In situations where the two cohort flight peaks cannot be separated (as when warm winters cause overlap of the two cohorts), REDSCALE3 is used and the model is initiated at the single peak of the spring male flight (fig. 1d). If it is still unclear which is the proper file to use, several simulations may be run and field observations compared with model predictions.

After the spring generation of CRS, all of the files will project a dual cohort population structure. Field studies have, in general, shown a dual structure in summer generations (especially for the second flight), even when the spring cohorts overlap.

High summer temperatures are believed to significantly increase mortality of the younger CRS life stages, especially during the third flight peak in the San Joaquin Valley. However, we have insufficient data to define this relationship quantitatively, and we have not included a model variable for seasonal (heat stress) mortality. As a result, the model overpredicts population levels during the third and fourth (if present) flights. A model scaling factor is imposed midway between the first and second cohort peaks of the second flight to scale down the later flight levels. At present, the model is intended for phenology (timing) prediction, and model density levels should be interpreted with great care.

After the CRS model was built, model output was compared to seven years of male flight data collected by D.S. Moreno, C.E. Kennett, and R.F. Luck from different sites in the San Joaquin Valley (four comparisons are shown in fig. 1). In five out of seven years, both the first and second flights were predicted accurately (within one week of the field surveys) for both cohorts. In the third flight, however, the simulation shows a merging of the two cohorts that was not generally observed in the field. Field surveys of the third flight show either a distinct separation between the two cohorts or an extra peak, especially in years such as 1981 when a relatively cool week was followed by a warm one.

Several factors may be responsible for the observed differences between field counts and model predictions. First, small errors in estimates, in addition to small deviations between model approximations and actual developmental distributions are compounded through several generations, resulting in increasingly larger errors. In addition, the model does not yet include factors accounting for the effect of host plant status (such as nutritional condition of the citrus tree) upon California red scale development and reproduction. Also, temperature records used to drive the model are usually obtained from a single site in the orchard or from a nearby weather station. This single record ignores the variability in CRS development in the field that may occur because of variability in environmental conditions in different parts of the tree or different trees within a grove. Finally, high summer temperatures, which usually occur during the second cohort of the second flight and during the third flight, may contribute to restructuring the cohorts in the field.

The model should be used with some caution. As mentioned, it is constructed to help predict population peaks and aid in understanding CRS phenology through the summer months, not to predict population density. As with any simulation of a complex biological process, it is a simplification of the actual field situation. Detailed field monitoring of California red scale populations will remain the backbone of any CRS management program. The computer model may assist in more efficient timing and interpretation of such field monitoring.

Although now limited to population peak prediction, the CRS model and the GPM system are perceived to be significant contributions to citrus pest population forecasting and management programs. As information from new studies becomes available, the simulation model can be improved with little effort. This information should aid in developing a model that will accurately predict population densities within and between field seasons. As information becomes available for other citrus insect pests, similar models can be created through utilization of the GPM system.

The CRS simulation model is available only to UC campuses, research stations, and farm advisors with access to terminals connected to the UC IPM computer network. Plans are under way to extend access to growers and others by writing versions of the simulation program for microcomputers.

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Predicting CRS infestations by trapping males

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Trapping can improve decision making in CRS control

In some properly managed orchards in southern California, natural enemies reduce California red scale populations to an acceptable economic level, but chemical control is normally required in the desert and San Joaquin Valley areas. We believe annual red scale sprays can be reduced when population densities are properly monitored with CRS pheromone traps. Our objective in this study was to relate year-end scale infestation levels on fruit to pheromone trap catches early in the season in the San Joaquin Valley, using numbers of trapped males as a population density index for CRS.

We gathered data from 1973 to 1983 in 15 San Joaquin Valley navel and Valencia orange orchards in Tulare and Fresno counties. Selected trees were inspected for scale on scaffold branches and twigs and were categorized according to density. Orchards with a light infestation (occasional single scales on twigs or branches) or less were selected for experimentation, because they could be monitored for at least 24 months with little likelihood of requiring scalicide applications.

The flight of the male scale was first monitored with traps baited with live virgin females (about 200 females per trap) from 1973 to 1978 and with a synthetic component of the pheromone (120 μg per rubber septum) from 1978 to 1983. The dose rate of the synthetic pheromone closely approximated the attractancy of 200 females. The females were replaced every two weeks and the synthetic pheromone every four weeks. All pheromone septae in our tests were prepared in our laboratory. Sticky cards on all traps were changed weekly.

Two hectares (5 acres) of an orchard were treated as an experimental unit. Within each unit, five pheromone traps were uniformly distributed in the center of 100 trees (about 1 acre). Four trees were randomly selected from the 24 trees immediately surrounding the trap tree and used to determine fruit infestation levels. Twenty fruit were randomly selected from each tree and assigned to categories of: 0 (no scale), I (1 to 5 scales), II (6 to 10 scales), III (11 to 50 scales), and IV (>50 scales). All live and dead scales were counted. One randomly selected tree from the eight trees immediately surrounding the trap tree was used to determine infestations of 20 twigs selected in the same manner as fruit. Only live adult females and immatures (including males) were recorded.

The proportions of infested fruit with one or more scales at season's end were plotted against the mean number of males caught per trap for each of the flights and a statistical comparison performed. The numbers of females and immatures on twigs were analyzed against the proportion of infested fruit and pheromone trap catches from the fourth male flight only. We defined a flight as the sum of males caught between the lowest point of ascendancy and the lowest point of descendancy from each peak. We used degree-days above a lower threshold of 11.7°C (53°F) to interpret phenological flights during the season.

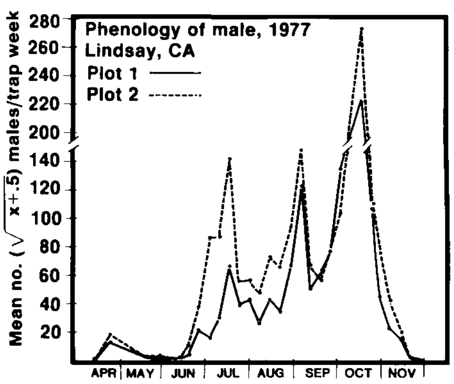


Fig. 1. Seasonal monitoring of male CRS in the San Joaquin Valley shows four distinct flight periods.

Data from orchards sprayed with scalicides or exposed to pesticide drifts were excluded from our analysis because of the disruptive nature of these treatments. Also, we excluded data from orchards where fruit infestation equalled or exceeded 50 percent, because this level of infestation is not commercially acceptable, and twig death, depending on the age, size, and condition of the tree, began to occur at about this point. For analysis, a total of 21, 59, and 79 2.5-acre observations were used for the first, second, and fourth male flight periods, respectively.

Findings

Generally, four flights occurred — in April-May (overwintering males), June-July (first generation), August (second generation), and September-October (third generation). We were able to correlate male flights to infested fruit at the end of the season, and this led to the development of a model for predicting fruit infestations. The nature of the relationship between male flights and infested fruit was not linear.

First male flight. The first male flight of the year is difficult to detect in orchards with low red scale infestations, because the populations early in the spring are at their lowest and temperatures are quite variable. Consequently, there is more inherent variation in the model for this flight than for the others. Future infestations can still be predicted, but a greater degree of error must be accepted than with the second or fourth flight.

Second male flight. The analysis of data for this flight showed the least variation in any of the flights, indicating more stability in the population. The weather during this flight is more conducive to scale survival and activity, because by this time of the season, most of the citrus thrips and orangeworm sprays have been applied and insecticidal interference is minimal.

Third male flight. The third flight was not used in our analysis because flights were unpredictable, curtailed, or lacking in some locations in some years.

Fourth male flight. This flight is the least affected by pesticide application and, during this time of season, the weather is conducive to scale survival. Our analysis shows it to be less sensitive for prediction than the second flight but better than the first flight. However, further analysis shows that the relationship between infested fruit and adult females on twigs corresponds well with previous results and indicates good cause and effect.

The second male flight is the best predictor of year-end fruit infestation. It is also a very timely predictor, because only a negligible amount of fruit becomes infested with scale by the end of the second flight (first summer generation).

TABLE 1. California red scale predictive fruit infestation levels based on trap catches of males and on infested orange fruit in the San Joaquin Valley.

No. males/flight period			Mean % with scale	
1st*	2nd†	4th‡	≥1	≥11§
	0	1,763	2	0.7
0	1,385	6,263	4	1.3
21	3,006	10,893	6	2.0
43	4,679	15,665	8	2.6
65	6,403	20,594	10	3.3
87	8,184	25,697	12	3.9
111	10,028	30,993	14	4.6
135	11,947	36,504	16	5.3
159	13,946	42,257	18	5.9
184	16,038	49,022	20	6.6
211	18,238	54,612	22	7.2
238	20,561	61,354	24	7.9
266	23,030	68,841	26	8.5
295	25,686	76,290	28	9.2
326	28,568	84,744	30	9.8
358	31,749	94,208	32	10.5
392	35,351	105,055	34	11.2
428	39,602	118,331	36	11.8
466	45,067	136,864	38	12.5
508	55,246	167,200	40	13.1

NOTE: Values given are expected fruit infestation at harvest, and various factors may affect actual levels observed in an individual's orchard.

* $Y = 4.02 + 9.57(10^{-2})\chi - 4.89(10^{-5})\chi^2$, $R^2 = 0.734$, SD= 6.843.

† $Y = 2.25 + 1.28(10^{-3})\chi - 1.08(10^{-8})\chi^2$, $R^2 = 0.825$, SD= 0.825.

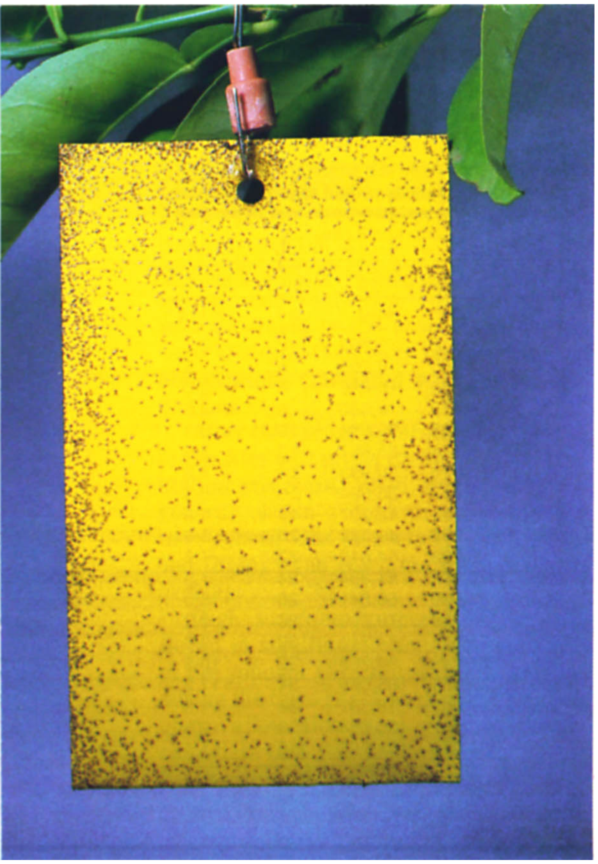
‡ $Y = 1.21 + 4.55(10^{-4})\chi - 1.36(10^{-9})\chi^2$, $R^2 = 0.743$, SD= 4.387.

§ $Y = 0.0006 + 0.328\chi$, $R^2 = 0.763$, SD = 1.652.

The first male flight is a precarious basis for predicting population density, because temperatures of 17°C (63°F) or less limit male flight and possibly reduce pheromone diffusion. Also, at the time of the first flight, insecticides that adversely affect male flights are often applied for orangeworm and citrus thrips control.

The second male flight comprises sons of gravid females surviving the winter and overwintering females that have matured and mated in the spring. There are two distinct cohorts in this generation but, because of the frequency of sampling, separation of the cohorts is often difficult to observe. At the onset of this first generation's male flight, most of the scale population would be in the immature stages; because the population has not yet begun to infest new fruit, it would be the ideal time to treat with a scalicide if such a decision has been made. If no decision has been made, trapping needs to continue for the entire flight period before a correct evaluation of population densities can be made. Generally, the crawlers do not migrate to fruit until the middle of July.

A comparison of male trap catches from the fourth flight and counts of infested twigs and fruit strongly suggests a direct cause-effect relationship. Therefore, if necessary, a twig sample can be taken and analyzed to verify earlier decisions



Yellow polyvinyl "sticky card" of the type used to trap California red scale males.

and serve as a basis for action or nonaction in the following year.

Predictive values generated from the various analyses are shown in table 1. The column with percent fruit with 11 or more scale per fruit was generated by comparing proportions of infested fruit with more than 11 scale against those proportions that had more than 1 scale. Thus, mean male catch of 184, 16,038, and 49,022 for the first, second, and fourth flights, respectively, can result in a mean of about 20 and 6.6 percent of the fruit with 1 or more and 11 or more scale, respectively, at the end of the growing season. In one of our orchards, male trap catches at the end of the first and second flights (181, 11, 299) projected 20 and 15 percent fruit infestations, respectively. The observed fruit infestation was 14.3 percent (1 or more scale). Twig infestation was 2.1 adult females per 10 twigs, which indicated a 14 percent (1 or more scale) fruit infestation. Thus, the second flight was a better predictor than the first, and the twig sample at the end of the year substantiated this information.

The value of our predictive fruit infestation levels under an IPM program is to assess fruit infestations before they occur. Proper trapping and data interpolation should generate three possible outcomes: (1) no action, (2) contemplation, and (3) control action. In the first case, no serious problems are expected, in the second, a "wait and see" or "willing to take a risk" attitude is taken, and in the third, action is necessary because the expected fruit infestation will be above a tolerable level.

The assumption in all three situations is that some degree of fruit infestation must be accepted. The projected amount of acceptable fruit infestation is a matter of individual preference and for that reason no "economic thresholds" are offered here. Whether a scale population is going to overinfest fruit and damage the tree depends on the density of the scale on the tree in the beginning of the year, rate of scale survival during the fruit growing season, rate of predation and parasitism, age and physiological condition of the tree, and other pest control practices. In our experience, 17-year-old navel orange trees in good physiological condition situated in Exeter, California, were able to support scale populations that inflicted 31.9 and 40 percent fruit infestations (1 or more scale) without apparent damage to the trees at the end of the season.

Through proper assessment of red scale populations, unnecessary scalicide sprays are avoided. At least in one orchard, proper monitoring resulted in a between-treatment interval of about 36 months. The economic and ecological implications of averting unnecessary scalicide treatments are obvious. We propose that by proper use of the pheromone trap and correct interpretation of male trap catches, an assessment of fruit infestation can be made before it occurs.

Our projections fall within an acceptable range of expectations. In the very few years when mild summers were encountered, our projections were somewhat underestimated. Even so, the citrus grower would have an idea of what is going to happen. Thus, pheromone trapping can more accurately measure California red scale population densities than can occasional visual observations. By doing so, trapping can improve the quality of decision-making in citriculture. However, caution is needed in utilization of the trap because of the male scale's sensitivity to extreme temperatures, winds above 1.6 km per hour, direct pesticide applications for other pests in the same orchard, pesticide drifts from neighboring orchards, trap placement in relation to neighboring orchards, and quality of pheromone used.

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Nitrogen

The continuing increase in production cost and the environmental concerns regarding nitrate pollution point to a need for more efficient fertilization of vegetables. Nitrapyrin [2-chloro-6 (trichloromethyl) pyridine] has been reported to reduce nitrogen losses by inhibiting bacterial action in soils (bacteria convert ammonium to nitrate, which is subject to loss by denitrification and by leaching).

Recent studies have investigated nutrient uptake and growth patterns in lettuce, Brussel sprouts, and celery, but little information is available on cauliflower.

This article presents data from field trials on the efficiency of nitrogen fertilizer uptake by cauliflower. We used isotopically labeled nitrogen at various rates in single and split applications with and without nitrapyrin.

The cauliflower cultivar 123 was direct-seeded on 40-inch beds with 16 inches between plants and one row per bed. Each treatment was replicated five times in plots of six beds by 60 feet long in a randomized complete block design. The soil was a Watsonville loam with a perched water table 3½ feet below the soil surface during the summer growing season.

Preplant soil analyses from check plots for bicarbonate soluble phosphorus (58 ppm), potassium (263 ppm), and DTPA extractable zinc (3.2 ppm) would generally indicate that these nutrients were in sufficient supply for normal growth and development of cauliflower. However, all plots received 200 pounds of 0-20-20 fertilizer banded into soil as the beds were listed up for planting. Nitrogen as ammonium sulfate was sidedressed into beds a few days before planting at rates of 0, 60, 120, and 180 pounds of nitrogen per acre in single applications. Rates of 120, 180, and 240 pounds were also applied as split applications: the second half was banded into the beds 35 days after planting or after one-third of the growing season had passed. Separate single-application treatments of 60, 120, and 180 pounds nitrogen received 0.5 pound per acre of nitrapyrin as a 10 percent aqueous solution injected into the dry ammonium sulfate band.