French prune trees: refuge for grape leafhopper parasite

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Prune trees planted next to vineyards allow early-season buildup of* Anagrus epos*, an important parasite of the grape leafhopper. After surviving the winter on an alternate host, the prune leafhopper,* Anagrus *moves into the vineyard in the spring, providing grape leafhopper control up to a month earlier than in vineyards not near prune tree refuges.

The grape leafhopper causes economic losses in California's major grape-growing regions by feeding on the vines, marring the fruit with frass, and annoying pickers at harvest. Populations of the leafhopper, *Erythroneura elegantula* Osborn, are usually smaller in vineyards near streams, where blackberry bushes are abundant. The bushes provide a winter refuge for the parasitic wasp *Anagrus epos* Girault, the most important natural enemy of grape leafhoppers. The wasp, which does not overwinter in grapes, depends for survival during the winter on its alternate host, the blackberry leafhopper, *Dikrella californica* (Lawson). Dispersal of *Anagrus* from blackberry bushes in early spring is responsible for effective natural control of grape leafhoppers in the summer in many nearby vineyards.

Efforts in the 1960s and 1970s to enhance biological control by establishing blackberry refuges near commercial vineyards have largely failed. *Anagrus* production is low, perhaps because the bushes are less attractive to their blackberry leafhopper hosts; the leaves of blackberries in such unshaded locations are leathery and the canopies are less vigorous.

Recent studies, however, demonstrate that *Anagrus* is also capable of overwintering within eggs of the prune leafhopper, *Edwardsiana prunicola* (Edwards), in commercially grown French prune trees. Vineyards distant from riparian habitats yet next to French prune orchards often have high, early-season populations of *Anagrus*.

We conducted refuge studies to: (1) demonstrate that spring emergence of *Anagrus* from prune trees coincides with first-brood grape leafhopper eggs in a nearby vineyard; (2) determine whether these trees can serve as a year-round refuge for *Anagrus*; and (3) examine management strategies that can increase the production of *Anagrus* in prune refuges.

Prune tree refuge

An experimental refuge of French prune trees was planted in 1983 at the University of California West Side Field Station in Fresno County. Three rows of trees spaced 20 feet apart, each with 27 trees 10 feet apart, were within 10 yards of a 1.5-acre "companion" vineyard. Except for management of insect pests, the trees were maintained by standard cultural practices. Dormant application of insecticide was omitted during 1986 and 1987. The companion vineyard was a mature block with alternating rows of Thompson Seedless and other cultivars.

In the fall of 1984, approximately 300 adult prune leafhoppers were placed in the prune refuge, confined on tree branches in cylindrical sleeve cages of synthetic organdy. The cages were 1 foot in diameter and enclosed a 3-foot length of branch. They were opened the following spring to release adult prune leafhoppers into the refuge. When monitoring of these insects began in July 1986, three years after trees were planted, abundant populations of both prune leafhopper and *Anagrus* were found. The *Anagrus* probably came initially from almond trees a half mile from the prune trees.

In the summer of 1986 and 1987, we counted parasitized and nonparasitized prune leafhopper eggs every other week by randomly selecting three prune leaves from every other tree. Prune leafhopper eggs were sampled from the refuge in the fall of

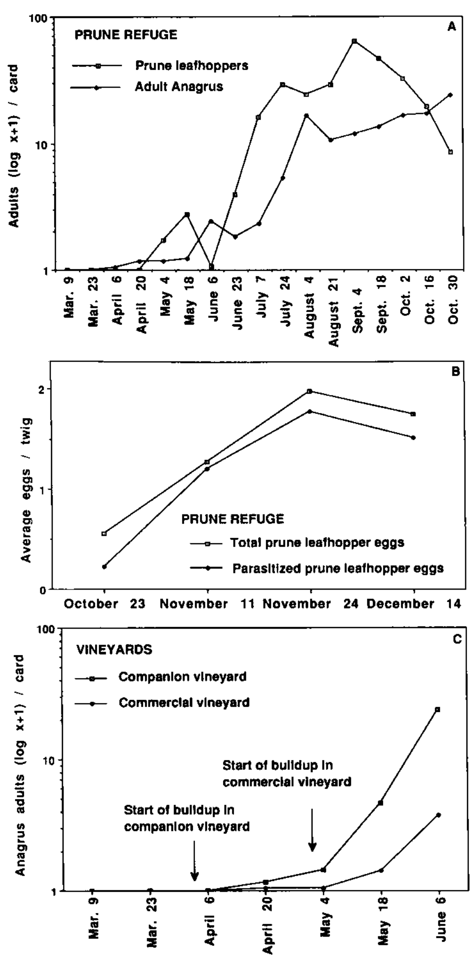

Fig. 1. Occurrence in 1987 of: (A) prune leafhopper (PLH) and *Anagrus* adults in refuge; (B) total and parasitized PLH eggs in refuge; and (C) *Anagrus* adults in companion vineyard and isolated commercial vineyard.

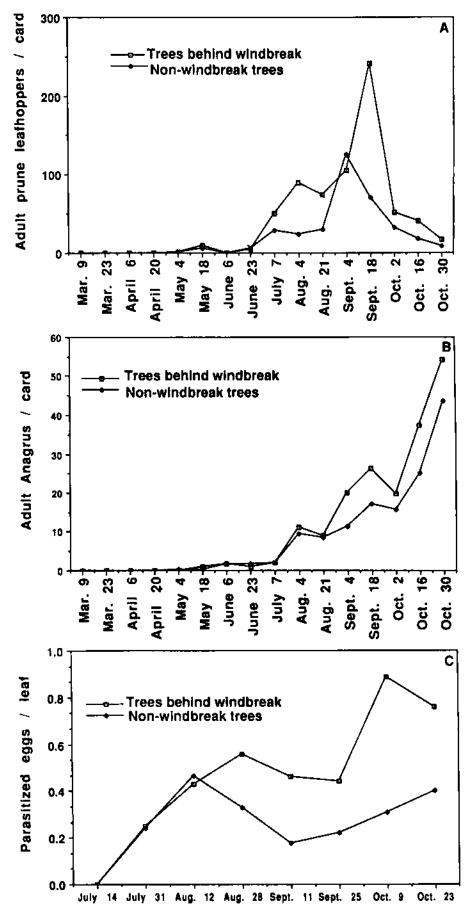

Fig. 2. Prune trees protected by windbreaks produced more *Anagrus* and their alternate hosts, the prune leafhopper, than did nonprotected trees, as shown by 1987 occurrence of: (A) adult prune leafhoppers; (B) adult *Anagrus*; and (C) parasitized prune leafhopper eggs.

1987 by recording eggs from second-year twig cuttings. Three 1-foot cuttings were removed from 10 evenly spaced trees in the southern row, the area of the refuge where prune leafhoppers were most numerous.

In the summer of 1987, we sampled adult populations of prune leafhoppers and *Anagrus* from the refuge every two weeks, using 3- x 5-inch yellow plastic sticky cards. The cards were evenly spaced throughout the refuge, one on each of six trees in the southern and middle rows and two on each of six trees in the northern row. (The additional cards in the northern row were used to increase the accuracy of the windbreak experiment.)

We evaluated the effect of the refuge on *Anagrus* and the grape leafhopper in the spring of 1987 by comparing counts in the companion vineyard with counts in a nearby isolated commercial vineyard of mature Thompson Seedless vines. Vineyard weeds were controlled by herbicides and cultivation. At both sites, we took samples of adults every 2 weeks from March to June using evenly spaced yellow sticky cards attached to the trellis wire, 20 cards in the companion vineyard and 24 in the isolated vineyard. In the companion vineyard, all *Anagrus* counts were restricted to Thompson Seedless vines.

The first adult *Anagrus* in the prune refuge during the 1987 field season was recorded April 6. Densities continued to increase in the refuge all summer and through the last sampling. Adult prune leafhoppers were first recorded in the refuge on May 4 (fig. 1A). The density of prune leafhopper eggs and parasitized eggs in twigs increased through late November (fig. 1B), long after grape leafhopper activity drops in San Joaquin Valley vineyards. The decline in egg density indicates the absence of reproductive prune leafhoppers after that time.

Adult *Anagrus* were recorded in the companion vineyard one sampling period after they were recorded in the prune refuge (fig. 1A and C). Parasites were probably present in this vineyard shortly after overwintering adult grape leafhoppers first began to lay eggs. In contrast, the buildup of *Anagrus* in the commercial vineyard a half mile from the prune refuge was delayed for about another month (fig. 1C), which may be enough to drastically reduce the wasp's impact on the first grape leafhopper brood. The earlier establishment of *Anagrus* in the companion vineyard appears to have resulted from the vineyard's close proximity to the overwintering population of parasites in the prune refuge, although other unmeasured factors may have been involved. *Anagrus* buildup in the commercial vineyard might have been delayed longer if it had not been near an almond orchard (a half mile upwind), a potential source of overwintering prune leafhoppers and *Anagrus*.

The use of windbreaks

Observations during 1985 and 1986 suggested that the strong winds in parts of the San Joaquin Valley may slow the rate of establishment of prune leafhoppers and *Anagrus* in prune refuges lacking well-developed canopies. The West Side Field Station is subject to predominantly northwesterly winds. The density of leafhopper eggs in the refuge in both years was generally highest in the southern, leeward row of trees, intermediate in the middle row, and lowest in the northern, windward row of trees. Significant differences in egg densities were detected between rows of trees when averaged over the entire sampling period (table 1).

To evaluate the impact of wind on establishment and buildup of the prune leafhopper and its parasite, we placed windbreaks (15- x 8-foot aluminum-framed mosquito netting) in front of three trees in the northern, windward row beginning in February 1987. Leafhoppers and parasites in trees behind windbreaks, and in paired control trees, were monitored as previously described, from March to October 1987.

Beginning in August, numbers of adult *Anagrus* from windbreak-protected trees were consistently higher than from control trees (fig. 2B). On several occasions, more than three times as many adult prune leafhoppers were found in trees behind windbreaks as in control trees. The effect of the windbreaks was most pronounced in the production of immature parasites (fig 2C). When results were averaged over the season, 2.2 times more parasitized eggs per leaf were found in trees behind windbreaks than in control trees (table 2).

TABLE 1. Parasitized and nonparasitized prune leafhopper (PLH) eggs, averaged across sampling dates, West Side Field Station, 1986 and 1987

	Average/leaf in row*		
PLH eggs	North	Middle	South
1986:			
Nonparasitized	0.15 a	0.47 b	0.96 c
Parasitized	0.07 a	0.34 b	0.74 c
1987:			
Nonparasitized	0.80 a	1.17 b	1.44 b
Parasitized	0.37 a	0.76 b	0.98 c

*Within each row for each season, averages followed by different letters are significantly different at $P = 0.05$ using Duncan's new multiple range test.

TABLE 2. Production of prune leafhopper and *A. epos*, averaged over 1987 field season, in windbreak and non-windbreak trees, WSFS

	Avg./sticky card or leaf	
Host, parasite	Behind windbreak	Non-windbreak
Prune leafhopper:		
Adults (n=12)	28.4	22.5
Eggs (n=8)*	1.15	0.61
***Anagrus*:**		
Adults (n=12)*	7.63	6.30
Immatures (n=8)*°	0.60	0.27

* Significant difference between windbreak and control populations ($P = 0.01$), using paired t-test.
° Immatures = parasitized prune leafhopper eggs.

Conclusion

The summer-long buildup of *Anagrus* in the prune refuge and its nearly simultaneous occurrence in the adjoining companion vineyard suggests that prune trees planted upwind from vineyards might be a suitable refuge for this parasite. The presence of parasites near vineyards throughout the season, promoted by the use of prune refuges, would also aid in the re-establishment of *Anagrus* if parasite populations were reduced by pesticide applications.

The windbreak study shows how a relatively simple management practice can increase parasite production in a refuge. The windbreaks that we used protected only 3 of 27 trees in the windward row, and each windbreak covered only a portion of each tree. Nevertheless, parasite production more than doubled in trees immediately behind windbreaks. These results suggest that such barriers may be useful in areas of the San Joaquin Valley with heavy winds, primarily the west side of the valley. They could be especially helpful during the initial phase of a refuge's development, when young trees provide only minimal protection from strong winds.

Although our research has not yet produced definitive recommendations on how to design and manage a prune refuge, they suggest that: (1) trees should always be planted upwind from the vineyard, but otherwise can be managed as a typical commercial prune orchard; (2) as many trees should be planted as is economically feasible, since the more trees there are, the more productive the refuge is likely to be; 3) winter dormant oil sprays can be used as required for managing other pests, since they will not affect the overwintering leafhopper eggs or parasites in these eggs. Our research on prune refuges is now focusing on other management practices, such as the use or manipulation of cover crops, pruning, and irrigation.

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