sectioning fresh leaves of woody plants. *Forest Sci.* 14:298-300.
7. ———. 1969. Ozone toxicity to sugar maple. *Phytopathology* 59:1423-1428.
8. ———, and J. T. Walker. 1966. A leaf roll-necrosis complex of lilacs in an urban environment. *Proc. Amer. Soc. Hort. Sci.* 89:636-642.
9. Hill, A. C., H. E. Heggestad, and S. N. Linzon. 1970. Ozone, p. B1-B22. *In* J. S. Jacobson & A. C. Hill [ed.]. Recognition of air pollution injury to vegetation: A pictorial atlas. Informative Rep. No. 2, TR-7 Agr. Comm., Air Pollution Control Assoc., Pittsburgh.
10. Mandl, R. H., L. H. Weinstein, J. S. Jacobson, D. C. McCune, and A. E. Hitchcock. 1966. Simplified semi-automated analysis of fluoride. Automat. Anal. Chem., Technicon Symp. 1965, p. 270-273.
11. Raymond, A., and G. Guiochon. 1974. Gas chromatographic analysis of C_8 - C_{18} hydrocarbons in Paris air. *Environ. Sci. & Technol.* 8:143-148.
12. Taylor, G. S., and S. Rich. 1962. Antiozonant-treated cloth protects tobacco from fleck. *Science* 135:928.
13. Thomas, M. D. 1961. Effects of air pollution on plants. *In* Air pollution, p. 233-278. WHO Monogr. Ser. No. 46, Columbia Univ. Press, New York. 442 p.
14. Treshow, M. 1970. Environment and plant response. McGraw-Hill Book Co., New York. 422 p.
15. ———, and M. R. Pack. 1970. Fluoride, p. D1-D17. *In* J. S. Jacobson & A. C. Hill [ed.]. Recognition of air pollution injury to vegetation: A pictorial atlas. Informative Rep. No. 1, TR-7 Agr. Comm., Air Pollution Control Assoc., Pittsburgh.

Effects of Date of Defoliation on Flower and Leaf Bud Development in the Peach (*Prunus persica* (L.) Batsch[1]

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Abstract. Three-year-old peach trees were manually defoliated on 6 successive biweekly dates starting in mid July of 1972. Approximately 30 days after treatment, flowers were forced. Flowers produced on 7/8 and 8/1 treatment trees were atypical, whereas flowers forced on 9/12 and 9/26 treatment trees were apparently normal. Defoliation on 8/15 and 8/29 produced flowers both atypical and normal types. The number of forced flowers, adjusted with trunk diameter, increased with each successive defoliation date although the number of flowers forced on any date was small. Floral abnormalities consisted of large leaf-like sepals without petioles, flowers with poorly colored petals, and exerted stigmas. Some abnormal flowers set fruit.

Vegetative bud break decreased with each successive defoliation date. Neither vegetative nor flower buds were forced when individual shoots were defoliated rather than whole trees.

Defoliation may cause many different responses in woody plants (1, 3, 4, 5, 6, 7, 8, 11, 12, 13, 14, 15, 16). The response varies with method of defoliation (8).

In this study we investigated the effects of single shoot vs. whole tree defoliation with time on rest induction, and resulting flower abnormalities in peach.

Materials and Methods

Three-year-old 'Washington' peach trees which had ceased shoot elongation and set terminal buds, were manually defoliated on 7/18, 8/1, 8/15, 8/29, 9/12, and 9/26 of 1972. The terminal bud on all shoots was removed at the time of defoliation. On each date, 10 individual shoots randomly distributed on the periphery of undefoliated trees were defoliated.

Number of flower buds forced per tree was recorded daily. Percentage of vegetative bud break on 25 shoots per tree was determined. Flowers per tree were adjusted for tree size by dividing trunk diameter into flowers forced. The design was a randomized complete block with single tree plots and 4 replications.

Results

Whole tree defoliation forced flower buds on all treatment dates. The number of flower buds forced per cm of trunk diameter increased with each successive defoliation date (Fig. 1). Over 80% of the flower buds forced from defoliation on 7/18 and 8/1 were abnormal, whereas 90% of those forced from defoliation on 9/12 appeared normal in all respects and all forced from 9/26 defoliation were normal. Some flowers forced from the 8/29 and 8/15 defoliation dates were abnormal and the balance normal. However, a significantly greater number of apparently normal flowers were produced on trees defoliated on 8/29 than those defoliated on 8/15.

In all treatments neither flower nor vegetative bud break occurred on individual defoliated shoots (Fig. 2).

Flower buds were forced in approximately 30 days (+ or -7) on trees defoliated on 7/18. Flower bud break was atypical in that it resembled vegetative bud break. At the green calyx stage, flower buds were pointed in contrast to the rounded, blunt bud associated with spring flower bud break (Fig. 3). The extended sepals resembled mature leaves (Fig. 4). The venation pattern of sepals differed from that of leaves. Each sepal contained 2 or more main veins which extended almost to the sepal apex rather than the single, widely branched main vein of a mature foliage leaf. The petals of abnormal flowers were small, poorly colored, and numbered from 9 to 12 rather than 5 which is characteristic of 'Washington' (Fig. 4). Pistils were exserted (Fig. 5). Some of the abnormal flowers set fruit that developed until killed by frost (Fig. 5).

Flowers forced on trees defoliated on 8/1 had the same abnormalities as did those from trees defoliated 7/18 except the sepal length was not as great (Fig. 5).

Variation in floral abnormalities appeared in flowers from trees defoliated on 8/15 and 8/29. Some flowers resembled those forced by the 8/1 defoliation (Fig. 5). Others were normal, except for poorly colored petals and others were normal in all aspects. Flower buds forced from defoliation of trees on 9/12 and 9/26 were normal.

Vegetative buds were forced on trees defoliated on the first 5

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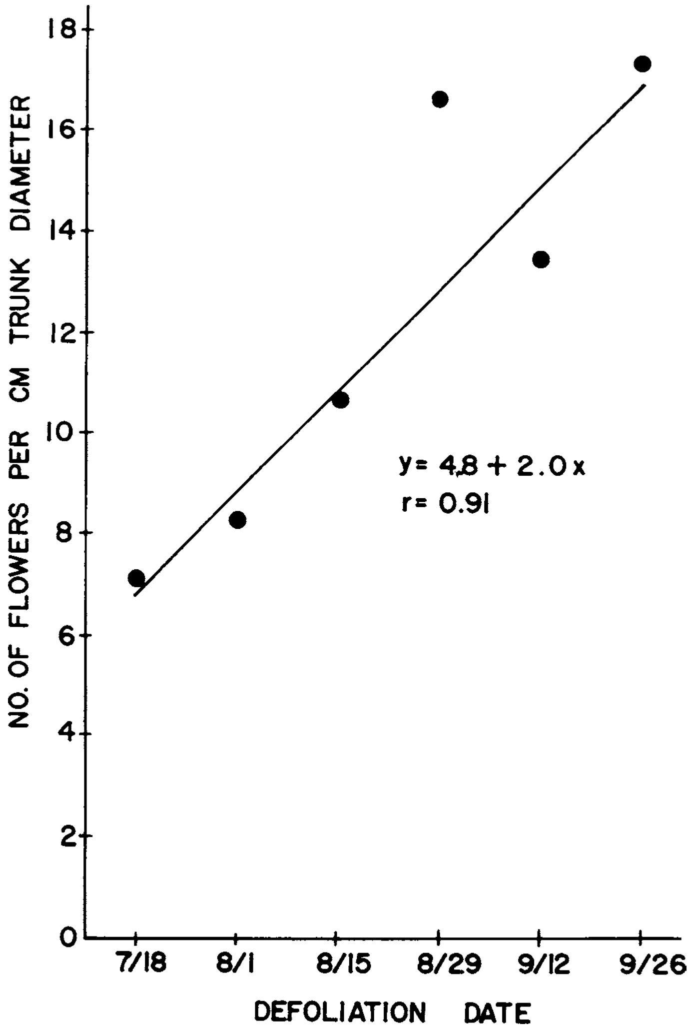

Fig. 1. The influence of defoliation date on number of flower buds forced per cm trunk diameter.

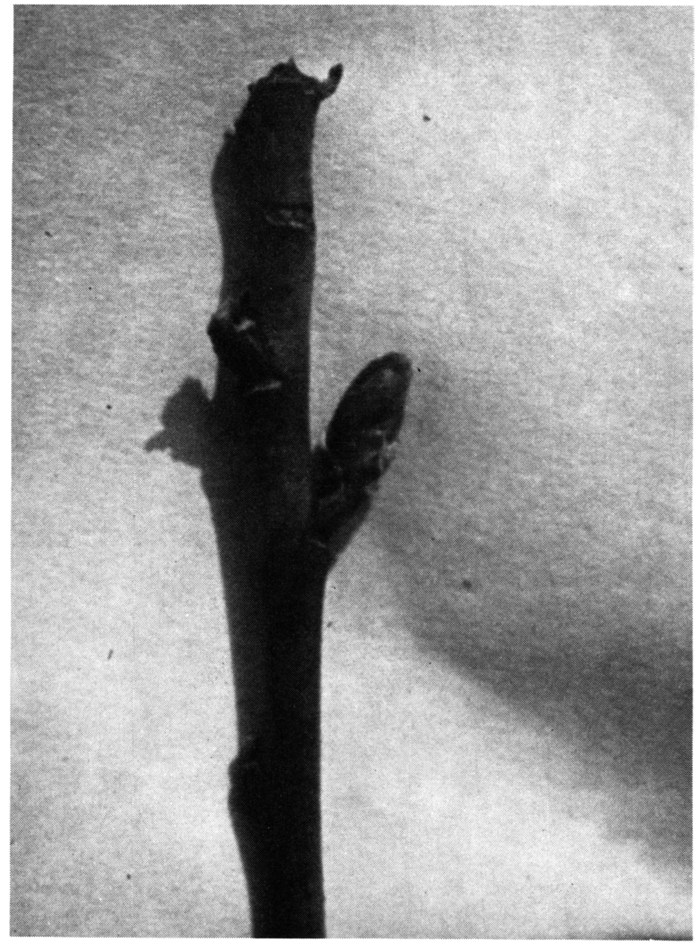

Fig. 3. Flower bud (forced by whole tree defoliation) at green calyx stage. Note pointed bud which resembles vegetative bud break.

dates (Fig. 6). There was a high inverse correlation (-.95) between percentage bud break and defoliation date. Approximately 45% of all vegetative buds were forced on trees defoliated on 7/18; none were forced on trees defoliated on 9/26.

Discussion

The forcing of flower buds in peach by whole tree

Fig. 2. Influence of single shoot defoliation on flower and vegetative bud break (shoots defoliated on trees that retained a predominance of foliage).

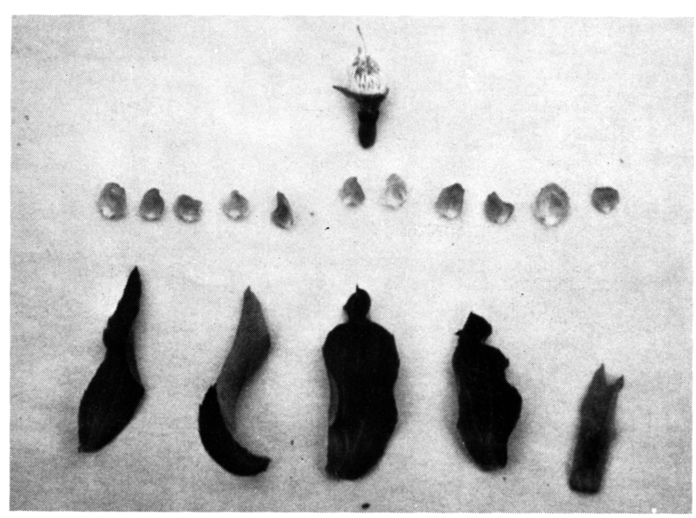

Fig. 4. Flower forced from tree defoliated on July 18, 1972. Note abnormally large number of petals and large leaf-like sepals.

defoliation was reported by Cooper (1), but he did not observe floral abnormalities. One explanation for the lack of floral abnormalities could be that he defoliated trees with $CuSO_4$ sprays. Chemical defoliation produces different effects than manual defoliation (as was the case in this study). Also, Cooper could have defoliated trees with buds in a physiological state similar to trees defoliated 9/12 and 9/26 which produced normal flowers. Floral and foliage abnormalities have been produced by whole tree defoliation of other species. Dostal (4) reported foliage abnormalities in new leaves on defoliated lilac trees. Defoliation of black currant produced abnormal flowers when the plants were grown under certain photoperiodic conditions (13).

The reason for abnormal flowers on trees defoliated in July and August is not clear. Dostal (4) suggested that abnormal leaves from defoliated lilac trees could be due to the induction of a particular metabolic state within the tree or the forcing of buds during a transition state between scales and typical foliage;

Fig. 5. The effects of defoliation date on floral and fruit abnormalities. Flower forced from tree defoliated 8/1 (upper left); (lower left) flower forced from tree defoliated 1/18; (upper right) flower with exserted pistil; (lower right) fruit resulting from flower forced by defoliation on 8/1.

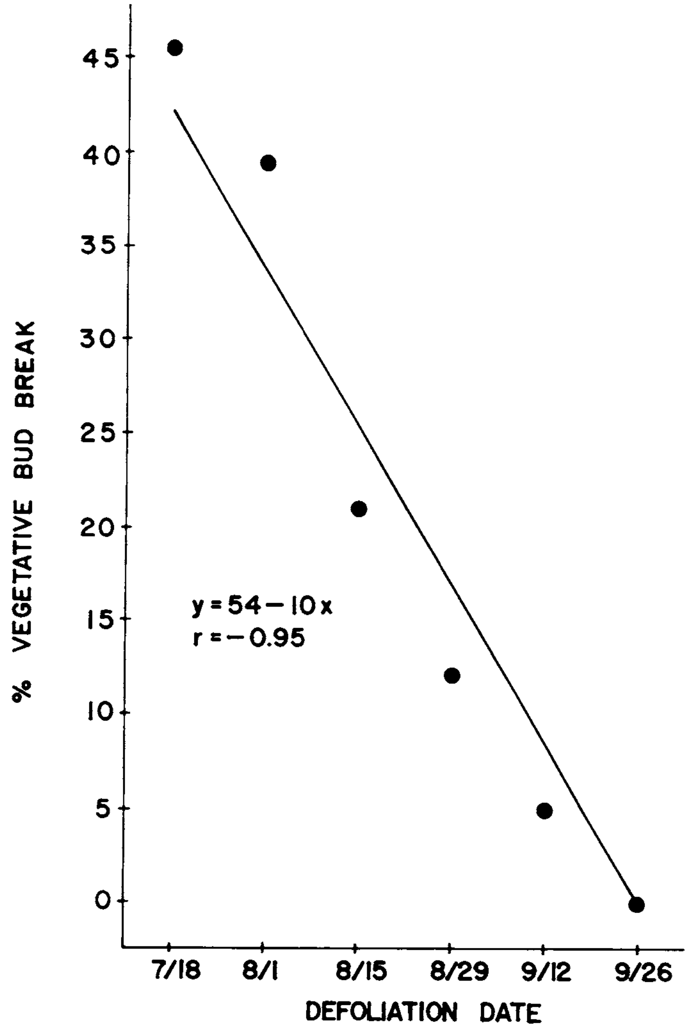

Fig. 6. The influence of defoliation date on percent vegetative bud break.

i.e., the abnormalities were ancestral forms. The latter possibility may have been the case in the present study since all flowers forced by early defoliations were abnormal. Those induced by intermediate defoliation dates were both normal and abnormal and flowers from the last defoliation dates were normal. In this study, flower buds were probably in the early stages of development on the earlier defoliation dates; thus, undeveloped flowers in transition from the vegetative to the reproductive meristem were forced. In September, the flower buds were fully developed; hence, normal flowers were forced.

The absence of the photoperiodic receptor could have played a role in the induction of the floral abnormalities described. Krishnamourthy and Nanda (10) obtained abnormal sepals on *Impatiens balsmina* similar to those found in this study (Fig. 4, 5) by exposing plants to noninductive photoperiods preceded by exposure to inductive photoperiods. Bracts, sepals, and petals were produced that resembled foliage leaves. This indicated to them that the floral bud reverted to the vegetative state. They proposed that the floral stimulus was not produced under noninductive photoperiods; thus, development of the flower bud was arrested, and irrespective of the developmental stage attained the bud reverted to vegetative activity. The photoperiodic receptor is located in the leaves (2, 9). Thus, defoliation of peaches would result in the removal of the photoperiodic receptor terminating the floral stimulus, possibly causing a reversion to the vegetative state. Flower buds forced by the later defoliation dates could have reached an irreversible stage in development; thus, they appeared normal. This reasoning is also supported by the data of Nasr and Wareing (13) who were able to produce floral abnormalities on black currant by placing decapitated defoliated plants previously exposed to 16 short day cycles under long days. Also, chemical defoliation of apple trees caused the younger floral primordia to revert to leaf production. The extent of reversion was dependent upon the age of the primordia (8).

The effect of defoliation date on vegetative bud break (Fig. 6) might be related to the progressive development of "rest" in buds. This would explain the reduction in vegetative bud break with each succeeding defoliation date. Apparently leaves play a significant role in "rest" induction, since vegetative or flower bud break did not occur on individually defoliated shoots. Also lack of bud break on individually defoliated shoots suggest that leaf removal does not stimulate bud break, but rather eliminates the source of materials which prevent bud break. Growth inhibitors could have been translocated from shoots with leaves to the defoliated shoots; thus, preventing bud break. Although nothing conclusive concerning "rest" induction can be drawn from this study, this aspect warrants further study.

That flower bud break increased with each successive defoliation date and vegetative bud break decreased, suggests that flower buds enter "rest" much later than vegetative buds. However, the increase in flower bud break with each successive defoliation date could be due to greater development of flower buds on the later defoliation dates.

Literature Cited

1. Cooper, J. R. 1953. Factors affecting winter injury to peach trees. *Arkansas Exp. Sta. Bul.* 536.
2. Cumming, B. G., and E. Wagner. 1968. Rhythmic processes in plants. *Ann. Rev. Plant Physiol.* 19:381-416.
3. Davis, L. D. 1957. Flowering and alternate bearing. *Proc. Amer. Soc. Hort. Sci.* 70:454-556.
4. Dostal, R. 1967. On intergration in plants. Ed. K. V. Thimann. Harvard Univ. Press. Cambridge, MA. p. 218.
5. Fulford, R. M. 1965. The morphogenesis of apple buds. I. The activity of the apical meristem. *Ann. Bot.* 29:167-180.
6. ———. 1966. The morphogenesis of apple buds. II. The development of the bud. *Ann. Bot.* 30:25-38.
7. ———. 1966. The morphogenesis of apple buds. II. The inception of flowers. *Ann. Bot.* 30:207-219.
8. ———. 1970. The effects of chemical defoliation on the development of apple spurs. *Ann. Bot.* 34:1079-1088.
9. Hammer, K. C., and J. Bonner. 1938. Photoperiodism in relation to hormones as factors in floral initiation and development. *Bot. Gaz.* 100:388-431.
10. Krishnamourthy, H. N., and K. K. Nanda. 1968. Floral bud reversion in *Impatiens balsamina* under non-inductive photoperiods. *Planta* 80:43-51.
11. Lenz, F. 1967. Relationships between the vegetative and reproductive growth of Washington navel orange cuttings (*Citrus sinensis* L. Osbeck). *J. Hort. Sci.* 42:31-39.
12. Nasr, T. A. A., and P. F. Wareing. 1961. Studies on flower initiation in black currant. I. Some internal factors affecting flowers. *J. Hort. Sci.* 36:1-10.
13. ———, and ———. 1961. Studies on flower initiation in black currant. II. Photoperiodic induction of flowering. *J. Hort. Sci.* 36:11-17.
14. Priestley, C. A. 1962. Carbohydrate resource within the perennial plant. Technical Communication No. 27, Commonwealth Bureau of Horticulture and Plantation Crops, East Malling, Maidstone, Kent, England. p. 116.
15. ———. 1970. Carbohydrate storage and utilization. Physiology of tree crops. Ed. L. C. Luckwill and C. V. Cutting. Academic Press, N. Y. p. 382.
16. Sparks, D., and C. E. Brack. 1972. Return bloom and fruit set of pecan from leaf and fruit removal. *HortScience* 7:131-132.