.9	14.9b	--	--	27.2	27.2a
Mean	26.2	28.0	19.1		36.8	33.5	27.6	

[z]Fruit set as number of fruits harvested per 100 flowers.

[y]A, B and C: 1st, 2nd and 3rd flower to open within a cluster.

[x]Mean separation within years by Tukey's ω test, 5% level.

Embryo-Sac Development of Flowers Within a Cluster

A higher percentage of normal embryo sacs was found in flowers A and B (more advanced) than in flower C on all sampling dates (Table 5). Regardless of time of flower opening, the percentage of flowers with differentiated egg cells declined with time. These data support the hypothesis that flowers A and B set better than C because of their greater embryo-sac normality.

Tetrad Formation in Anthers of Flowers Within a Cluster

The largest flowers (most advanced) within a bud formed tetrads 1-2 days earlier than the smallest ones, indicating than even though flowers may appear similar within the bud, they may differ internally in stage of development.

The time of flower initiation may affect fruit-setting potential. The sour cherry inflorescence is a raceme bearing one to five flowers (2) and scanning electron microscope observations (5) indicate that differences in development are apparent up to the time of sepal differentiation, although no external differences are evident thereafter. The flower which opens last and sets least is probably the last to differentiate within a bud.

Table 5. Effect of Flower Position on Egg Cell Normality, 1978.[z]

Flower Position[y]	Days in Relation to Anthesis						Flower Mean
	-3	-2	0	3	5	7	
	(Percentage with differentiated egg cells)						
A	90	85	89	70	55	45	70.8a[x]
B	90	85	80	60	55	45	69.2a
C	85	75	70	55	45	40	61.7b
Date mean	88a	82b	77c	62d	52e	43f	

[z]Nine to twelve embryo-sacs examined per date per flower type.

[y]A, B, and C: 1st, 2nd and 3rd flower to open within cluster.

[x]Mean separation in rows and columns by Tukey's ω test, 5% and 1%, respectively.

LITERATURE CITED

1. Bradbury, D. 1925. Notes on the dropping of immature sour cherry fruits. _Proc. Amer. Soc. Hort. Sci._ 22:105-110.

2. ________. 1929. A comparative study of the developing and aborting fruits of _Prunus cerasus_. _Amer. J. Bot._ 16:525-543.

3. Collins, M. D., P. B. Lombard, and J. W. Wolfe. 1978. Effects of evaporative cooling for bloom delay on 'Bartlett' and 'Bosc' pear tree performance. _J. Amer. Soc. Hort. Sci._ 103:185-187.

4. Dennis, F. G., Jr. 1976. Trials with ethephon and other growth regulators for delaying bloom in tree fruits. _J. Amer. Soc. Hort. Sci._ 101:241-245.

5. Diaz, D. H., H. P. Rasmussen, and F. G. Dennis. 1978. Scanning electron microscope observations on flower bud differentiation in sour cherry (_Prunus cerasus_ L.). _HortScience_ 13:382.

6. Dorsey, M. J. 1919. A study of sterility in the plum. _Genetics_ 4:417-488.

7. Gardner, V. R. 1936. Factors influencing the yields of Montmorency cherry orchards in Michigan. _Michigan Agr. Exp. Sta. Special Bul._ 275.

8. Gray, G. F. 1933. Relation of light intensity to fruit setting in the sour cherry. _Michigan Agr. Expt. Sta. Tech. Bul._ 136.

9. Hitchcock, A. E., and P. W. Zimmerman. 1943. Summer sprays with potassium α-naphthaleneacetate retard opening of buds in fruit trees. _Proc. Amer. Soc. Hort. Sci._ 42:141-145.

10. Howlett, F. S. 1928. Fruit setting in the Delicious apple. _Proc. Amer. Soc. Hort. Sci._ 25:143-148.

11. ________. 1931. Effect of thinning before the June drop upon fruit production. Proc. Amer. Soc. Hort. Sci. 28:605-609.

12. Johansen, D. A. 1940. Plant microtechnique. McGraw Hill Book Co., Inc.

13. Lipe, W. N., O. Wilke, and O. Newton. 1977. Freeze protection of peaches by evaporative cooling in the post-rest, pre-bloom period. J. Amer. Soc. Hort. Sci. 102:370-372.

14. Miller, M. B. 1977. Comparison of models for predicting end of rest of flower buds and use of evaporative cooling to delay bloom in sweet cherry (*Prunus avium* L.). M.S. Thesis, Michigan State University.

15. Pratt, C. 1973. Reproductive system of 'Concord' and two sports (*Vitis labrusca* Bailey). J. Amer. Soc. Hort. Sci. 98:489-496.

16. Sass, J. E. 1958. Botanical microtechnique. Iowa State College Press, Ames, Iowa.

17. Sax, K. 1921. Studies of orchard management. II. Factors influencing fruit development in the apple. Maine Agr. Expt. Sta. Bul. 298. pp. 53-84.

18. Srivastava, D. N. 1938. Studies in the non-setting of pears. I. Fruit drop and the effects of ringing, dehorning and branch bending. J. Pom. and Hort. Sci. 16:39-62.

19. Weinbaum, S. A., and R. K. Simons. 1976. Relationship of seed number to fruit set in apple--an alternate hypothesis. Fruit Var. J. 30(3):82-84.

20. Zucconi, F. 1975. Reassessment of the relationship between hormonal and developmental changes during abscission with particular reference to the peach (*Prunus persica* (L.) Batsch) fruit. Ph.D. dissertation, Michigan State University.

SECTION II

SCANNING ELECTRON MICROSCOPE OBSERVATIONS OF FLOWER BUD DIFFERENTIATION IN SOUR CHERRY (*PRUNUS CERASUS* L. CV. MONTMORENCY)

SCANNING ELECTRON MICROSCOPE OBSERVATIONS OF FLOWER BUD DIFFERENTIATION IN SOUR CHERRY (*PRUNUS CERASUS* L. CV. MONTMORENCY)

Abstract

Axillary buds on 'Montmorency' sour cherry (*Prunus cerasus* L.) spurs and shoots on current season's growth were sampled and prepared for scanning electron microscopy. Five weeks after full bloom the first evidence of change from the vegetative to the reproductive stage appeared as a rounding of the apex. Flower primordia arose in the axils of bracts in an acropetal pattern. Bracts and flower primordia continued to form until all available space on the apex had been occupied. The flower primordia changed from ovate to round as development proceeded. Sepal primordia became evident forty-five days after the first signs of initiation, and later petal primordia arose, alternating with sepal primordia. Stamen primordia developed in concentric rings below the petal primordia. Pistil initiation did not occur until the middle of September.

The morphological changes occurring during flower bud formation in fruit trees have been described by various workers beginning in the late 1800s (4, 6, 7, 9) using medial longitudinal or transverse stained sections and light microscopy.

In sour cherry the first visible signs of flower initiation occur about 5-6 weeks after full bloom (9) and differentiation of most flower parts is complete about 8-10 weeks later. Timing varies depending on location and tree vigor. Inflorescences generally contain 2 to 4 flowers arranged in a corymb (6).

Studies by DeHertogh et al. (1), Emino and Rasmussen (5) and Scholefield and Ward (8) of flower development in Easter lily, carnation and grape, respectively, have illustrated the value of the scanning electron microscope (SEM) in studying flower development. Advantages include increased depth of field and magnification and resolution of the entire apex.

This study describes the morphological changes which occur in the developing shoot apex of sour cherry during flower formation.

Material and Methods

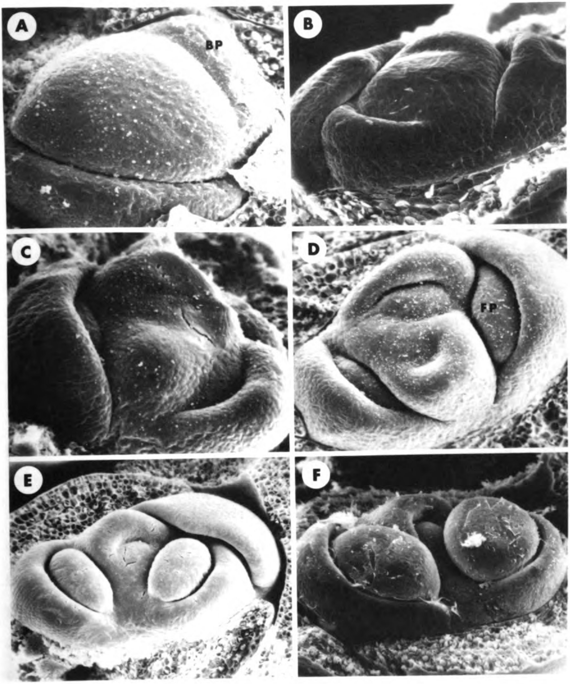
Buds from 18-year-old 'Montmorency' sour cherry trees were collected periodically during 1976 in a commercial orchard at Mears, Michigan. Full bloom occurred on May 10 in 1976. Ten trees were selected for uniform size and vigor, and a total of 50 buds were collected at each sampling date. Their scales were removed and the apex was placed in a glass vial containing distilled water. Within 24 hrs of sampling, the apices were dehydrated using a 10-step graded ethanol series (10 to 100%). The apices were left at least 20 minutes in each solution. Following three changes of 100% ethanol, samples were critical point dried (CPD Denton DCP-1) using clean liquid CO_2. The buds were then stored in a vacuum desiccator over anhydrous $CaSO_4$. Before the samples were examined in the SEM, buds were further dissected under a stereo light microscope to expose the apex, mounted on aluminum SEM stubs using 'Tube Coat' (G. C. Electronics Co., Rockford, Ill.) and then sputter coated with 40-60 nm of gold. A Super II SEM (International Scientific Instrument Co.) operated at an accelerating voltage of 15 kV was used to view the samples.

Initial observations indicated that lateral buds on current season's wood and buds on spurs of 2-, 3- or 4-year-old wood were similar in stage of flower development. Lateral buds were easier to manipulate and were therefore the primary material used. At least 10 specimens were examined for each sampling date.

Results and Discussion

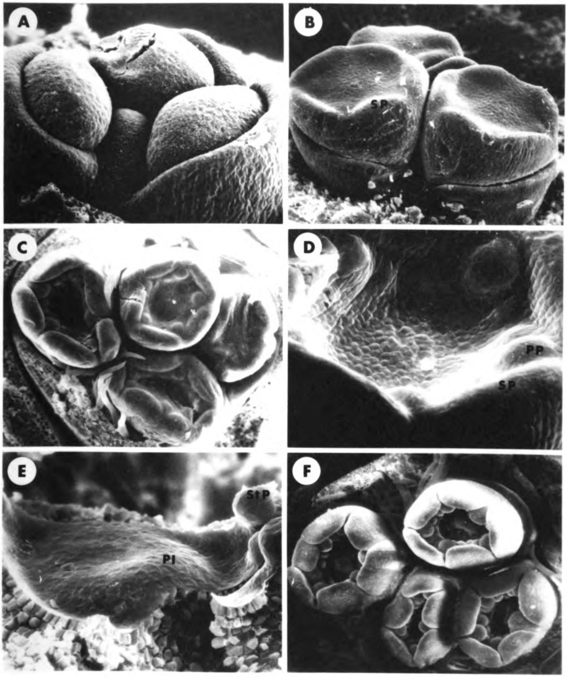
On June 10, 1976, the first sampling date, shoots were about 10 cm in length. Although some vegetative apices were evident, most of them were desiccated and cells appeared concave. For most deciduous fruit trees, including sour cherry, cross sections of the apex exhibit a smooth rounded crown of meristematic tissue more or less enclosed by primordial leaves, bracts or bud scales (4, 6, 9). Such a structure is evident in Figure 1A. As the season

Figure 4. Daily absolute fruit drop for 'Montmorency' sour cherry, 1977. Data based on number of falling fruits.


A
BP
B
C
D
FP
E
F

progressed, the apex became broadly rounded or flattened (Figure 1B) with two well-developed bract primordia and others being formed in an apparently spiral fashion. The youngest bract primordium occurred at the apex of the meristem, indicating an acropetal pattern of formation. The flattening of the apex was the first noticeable evidence of the change from vegetative to reproductive phase as previously reported (4, 6, 9) and occurred at a similar time, that is, 5 weeks after full bloom. The individual flower primordia later formed in the axils of these bracts (Figure 1C). The individual flower primordia continued to develop through August and September (Figures 1D, 1E). Differences in stage of development were evident among flowers. The only evidence for some of the flower primordia was the presence of the bract. About 18 days after the first signs of initiation were apparent, flower primordia were ovate in shape (Figure 1E) then became round (Figure 1F, 2A). Forty-five days after the first signs of initiation, sepal primordia appeared (Figure 2B) as a pentagonal whorl. The rounded apex gradually became concave as previously described (7). Immediately within the sepal primordia five small petal primordia arose (Figures 2C, 2D). The central part of the meristem was no longer concave but flat, and the stamen primordia developed in circular layers immediately within the petal primordia (Figure 2D). At this time differences in stage of organogenesis between flowers within apices were still apparent

Figure 2. Scanning electron micrographs of critical point dried apices of sour cherry (*Prunus cerasus* L. cv. 'Montmorency') showing developmental changes during flower differentiation. A. All apex space occupied by three floral primordia, July 20. x410. B. Calyx evident as sepal primordia (SP) in a pentagonal whorl, July 30. x300. C. Corolla and stamens evident as petal primordia develop within sepal primordia, August 15. x165. D. Stamen primordia developing below petal primordia (PP), August 15. x400. E. Pistil initial (PI) arising from flat apex, September 10. x360. F. All floral organs present, September 29. x150.


A
B
SP
C
D
PP
SP
E
StP
Pl
F

some having large stamens while others had yet to differentiate petal primordia. Near the middle of September, the pistil primordium was initiated on the flat surface of the apex (Figure 2E), and continued expanding with the other floral parts (Figure 2F).

Most of the reproductive apices produced 3 to 4 flowers. This characteristic seems to be determined by the apex size, which will allow the development of only a certain number of bract primordia. In some instances, even though a bract primordium developed, the flower in its axil either did not develop at all (Figure 2A) or developed slowly.

Within an apex flowers developed differentially up to a certain stage (anther and probably pistil initiation), after which no external differences were evident. However, internal differences do seem to occur as Diaz (2) has observed that at bud swell tetrad formation in the anthers occurs consistently 2 days earlier on the most expanded flower while embryo-sac degeneration is significantly more frequent in the least advanced flower. The external differences apparent in flower development within a bud probably are responsible for the differences in fruit setting potential observed by Diaz (3).

LITERATURE CITED

1. De Hertogh, A. A., H. P. Rasmussen, and N. Blakely. 1976. Morphological changes and factors influencing shoot apex development of Lilium longiflorum Thunb. J. Amer. Soc. Hort. Sci. 101:463-471.

2. Diaz, D. H. 1978. Effect of flower and fruit density on fruit set and abscission of sour cherry (Prunus cerasus L. cv. Montmorency). In press.

3. ________, and F. G. Dennis, Jr. 1978. Effect of flower density on fruit set and abscission in 'Montmorency' sour cherry (Prunus cerasus L.). HortScience 13:383.

4. Drinkard, A. W. 1909. Fruit-bud formation and development. Annu. Rept. Virginia Agr. Expt. Sta. pp. 159-205.

5. Emino, E. R., and H. P. Rasmussen. 1971. Scanning electron microscope studies of the shoot apex in Dianthus caryophyllus L. cv. Scania. J. Amer. Soc. Hort. Sci. 96:253-256.

6. Goff, E. S. 1899. The origin and early development of the flowers in the cherry, plum, apple and pear. 16th Annu. Rept. Wisconsin Agr. Expt. Sta. pp. 289-303.

7. Gracza, P., and M. Gergely. 1973. Some questions of flower organization in sour cherry. Acta Agron. 22:366-375.

8. Scholefield, P. B., and R. C. Ward. 1975. Scanning electron microscopy of the developmental stages of the Sultana inflorescence. Vitis 14:14-19.

9. Tufts, W. P., and E. B. Morrow. 1925. Fruit-bud differentiation in deciduous trees. Hilgardia 1:1-14.

APPENDICES

APPENDIX A

PREDICTING PERSISTENCE OF SOUR CHERRY FRUITS BY OVARY DIAMETER

PREDICTING PERSISTENCE OF SOUR CHERRY FRUITS BY OVARY DIAMETER

Stone fruits such as sour cherry exhibit a double sigmoid growth curve which can be divided into 3 stages (1, 5, 6). During each stage different events are occurring within the developing embryo. Investigators have attempted to distinguish between fruits which will persist versus those that will abscise using such criteria as size, color or removal force (2). However, by the time such differences are evident the process of abscission may be well advanced.

Flowers and immature fruits of sour cherry drop in two or three waves, different populations occurring in each wave (1, 3, 4). Knowing when induction of abscission occurs would be useful in attempting to either enhance or reduce abscission.

In order to compare the growth rates of persisting and abscising fruits and to determine the time of induction of abscission, 150 flowers were labeled at full bloom in 1977 and ovary diameter was measured 13 days later and at 2 to 10 day intervals thereafter until either abscission or harvest. The trees used were

17 years old and were part of a commercial orchard at Mears, Michigan. Data were plotted as means for groups of fruits that dropped on a certain date.

The growth curve of persisting fruits was double sigmoid (Figure A-1). Fruits with a diameter of 1.5-3.3 mm 13 days after full bloom (AFB) abscised 15-17 days AFB, while those 3.5-6.5 mm in diameter abscised 18-23 days AFB. These fruits were representative of the first and second wave drops, respectively. The growth rates of fruits that abscised late in the growing period (30 days AFB) were indistinguishable from those of persisting ones up to 18 days AFB. Growth then ceased. None of the fruits which were 7 mm or less in diameter 13 days AFB reached maturity, whereas almost all of those larger than 7 mm persisted until harvest (Table A-1). Fruits which fell in the first 2 drops never approached the size of those that persisted. Their diameters were only half of those of persisting fruits 13 days AFB, suggesting that either the flowers were defective or that induction occurred at bloom or shortly thereafter. For late abscising fruits, induction of abscission must have occurred at least 12 days before separation, based upon growth rates.

In studies to reduce abscission of sour cherry flowers and fruits, observations or treatments should be started at bloom or shortly thereafter, for induction of abscission apparently occurs very early.

Figure A-1. Growth curves for groups of persisting and abscising fruits, 1977.

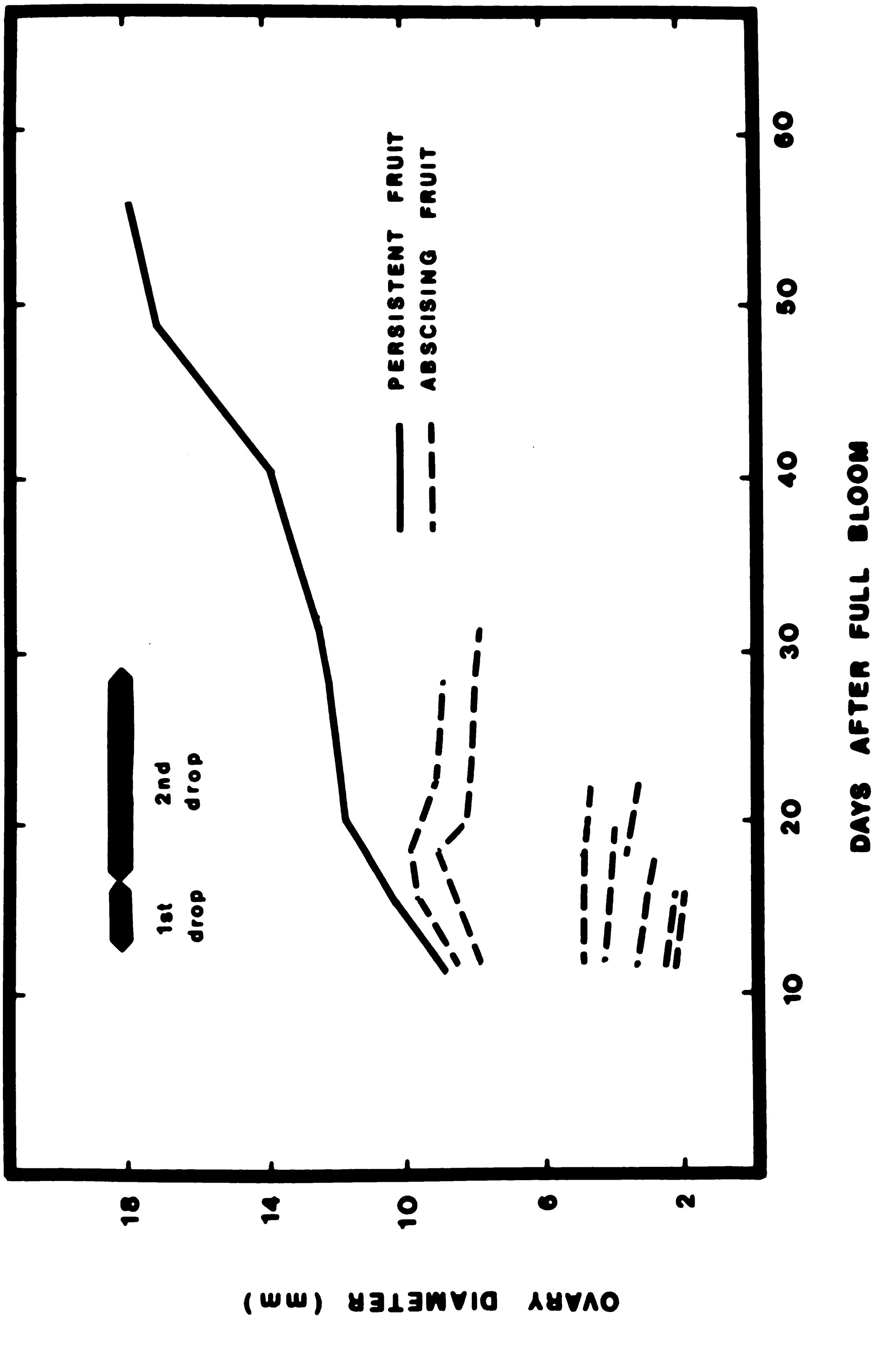

1st drop
2nd drop
PERSISTENT FRUIT
ABSCISING FRUIT
18
14
10
6
2
OVARY DIAMETER (mm)
10
20
30
40
50
60
DAYS AFTER FULL BLOOM

Table A-1. Abscission Date and Percent Set at Harvest of 'Montmorency' Sour Cherry Fruits in Relation to Ovary Diameter 13 days AFB, 1977.

Ovary Diameter (mm) 13 Days AFB	No. Fruits	Date of Abscission (Days AFB)	Mature Fruits Harvested (%)
0-2.0	0	--	--
2.1-3.0	8	18	0.0
3.1-4.0	7	18	0.0
4.1-5.0	3	18	0.0
5.1-6.0	2	25	0.0
6.1-7.0	1	25	0.0
7.1-8.0	8	--	100.0
8.1-9.0	13	30	85.0
9.1-10.0	31	--	100.0
10.1-11.0	10	--	100.0
11.1-12.0	1	--	100.0

LITERATURE CITED

1. Bradbury, D. 1929. A comparative study of the developing and aborting fruits of Prunus cerasus. Amer. J. Bot. 16:525-542.

2. Bukovac, M. J. 1971. The nature and chemical promotion of abscission in maturing cherry fruit. HortScience 6:385-388.

3. Diaz, D. H., and F. G. Dennis, Jr. 1978. Effects of flower density on fruit set and abscission in 'Montmorency' sour cherry (Prunus cerasus L.). HortScience 13:383.

4. Gray, G. F. 1933. Relation of light intensity to fruit setting in the sour cherry. Michigan Agr. Expt. Sta. Tech. Bul. 136.

5. Harrold, T. J. 1935. Comparative study of the developing and aborting fruits of Prunus persica. Bot. Gaz. 96:505-520.

6. Tukey, H. B. 1935. Development of cherry and peach fruits as affected by destruction of the embryo. Proc. Amer. Soc. Hort. Sci. 33:265-266.

APPENDIX B

EFFECTS OF NUMBERS OF TREE AND LIMB REPLICATES AND OF NUMBER OF BUDS PER LIMB ON VARIABILITY OF DATA FOR FRUIT SET OF SOUR CHERRY

EFFECTS OF NUMBERS OF TREE AND LIMB REPLICATES AND OF NUMBER OF BUDS PER LIMB ON VARIABILITY OF DATA FOR FRUIT SET OF SOUR CHERRY

Fruit set has been evaluated and expressed in various ways. The Michigan Crop Reporting Service (3), in making their survey for forecasting yields of sour cherry, records fruit set from 600 sample trees, randomly selected from all growing areas, using one limb per tree. In experiments with cherries, data have usually been recorded as numbers of fruits per 100 flower buds (1, 2). Treatments are often applied to one limb on each of 4 trees and data recorded for 100 to 200 flower buds per limb, counted from the apex toward the base (1, 2, 4).

Experiments were designed to evaluate the minimum number of trees, limbs per tree and buds per limb which would yield a sufficiently small variance of the sample mean to allow detection of differences among treatments.

Experiment 1

Four 18-year-old uniform trees of 'Montmorency' sour cherry located at Mears, Michigan, were used in a completely randomized design and ten limbs were selected on each tree. Two hundred flower buds were counted from the apex toward the base, the numbers of viable flowers were recorded at bloom, and all persistent fruits were counted at harvest. Values for fruits per 100 flowers were subjected to a model II analysis of variance (5) to provide an unbiased estimate of the variance among trees (S^2t) and within trees (S^2l). These values were used to calculate the variance of the sample mean ($S^2_{\bar{x}}$) according to the formula:

$$S^2_{\bar{x}} = \frac{S^2l}{LT} + \frac{S^2t}{T}$$

where L = number of limbs, and T = number of trees.

Experiment 2

Five trees and four limbs per tree were selected in a randomized block design using 18-year-old trees at Mears, Michigan. On each limb, flower buds were counted from the tip toward the base and labels were used to mark 25, 50, 150 and 200 buds. The numbers of flowers with no visible injury were recorded at bloom, and the number of fruits were counted at harvest. The data were converted to percentage. Once the analysis of variance was calculated, the coefficients of variation (CV) were obtained.

Results and Discussion

Experiment 1

Values of $S^2_{\bar{x}}$ declined as the number of limbs per tree increased from 1 to 10 (Table B-1), and the same was observed as the number of trees increased. Using relatively few limbs per treatment per tree and more trees is more efficient than using more limbs per tree but fewer trees. For example, the $S^2_{\bar{x}}$ values using 1 limb on each of 4 trees is similar to that obtained using 3 limbs on each of 2 trees, but only two-thirds as many total limbs need to be used in the former case.

Experiment 2

Using a limb unit with only 25 flower buds yields a high coefficient of variation (CV) of fruit set data (Table B-2). The CV decreases as the number of buds per limb increases from 25 to 100, then increases to plateau at 150 to 200 buds. There is about 1.3 times as much variability with 25 buds as with 50 buds. The low value at 100 buds is probably not valid, as values for 150 and 200 are no less than that for 50 buds. Therefore 50 buds per limb appears to be the minimum number required for a reliable estimate of fruit set.

Table B-1. The Effect of Number of Trees and Limbs per Tree on the Estimated Variance of the Sample Mean ($S^2_{\bar{x}}$) for Percentage Fruit Set in a Population in which $S^2_L = 53.16$ and $S^2_T = 13.45$, with 1 to 10 Trees per Replication, 1978.

No. of Trees	Number of Limbs per Tree									
	1	2	3	4	5	6	7	8	9	10
1	66.6	33.3	31.2	26.7	24.1	22.3	21.0	20.1	19.4	18.8
2	33.1	20.0	15.6	13.4	12.0	11.2	10.5	10.0	9.7	9.4
3	22.2	13.3	10.4	8.9	8.0	7.4	7.0	6.7	6.4	6.3
4	16.7	10.0	7.8	6.7	6.0	5.6	5.2	5.0	4.8	4.7
5	13.3	8.0	6.2	5.3	4.8	4.5	4.2	4.0	3.9	3.8
6	11.1	6.7	5.2	4.5	4.0	3.7	3.5	3.3	3.2	3.1
7	9.5	5.7	4.5	3.8	3.4	3.2	3.0	2.9	2.8	2.7
8	8.3	5.0	3.9	3.3	3.0	2.8	2.6	2.5	2.4	2.3
9	7.4	4.5	3.5	3.0	2.7	2.5	2.3	2.2	2.2	2.1
10	6.7	4.0	3.1	2.7	2.4	2.2	2.1	2.0	1.9	1.9

Table B-2. Effect of the Number of Flower Buds per Limb on the Coefficient of Variation (%) of Fruit Set Data, 1978.

No. Flower Buds	C. V. (%)
25	34.0
50	26.0
100	20.0
150	25.0
200	26.0

LITERATURE CITED

1. Dennis, F. G., Jr. 1976. Trials of ethephon and other growth regulators for delaying bloom in tree fruits. J. Amer. Soc. Hort. Sci. 101:241-245.

2. Howell, G. S., and S. S. Stackhouse. 1973. The effect of defoliation time on acclimation and dehardening of tart cherry. J. Amer. Soc. Hort. Sci. 98:132-136.

3. Michigan Crop Reporting Service. 1975. Objective yield survey. Tart cherry. U.S. Dept. Agric. and Michigan Dept. Agric.

4. Miller, M. B. 1977. Comparison of models for predicting end of rest of flower buds and use of evaporative cooling to delay bloom in sweet cherries (*Prunus avium* L.). M.S. Thesis, Michigan State University.

5. Snedecor, G. W., and W. G. Cochran. 1973. Statistical methods. Iowa State University Press. 539 pp.

APPENDIX C

EFFECT OF NITROGEN FERTILIZATION ON VEGETATIVE AND REPRODUCTIVE CHARACTERS OF SOUR CHERRY (*PRUNUS CERASUS* L.)

EFFECT OF NITROGEN FERTILIZATION ON VEGETATIVE AND REPRODUCTIVE CHARACTERS OF SOUR CHERRY (*PRUNUS CERASUS* L.)

Nutrition, particularly the supply of nitrogen, plays an important role in yield of cherries (1, 2, 4) but few experiments have been designed to evaluate its effects on fruit set *per se*.

To obtain such data for sour cherry, observations were made in 1977 on 9-year-old 'Montmorency' trees which had received various nitrogen levels for 4 consecutive years (1974-1977): 0.56 Kg N per tree applied to the soil in the fall (Ground), and 0.56 (100%) or 0.14 (25%) Kg N per tree applied through trickle irrigation during the summer. Experimental plots were located in a commercial orchard near Traverse City, Michigan.

The nitrogen contents of leaves sampled in July 1977 were 2.8, 2.2 and 2.6% of the dry weight for ground, 100% and 25% treatments, respectively (3), while yields in 1976 were 12.7, 10.9 and 9.1 kg/100 cm^2 trunk area for the same treatments.

Four trees per treatment were selected at random for uniform size and vigor and data were recorded for 50 cm of shoot length on each individual limb per tree. Only terminal and lateral shoots more than 5 cm long were measured. Parameters evaluated are indicated in Table C-1. At bloom in 1977 the numbers of uninjured flowers were counted, and fruit set was recorded shortly before harvest.

The only significant difference between treatments was reduced vegetative growth in the 25% treatment in comparison with the other two (Table C-1). Although differences occur in other observations, none were statistically significant. In general, nitrogen fertilization appears to stimulate growth and therefore increases the bearing area of the tree. It also increases the number of flowers per bud, especially in spur buds, and fruit number and set. All these effects would tend to increase yield.

Table C-1. Vegetative, Flowering, and Fruiting Responses of 9-Year-Old 'Montmorency' Sour Cherry Trees to 3 Levels of Nitrogen, 1977.

Observation	Method of Application		
	Ground	Trickle Irrigation	
	0.56 Kg N	0.56 Kg N	0.14 Kg N
1976 Vegetative growth (cm)	81.3a^{z}	76.8a	56.3b
No. flower buds/50 cm^{y}			
On shoots	47.0	44.3	35.8
On spurs	16.0	11.8	23.0
Total	63.0	56.1	58.8
No. flowers/flower bud			
On shoots	2.3	2.5	2.3
On spurs	2.7	2.6	2.0
Total flowers/50 cm	150.0	142.2	131.2
Total fruits/50 cm	22.7	24.5	14.5
Percent set	28.3	32.0	23.8

^{z}Mean separation within rows by Tukey's ω test, $P = 0.05$.

^{y}50 cm of shoot length, spurs disregarded.

LITERATURE CITED

1. Bryant, L. R., and R. Gardner. 1937. Fertilizer trials with sour cherries under limited irrigation. Proc. Amer. Soc. Hort. Sci. 35:347-351.

2. Crocker, T. F. 1971. The effect of nitrogen, potassium and SADH on yield, quality and vegetative growth of sour cherry (*Prunus cerasus* L., var. Montmorency). Ph.D. Dissertation, Michigan State University.

3. Kenworthy, A. L., and M. Smith. 1977. Fertilizing orchards through trickle irrigation systems. 107th Annu. Rept. Michigan State Hort. Soc., pp. 73-76.

4. Tukey, H. B. 1927. Response of the sour cherry to fertilizers and to pruning in the Hudson River Valley. New York State Agr. Expt. Sta. Bul. 514.

APPENDIX D

GROWTH REGULATORS AND FRUIT SET OF SOUR CHERRY (*PRUNUS CERASUS* L.)

GROWTH REGULATORS AND FRUIT SET OF SOUR CHERRY (*PRUNUS CERASUS* L.)

Growth regulators have been used successfully to increase the setting potential of some species of fruits including grape (8), citrus (6) and pear (9). However, inconsistent or poor results have been obtained with stone fruits (2, 3). The growth regulators used have included GA_3, $GA_{4/7}$, 2,4,5-TP, SADH, CCC and NAA. Timing is important and Degman and Batjer (1) and Westwood et al. (9) obtained responses in pear when auxin was applied as early as the previous fall.

In cherries, growth regulators have had variable effects on set. In sweet cherry (*Prunus avium* L.) Misra and Sharma (4) obtained a response with NAA applied at full bloom. When GA_3 and NAA were applied together at full bloom, fruit abscission was delayed but final set was unaffected. In 'Pandy' sour cherry, a self-sterile cultivar, GA_3 and 2,4,5-TP applied together at bloom and 2 weeks later promoted set (5). The use of 2,4,5-TP and Gibrescol (GA_1 + GA_3) increased set on the cultivars 'Podbielski' and 'Hiszpanka' in Poland (7). Numerous attempts to increase set of 'Montmorency', the leading commercial cultivar in the United States, with growth regulators have failed (Bukovac, Dennis, personal communication).

To evaluate the fruit setting response of 'Montmorency' sour cherry to growth regulators, 18-year-old trees were arranged in 4 separate randomized blocks, each with 4 replications (trees), in 1977. Sprays were applied on May 5 (full bloom) in block I and on May 15 (petal fall) in block II to determine their effects on fruit set in 1977, and on August 15 and October 9 in blocks III and IV, respectively, to evaluate effects on fruit set in 1978. Chemicals and concentrations are indicated in Table D-1.

Each treatment was applied with a hand sprayer until run-off to one branch of each tree within a plot. For plots I and II two hundred flower buds were counted per treated branch from the tip towards the base and the number of flowers which survived freezes was recorded. The number of persisting fruits were recorded several times in early summer and at harvest. In 1978 the same procedure was used for plots III and IV but the numbers of persisting fruits were recorded only at harvest.

Both full bloom and petal fall applications of GA_3 and 2,4,5-TP increased set recorded 20 or 25 days after full bloom, but did not affect final set significantly. All other treatments were without effect on either 1977 or 1978 set. The effects of GA_3 and 2,4,5-TP in delaying abscission suggest that mixtures and/or multiple applications of these chemicals might be more effective than single treatments.

Table D-1. Effects of Growth Regulators Applied in 1977 on Fruit Set of 'Montmorency' Sour Cherry in 1977 (Experiments I and II) or 1978 (Experiments III and IV).

Chemical[z]	Conc. (ppm)	Experiment and Date of Application					
		I May 5		II May 13		III August 15	IV October 9
		1[y]	2[y]	1	2	2	2
None	--	29c[x]	27	40c	24	24	22
GA_3	5	24c	20	--	--	21	22
	25	41bc	27	48c	20	19	30
	50	33c	23	--	--	--	--
	75	--	--	--	--	18	21
	100	46bc	25	66abc	24	--	--
$GA_{4/7}$	5	33c	27	44c	27	18	28
	25	20c	20	42c	20	23	26
	50	23c	22	55bc	25	--	--
	75	--	--	--	--	25	25
	100	32c	18	49c	34	--	--
2,4,5-TP	5	86a	27	82bc	24	31	26
	10	69ab	27	88a	24	24	31
Benzyladenine	5	28c	25	47c	22	25	21
	25	27c	25	40c	20	21	25
	50	29c	27	38c	18	--	--
	75	--	--	--	--	18	30
	100	30c	28	41c	26	--	--

Table D-1. Continued.

Chemical	Conc. (ppm)	Experiment and Date of Application					
		I May 5		II May 13		III August 15	IV October 9
		1	2	1	2	2	2
Promalin[w]	5	26c	21	42c	20	20	27
	25	33c	19	41c	21	18	23
	50	31c	18	53bc	25	--	--
	75	--	--	--	--	23	29
	100	28c	25	54bc	28	--	--

[z]All solutions contained Tween 20 surfactant at 0.1%.

[y]1 = Initial set (%) 20 or 25 days after full bloom; 2 = fruit set at harvest.

[x]Mean separation within rows by Tukey's ω test, P = 0.05.

[w]Benzyladenine plus $GA_{4/7}$ (Abbott Laboratories, Chicago, Illinois). Concentration shown refer to the mixture.

LITERATURE CITED

1. Degman, E. S., and L. P. Batjer. 1955. Delayed effects of 2,4,5-trichlorophenoxypropionic acid sprays on Anjou pears. Proc. Amer. Soc. Hort. Sci. 66:84-86.

2. Dennis, F. G., Jr. 1972. Physiological control of fruit set and development with growth regulators. Acta Hort. 34:251-259.

3. Hartmann, H. T. 1950. Tests with growth-regulating chemicals for increasing fruit set and yield of olives. Proc. Amer. Soc. Hort. Sci. 55:181-189.

4. Misra, L. P., and V. K. Sharma. 1972. Effect of growth regulating substances on the control of flowering and fruit setting in sweet cherry cv Black Heart. Indian J. Hort. 29:292-297.

5. Nyeki, K. 1973. Fruit set promoted by chemical induction in Pandy sour cherry. Acta Agron. 22:207-209.

6. Soost, R. K. 1958. Gibberellic acid on mandarin. Calif. Agric. 12:5.

7. Ugolik, M. 1975. Regulatory wzrostu w procesach zawiazywania i rozwojov owocow wisni. Roczniki Akademii w Poznaniu No. 56, 50 pp. (Hort. Abst. 47:5290).

8. Weaver, R. J., and W. D. Williams. 1950. Response of flowers of Black Corinth and fruits of Thompson Seedless grapes to applications of plant growth regulators. Bot. Gaz. 111:477-485.

9. Westwood, M. N., P. B. Lombard, and L. D. Brannock. 1968. Effect of seeded fruits and foliar-applied auxin on seedless fruit set of pear the following year. HortScience 3:168-169.