citrus pest in South Africa. Another, the orange dog (*P. cresphontes*), long common in the southeast, has expanded its range from Arizona into southern California. As early as 1941, Vincent G. Dethier, working with another swallowtail (*P. polyxenes* of the eastern United States, a close relative of *P. zelicaon*), showed that the rue and citrus families shared essential oils (anethole, methyl chavicol, anisic aldehyde, and the like) that were feeding stimuli to the insect: caterpillars will eat filter paper treated with them, but won't eat umbellifer foliage that lacks them. The chemistry provided a natural "bridge" to a new host plant.

We believe that *P. zelicaon* has crossed that chemical bridge at least twice—once in the south and a second time, more recently, in the north. (This is to be studied further by genetic analysis of crosses between the northern and southern citrus-feeding populations and crosses of both with tester stocks.) We wondered *why*, and whether it was evolving a citrus race just as it had evolved a sweet fennel race.

Sweet fennel is highly attractive to females from populations feeding on wild umbellifers. Sims also found in split-brood experiments that the insect has a lower propensity to dormancy when fed on fennel than on short-lived plants, even in the multiple-brooded strains. The shift onto fennel over a century ago might have been aided by the "Hopkins Host-Selection Principle" proposed by A. D. Hopkins in 1917, which holds that given a choice among acceptable hosts, a female insect will prefer to lay eggs on the one she herself ate. Once the species had made an initial breakthrough, the developmental-time advantages would assure a rapid spread of fennel preferences in the population. James Erickson found in research at Cornell that this "larval memory " occurred in *Papilio polyxenes*, but Christer Wiklund, working on a Swedish species of the same group, found it did not.

We wondered if something of the sort had happened on citrus. Fennel-feeding stock was obtained from Fairfield and Suisun City, Solano County. Citrus feeders were taken from the Bailey Ranch near Orland, Glenn County. The two strains were maintained in continuous lab culture, and egg-laying females were tested for plant preference. A completely unattractive control, the landscaping shrub *Escallonia* (Saxifrage family), was used with them in the experimental design. With scores of replicate tests, we found that *sweet fennel was the host preferred by females for egg-laying regardless of what they had eaten or what strain they represented.* The "Hopkins Host-Selection Principle" did not hold.

Evolution of a citrus race was still possible if citrus were intrinsically a better host than sweet fennel; we therefore compared growth, survivorship, and fecundity of both strains on both plants. Once again, we found *fennel was intrinsically superior to citrus on all counts.* The female lays her eggs on the young, growing shoot tips of citrus; young caterpillars can eat only tender, young leaves, although larger ones can handle mature foliage. This limits population levels, focuses the damage, and makes citrus trees a trickier host than fennel, all parts of which are available all year.

Why, then, is the anise swallowtail attacking citrus at all? The answer seems to be straightforward: it has nothing to lose. There is no fennel in the vicinity of the orange groves. By using citrus, the butterfly has expanded its range into areas it could not occupy before. There is nothing wrong with using a suboptimal host if that is the only host around.

Right now the U.C. recommendations for swallowtail control on citrus are Parathion, Phosdrin (mevinphos), or Guthion (azinphosmethyl). All are highly toxic, deadly to honey bees and beneficial parasites, and subject to many restrictions. The ecology of the situation suggested the possibility of trap-cropping with sweet fennel where the swallowtail becomes a significant problem. We carried out field tests with potted plants in citrus orchards, which showed the same female preference for fennel as had been found in the lab.

Because fennel regenerates quickly from its taproot, strips of it interplanted with citrus could be mowed regularly, after the egg-laying peak in each generation. We have found that regenerating sweet fennel is *more* attractive to females than uncut tops. Sweet fennel flowers are visited by many dipteran and hymenopteran natural enemies of a variety of pests, but not by the pests themselves. The plant is not known to harbor other potential citrus pests.

The most successful use of trap-cropping in California has been the interplanting of alfalfa and cotton to control lygus bugs. Perhaps one day sweet fennel will be a common sight in citrus orchards, and the anise swallowtail will once again be merely a pretty ornament to the landscape—not a pest.

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Spring planting is best for oilseed sunflower

Benjamin H. Beard □ Karl H. Ingebretsen

Non-oil (confectionery) sunflowers (*Helianthus annuus* L.) have been grown in the Sacramento Delta of California since the early 1930s. Production has varied from about 800 to 3,200 hectares (2,000 to 8,000 acres) per year with yields of 1,100 to 3,900 kilograms per hectare (1,000 to 3,500 pounds per acre). The larger seeds are used for direct human consumption, and the small seeds are fed to birds. The oil content of the whole seed ranges from 25 to 30 percent.

In the 1940s an oil-type sunflower with seeds containing 30 to 35 percent oil was introduced into the United States. These oilseed types had been developed by plant breeders in the U.S.S.R. Production of these types was on a limited scale until 1964, when new high-oil varieties representing a second major improvement abroad were introduced from Russia to Canada. These varieties produced seed containing 40 to 50 percent oil, had improved disease and pest resistance, and had a yield potential equal to previously grown varieties. They were grown commercially for the first time in the United States in 1967.

The first oilseed sunflowers were open-pollinated varieties. The plants were 1.8 to 2.4 meters tall, with small, thin-hulled seeds. Because the varieties were open-pollinated, there was extreme variation in plant height, bloom date, and other characteristics, which caused many production problems. Experiences with other crops had shown that many of these problems could be reduced through the use of hybrid varieties.

Like corn, sunflowers are a cross-pollinated crop but, unlike corn, where the male and female flowers are widely separated, in sunflowers the male and female organs are close together. A corn plant can be detasseled in a few seconds, so hybrids can be produced simply by detasseling the plants to be used as females. Emasculating a sunflower plant requires 15 to 30 minutes each day for 4 or 5 days, which would make hybrid sunflower seed exorbitantly expensive. Even the use of genetic male sterility, where half of the plants in the female line are male fertile and must be destroyed, proved to be too costly and unreliable for commercial production.

Cytoplasmic male sterility was discovered in 1968 by Dr. P. Leclerq of France. Dr. Murray Kinman of the U.S. Department of Agriculture discovered the germplasm with the necessary restorer genes to ensure fertility of the hybrid. This made the commercial production of hybrid sunflower seed possible.

The development of cytoplasmic male-sterile inbred lines for the seed parent and fertile inbred lines with restorer genes for the pollen parent was accomplished by about 1972. New, improved inbred lines have been under continuous development since, but only limited quantities of hybrid seed were available in 1973. In 1974, when the study described here was started, one of the hybrids (Romsun HS52) was produced using the genetic male sterile system.

The development of, and expansion into commercial use of, hybrid seed has helped to make sunflowers a profitable commercial crop. Crop yield is up to 20 percent higher with hybrids than with older open-pollinated varieties. Disease resistance has been easier to incorporate into hybrids, and insect control periods have been shortened because of the greater uniformity of the plants. Hybrid seed was planted on 75 to 80 percent of the 2 million hectares grown in the United States in 1979.

In 1974 and 1975, tests were conducted in California with oilseed sunflower to determine the effects of date of planting, rate of planting, and environments in different years on yield of seed, oil content of the seed, and fatty acid composition of the oil. Two open-pollinated varieties, Tchernianka and Peredovik, and two hybrids, Romsun HS52 and Sunhi 304, were planted at monthly intervals in 1974 and 1975. Varieties were arranged in a Latin square with four replications. Dates of planting were strips across the varietal blocks, and rate of planting or plant spacing was randomized within each date of planting for each variety. Plots were four rows wide, and 6.1 meters long. Yields were obtained from 4.1 meters of the two center rows. Rows were 76 centimeters (30 inches) apart, and plants were thinned after emergence to provide 10, 20, 30, and 40 centimeters between plants in the row. All tests were on raised beds, and plants were furrow irrigated as needed to avoid stress.

When the plants were mature, heads were harvested by hand, threshed, and the seed allowed to reach an equilibrium moisture content before weighing. Oil content of the seed was determined by wide-line nuclear magnetic resonance (NMR) analysis and is reported on an oven-dry basis. Fatty-acid composition of the oil was determined by gas-liquid chromatography.

Effect of Date of Planting, Spacing, Varieties, and Years on Yield, Oil Percentage, and Linoleic Acid Percentage of Sunflower at Davis, California

		Yield	Oil		Linoleic acid
		(kg/ha)	Percent	Kg/ha	(%)
Date of seeding					
April	1974	2592	45.5	1179	61.5
	1975	3181	48.5	1543	63.9
May	1974	2676	45.5	1218	65.9
	1975	3161	48.4	1530	66.0
June	1974	956	40.8	390	69.0
	1975	2643	43.7	1155	69.6
July	1974	702	40.2	282	72.3
	1975	2447	42.6	1042	70.0
Spacing (cm)					
10		1998	44.8	895	68.4
20		2374	44.7	1061	67.4
30		2418	44.5	1076	67.0
40		2388	43.5	1039	66.3
Varieties					
Tchernianka		2071	43.6	903	66.3
Peredovik		2262	44.5	1007	66.5
Sunhi 304		2296	44.2	1015	68.6
Romsun HS52		2548	45.2	1152	67.6

Results and discussion

Plantings in April or May gave the highest seed production each year. The percentage reduction in yield from June and July plantings was much larger in 1974 than in 1975. This is believed to be associated with the higher temperatures during the seed filling period in 1974. Plant population did not affect yield except at the 10 centimeter (4-inch) spacing. Populations varying between 44,500 and 86,500 plants per hectare (18,000 to 35,000 per acre) produced similar yields. Over 124,000 plants per hectare did decrease seed yield. Plants with only minimal spacing had very slender stems, small heads, and lodged more than those in other plots. The same trend was observed in each year.

Oil content of the seed was highest from April or May plantings and decreased with later plantings. Oil yield per hectare shown in the table was calculated from seed yield and oil content. Oil content and oil yield relationships within years are valid, but differences between years may be due to the standardization procedures for the NMR analyzer. Oil content did not vary significantly with plant spacing, although there was a consistent trend toward lower oil with decreasing plant populations.

Sunflower oil is usually advertised as a highly polyunsaturated vegetable oil, which makes the level of linoleic acid in the seed very important. Sunflower oil with a linoleic acid content of less than 70 percent is sometimes discounted. The fatty-acid composition of sunflower oil is strongly influenced by the temperatures during seed formation. Generally, areas at less than 39° latitude produce sunflower oil with less than 70 percent linoleic acid. Davis, at about 38° north latitude, is also in an area with much higher temperatures than is commonly experienced at comparable latitudes. Thus, the linoleic acid component in the sunflower oil from these tests is low. Even though the linoleic acid level is above 70 percent from the July planting, yields were so depressed it would be advisable to consider net income before planting this late in the season. Both hybrids had a higher level of linoleic acid than the open-pollinated varieties. Plant breeding might increase the linoleic acid component of the oil even with higher temperatures.

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