Citrus flower model may aid in timing pest controls

Thomas S. Bellows □ Joseph G. Morse
Neil V. O'Connell □ Donald L. Flaherty

More precise timing would protect honey bees

A branch tip from a navel orange tree showing three of four stages of flower development used to time pesticide treatments: (a) small round buds; (b) elongate buds; (c) open flowers. A fourth stage, flowers with one or more petals fallen, is not shown.

Each year in the spring, citrus production managers are required to make numerous pest management decisions, which are complicated by the bloom period. Most citrus varieties, except tangelos, do not require pollination by bees. Citrus flowers, however, are excellent pollen and nectar sources, which beekeepers widely use to provide rearing stimuli for the spring brood important in summer pollination of various crops. Citrus is a link in the rotation of honey bee colonies between food sources, because it blooms after almonds and avocados and before seed alfalfa and melons. Citrus nectar also produces a very light, high-quality honey representing approximately 25 percent of annual honey production in California.

Potentially at odds with the needs of the beekeeper are the grove manager's requirements for insect pest management during the spring. Various lepidopterous species, such as the fruittree leafroller and citrus cutworm, may appear in destructive numbers before or during the bloom period. Citrus thrips is commonly of economic importance at the end of the bloom period. Most pesticides used to control these pests are highly toxic to bees, so most applications must be made either before the flowers open and attract bees or after petals have fallen.

Models for temperature-dependent development have been widely used in agriculture, most notably in management of insect pests. Our objective was to determine if such techniques could be used to follow the development of citrus flowers, creating a predictive model that would be useful in pest management, particularly in timing pesticide treatments to avoid danger to bees. In this study, we constructed an experimental model of citrus flower phenology and examined its abilities to track the development of flowers in a particular orchard.

Field studies

We studied the population of flowers in a navel orange grove in Porterville, California, by frequent sampling during the spring of 1982. Ten branch tips on both the north and south sides of three trees were tagged, and all flowers developing on each tip were counted two or three times a week during the bloom period. Flowers were recorded in four categories representing stages of maturity: small round buds; elongate buds; open flowers (either partially or fully); and flowers with one or more petals fallen.

We constructed a model that included the four developmental stages of a flower population. The model assumed that (1) each stage was subject to a rate of loss (through flowers dying, being blown away

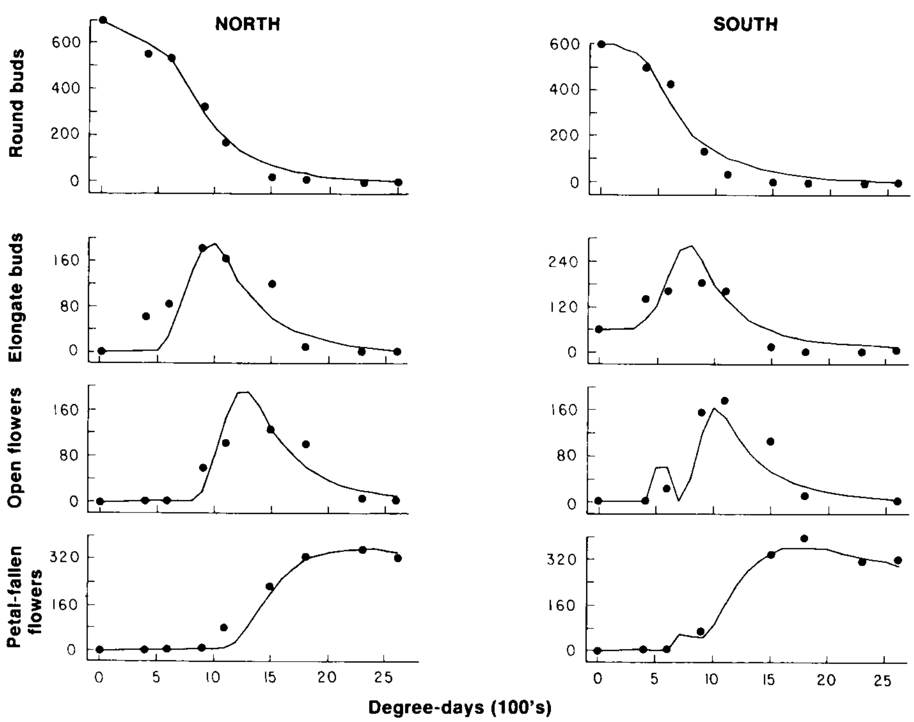

Fig. 1. Flower stage observations (•) and predictions utilizing the four-stage flower model (solid lines) were in general agreement.

by wind, and the like), and that (2) flowers in each stage matured at a specific rate towards the next stage. We estimated developmental and loss rates from the number and type of flowers present during the season.

Flower development depends to a large extent on temperature. We incorporated this factor into the model by using the concept of degree-days. This gives an account of the different heat units accumulated on each day, providing a physiological time scale for assessing rates of development.

Two biological reference points are needed to implement a degree-day scale: a minimum temperature (below which development does not occur) and an initial time or date to begin accumulating degree-days. We used 12.5°C (54.5°F) as a minimum temperature when calculating degree-days (following work published earlier by Dr. W. Reuther, Department of Botany and Plant Sciences, UC Riverside). We started the degree-day scale at zero on April 13, the first day on which we recorded data. Further research is needed to identify a more general starting time, based possibly on air or soil temperature, before the model can be used over a wider geographic range.

Results

The flowers on the north side of the trees were primarily in the small, round stage (99.6 percent) on April 13, with 0.4 percent in the elongate-bud stage. The maturing bud population reached peak numbers of elongate buds 900 degree-days after the experiment began. Peak numbers of open flowers occurred approximately 600 degree-days later. The 704 initial buds yielded 329 fruit on May 11. Ten percent flower opening was at approximately 900 degree-days, and 75 percent petal drop at 1800 degree-days after the start of the experiment.

Development on the south side of the trees was slightly earlier. The initial population consisted of 90.1 percent small buds and 9.9 percent elongate buds. Peak numbers of elongate buds occurred at 900 degree-days, and peak numbers of open flowers at 1100 degree-days. The 670 initial buds yielded 310 fruit on May 11. Ten percent flower opening occurred between 400 and 500 degree-days, and 75 percent petal drop by 1500 degree-days.

The four-stage flower model was applied directly to the data, and developmental and loss rates were estimated separately for flower populations from the north and south sides of the trees. The model predictions and observed results are in general agreement (fig. 1), with overall correlations of 97 and 96 percent for the north and south populations, respectively. Model estimates of times to 10 percent flower opening were 650 and 820 degree-days for north and south populations. Estimated times to 75 percent petal drop were 1850 and 1650 degree-days for north and south populations. These estimates were within approximately three days of the observed times; the estimates of petal-drop times were more precise than those for flower opening.

Conclusions

Temperature-dependent models can play a major role in a management program and can reduce the need for field plot examination to determine stages of population development. Application of this technology to citrus production is relatively new. The model constructed in this study was able to capture two features of concern in early-season crop management — the timing of bloom initiation and petal fall — which are vital to the protection of bees in orchards during flowering. The model predictions regarding flower development from bud through young fruit agreed in general with the field observations. Furthermore, there was close agreement at two points of particular concern — 10 percent flower opening and 75 percent petal drop. A more general model similar to this one therefore might be used to predict flower opening and petal fall, aiding managers in making pest management decisions. Such models probably would not be sufficiently accurate to eliminate the need for at least some field sampling in determining the actual status of flower development, particularly with respect to harmonizing the requirements of beekeepers and citrus pest managers.

The experimental model thus far developed does not permit general application over a wide geographical area. First an initial time or biological occurrence (such as the beginning of root activity based on soil temperatures) must be identified as a starting time for the degree-day scale. Also, values for developmental parameters must be obtained for citrus growing areas other than Porterville so that the generality of such values can be determined. Nonetheless, it appears that modeling citrus crop development may contribute to the establishment of computer-assisted management programs for this crop. Models like this one may also be coupled with other models of key citrus pests (such as citrus thrips) to aid in understanding the effects of weather on relationships among tree and insect phenologies and insect pest status.

Thomas S. Bellows and Joseph G. Morse are Assistant Professors, Department of Entomology, University of California, Riverside; Neil V. O'Connell and Donald L. Flaherty are Farm Advisors, Tulare County. *The authors thank Carol Lovatt, UC Riverside, for helpful discussion and William and Robert Bennett for providing field plots. Ann Strawn, UC Riverside, assisted in coding the computer model.*