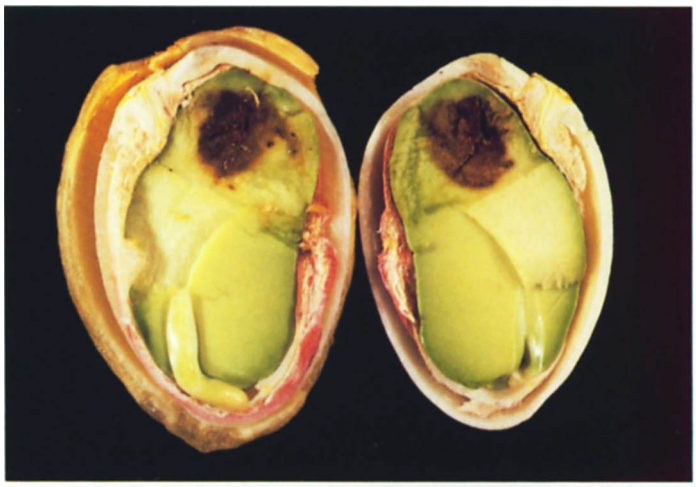


Less firmness at the stem end or base (white area in photo above) than in other parts of pistachio fruit was associated with higher percentages of epicarp lesion begun at the base (discolored area, or kernel necrosis, in photo at upper right). Another area of feeding by leaffooted bugs or stinkbugs is along the suture or split line, producing kernel necrosis and concentric rings (lower right).

The 'Achilles heel' of pistachio fruit

Themis J. Michailides

A small area at the stem end of the pistachio fruit, which hardens later than the rest of the tissues, is susceptible to puncturing by several insects during the growing season. Studies found that 60% to 74% of the kernel damage symptoms were at the stem end and along the suture areas.

The pistachio is now a firmly established crop in California with more than 50,000 acres planted and 33,000 in production. The San Joaquin Valley has 94% of the state's total pistachio acreage, occupying continuous large areas; the rest of the plantings are in the Sacramento Valley, usually in smaller, separated orchards.

During 1983-85, researchers at the University of California at Davis showed that several species of hemipteran insects were responsible for epicarp lesion, a disorder that had puzzled pistachio growers for years. The term "epicarp lesion" describes fruit symptoms that appear as dark to black and collapsed hull tissues and abortion of immature fruits. The epicarp of pistachio fruit is the outer layer of the hull. The researchers captured insects of the following species feeding on pistachios, *Pistacia vera* L., in the field: small hemipterans such as *Psallus vaccinicola* and *P. ancorifer*, *Calocoris norvegicus*, *Lygus hesperus*, *Neurocolpus longirostris* (buckeye bug), and *Phytocoris relativus* and *P. conspurcatus*, all true bugs (Miridae family); *Liorhyssus hyalinus* and western boxelder bug, *Boisea rubrolineata* (*Leptocoris rubrolineatus*), of the family Rhopalidae; the stinkbugs *Thyanta pallidovirens* and *Chlorochroa uhleri* (Pentatomidae); and leaffooted bug, *Leptoglossus clypealis* (Coreidae).

In laboratory experiments, all of these insects induced epicarp lesion on pistachio, and those of the Pentatomidae and Coreidae families induced both epicarp lesion and kernel necrosis. Attacked kernels show brown, discolored areas that become spongy and punky (see *California Agriculture*, January-February 1985). The small hemipterans feed on pistachio fruit as long as they can insert their stylets through the soft epicarp and mesocarp (inner layer of hull) tissues, and they quit feeding when the endocarp (shell) of the fruit hardens. They then move to other suitable hosts. Larger insects, such as leaffooted bugs and stinkbugs, are capable of penetrating partially hardened endocarp tissues.

Hardened endocarp tissues act as physical barriers to successful puncturing of pistachio fruits by some sucking insects. As the firmness of the pericarp (epicarp + mesocarp + endocarp) accelerates rapidly in the apical portion of the fruit (fig. 1), the smaller plant bugs (the mirids) and the two rhopalids, but not the stinkbugs and leaffooted bugs, start feeding preferentially at the fruit base (table 1). At the base, an area of about 10 square millimeters remains relatively soft and is vulnerable to insect punctures until later in the season. Incidence of epicarp lesion originating from punctures through the base of the fruit is high, particularly since this area represents such a small part of the entire pericarp surface.

Experiments

In 1986, experiments were begun to determine whether leaffootted bugs and stinkbugs show a similar feeding site preference after May, when pericarp firmness increases. Although these two bugs can puncture hardened pistachio shells, they too seem to prefer puncturing the fruit base where the pericarp is softer and the suture (split) line occurs. 'Kerman' pistachio fruits from the UC Wolfskill Experimental Orchards at Winters, California, which had fresh-appearing epicarp lesion symptoms,

were sampled from April 25 through August 5, 1986. The site of epicarp lesion was recorded in three samples of 20 fruits each. These orchards had at least a 4-year history (1983-86) of natural high infestations by leaffooted bugs and stinkbugs.

In an experiment to study the sites of kernel necrosis, 50 to 250 randomly selected fruits were collected on September 10, 1985 and September 15, 1986, and sectioned with a knife along the suture. The two halves of the kernel were then sliced into sections of 1 to 2 mm to determine kernel necrosis sites different from those at the stem end and along the suture line, and to calculate the percentage of kernel necrosis of the stem end and suture line.

Fruit firmness was measured with a firmness tester equipped with a hypodermic needle on the stem end and apex of 10 randomly collected pistachio fruits. Firmness determinations were performed from May 1 to August 5.

Calculations were made to correlate the percentage of epicarp lesion initiated at the stem end of pistachio fruit with the increase of pericarp firmness from April 25 to August 5.

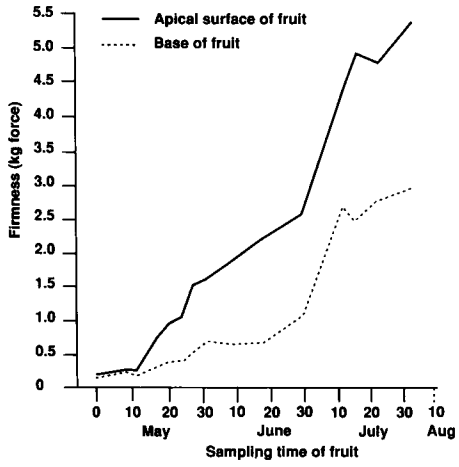
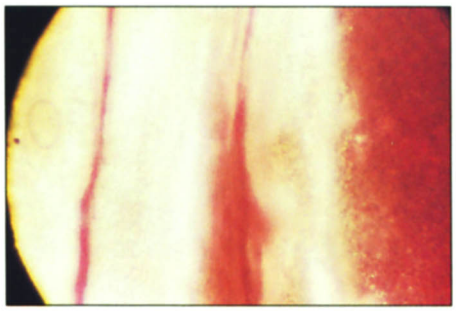
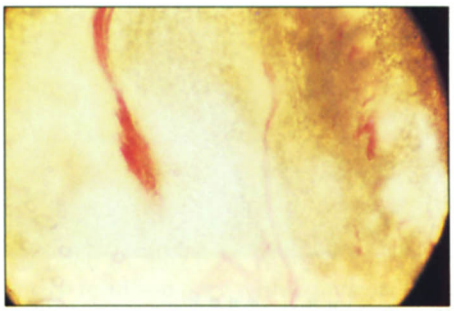


Fig. 1. Pericarp firmness of pistachio fruit increased rapidly at the apex or tip but remained lower at the base or stem end. (Values are averages from 10 fruits per test date.)





Stained fruit tissue sections show a greater amount of lignified or hardened elements (red areas) at the tip of the fruit (left) than at the stem end (right) on the same date, May 31.

Results and conclusions

Early in the season, in April, only a small percentage of fruits with epicarp lesion damage showed symptoms initiated at the stem end (8.3%) but the percentage increased rapidly, going from about 40% at the end of May to 80% at the beginning of August. Pericarp firmness at the apex of the fruit remained below 2 kg until June 20, then increased to about 5.5 kg at the beginning of August 1986 (fig. 1). In contrast, pericarp firmness at the stem end of the fruit was about 2.5 to 3 kg at the beginning of August. These results agreed with those determined in 1985.

Percentages of epicarp lesion initiated at the stem end and pericarp firmness were closely related (significant positive correlation: $\underline{r} = 0.918$; $\underline{P} < 0.01$). The increased percentage of epicarp lesion begun at the stem end suggests that, as pericarp firmness increases, leaffooted bugs and stinkbugs feed preferentially at that end, where pericarp firmness is lower. Thickening of the cell wall and greater toughness of plant tissues due to increasing woodiness or lignification have been implicated in interference with feeding and egg-laying mechanisms in other insects. For instance, wheat varieties with a higher firmness index have shown better resistance to cutting by the wheat stem sawfly, *Cephus cinctus*.

In the 1985 kernel necrosis study, three random samples of 250 pistachio fruits each collected in September from a commercial orchard heavily infested with leaffooted bugs and stinkbugs had 27.3% kernel necrosis. Approximately 74% (151 of 205 fruits) of the kernel necrosis was found at the stem end and along the suture line. In samples collected in mid-September 1986 at Wolfskill Experimental Orchards, of fruit with kernel necrosis, the disorder had begun in 60.6% at the base of the fruit, 25.8% along the suture line, and only 13.6% in other sites. Kernel necrosis at the fruit stem end often showed concentric, dark brown to black rings alternating with light brown rings.

These findings suggest that even the leaffooted bugs and the stinkbugs, which have been shown to be capable of puncturing hardened endocarps of pistachio fruits (*California Agriculture*, January-February 1985), shifted their feeding to the base of the fruit or to points along the suture line. Normally, the hull (mesocarp + epicarp) loosens from the shell (endocarp) that covers the kernel (seed) before the shell splits. The hull remains intact, completely covering and protecting the shell even after the shell has split. Leaffooted bugs and stinkbugs can locate these softer areas, even though they are not visually apparent.

The 1985-86 experiments show that, although increased pericarp firmness provides some defense against feeding by several species of hemipterans, a small area around the stem hardens later and is thus vulnerable to the punctures for a longer time. The small hemipterans (mirids and rhopalids) find this area of the pistachio at the end of their feeding period (middle to end of May). Stinkbugs and leaffooted bugs, however, can puncture the pistachio fruit through this "Achilles heel" until harvest. Pistachios thus require protection from the small hemipterans until at least as late as the beginning of June and from the stinkbugs and leaffooted bugs until harvest.

TABLE 1. Incidence of epicarp lesion (EL) induced by various hemipterous insects at stem end of immature (green) pistachio fruits

Access feeding dates*	Percent EL originated at stem end[◊§]							
	Miridae							
	Cal	Neu	Pan	Phy	Lio	Thy	N. Lfb	Lfb
	%							
May 7	—	31	43	—	—	—	—	—
May 10	—	53	63	73	58	—	—	—
May 14	—	75	65	—	50	35	28	—
May 16	—	57	68	77	83	55	—	42
May 20	—	100	—	100	—	34	40	43
May 24	100	—	—	100	—	—	—	—

* Dates insects caged with fruit clusters.
◊ Percentages based on 4 to 52 fruits.
§ Insects: Miridae—Cal, adults of *Calocoris norvegicus*; Neu, adults of *Neurocolpus longirostris*; Pan, adults of *Psallus ancorifer*; Phy, adults of *Phytocoris* spp. Lio, adults of *Liorhyssus hyalinus*. Thy, adults of *Thyanta pallidovirens*. N. Lfb and Lfb, nymphs and adults of *Leptoglossus clypealis*, respectively.

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