

Foreign exploration for Asian citrus psyllid in Pakistan

The hunt for natural enemies and observations on 'Kinnow' mandarin

Mark S. Hoddle

Asian citrus psyllid (ACP), *Diaphorina citri*, is considered to be one of the world's most serious threats to economic citrus production because it vectors the bacteria, *Candidatus Liberibacter asiaticus*, that causes Huanglongbing (HLB) (also known as citrus greening), a disease that is lethal to most varieties of citrus.

In countries where this psyllid-bacteria combination have successfully invaded, citrus production has dropped markedly because trees go into decline -- losing vigor, leaves drop from trees and the canopy becomes thin, developing fruit tends to become small, misshapen, and juice quality may diminish. The most dramatic impacts in the last decade have been observed in Brazil and Florida, the world's two largest producers of orange juice. In Florida alone, about 10% of citrus acreage (~60,000 acres) has become unproductive because of HLB.

In September 2008, ACP was found in southern California, and it is thought that this insect entered California from Mexico where both the insect and HLB are present. Currently, HLB is not known to be found in California. However, it is thought the bacteria are likely present in citrus or curry plants that are growing in home gardens in California. The reason this possibility exists is because people may have smuggled plants from Asia into California to plant. Interceptions of smuggled plant material last year at Fresno international airport in California detected the presence of HLB in psyllids on Indian curry leaves. These intercepted psyllids and plant material were destroyed. However, it is possible that other illegal introductions may have escaped detection by border inspection and quarantine officials and this material has successfully entered California.

In an attempt to biologically manage ACP in California, entomologists at the University of California Riverside



Healthy Asian citrus psyllid nymph.

Photo courtesy of Michael Rogers, University of Florida.



Adult *Tamarixia radiata* parasitoid.

Photo courtesy of Marjorie Hoy, University of Florida.

have been working at the University of Agriculture in Faisalabad in Pakistan (formerly known as the Punjab Agricultural College and Research Institute in Lyallpur) to better understand the impacts natural enemies have on controlling ACP in the Punjab region of Pakistan.

The reason this area was selected for investigation is because the Punjab region of Pakistan and India may be the area of origin where ACP and HLB evolved. The reason for this assumption is that the first study on ACP was published by two "Imperial Entomologists", Mohammad Husain and Dina Nath, who studied ACP attacking citrus primarily in the Punjab region of Pakistan. Their research entitled "The Citrus Psylla (*Diaphorina citri* Kuw.) Psyllidae: Homop-

tera" was published in 1927. Since this study, ACP has spread to many different parts of the world where citrus is grown.

From the point of view of a biocontrol specialist, one of the most intriguing statements made in Husain and Nath's study is on page 24 of their 27-page publication. Here they state that nine species of parasitoid wasps attack ACP in the Punjab, and several of these parasitoid species have their own parasitoids, or hyperparasitoids, attacking them. Hyperparasitoids are parasitoids attacking the parasitoids that are killing ACP. Consequently, hyperparasitoids may limit the impact some ACP parasitoids have on the pest because they are killing these ACP natural enemies.

This high diversity of parasitoid species associated with ACP as reported by Husain and Nath also suggests that the Punjab may be the home region for ACP. Biological control theory states that natural enemy diversity should be highest at the evolutionary center of origin of a pest, because at this location, the greatest amount of time has been available for the evolution of a diverse guild of natural enemies to exploit ACP as food.

What is very curious about Husain and Nath's work is that today we know of only two species of parasitoids that attack ACP, not nine species. One of these parasitoids, *Tamarixia radiata*, was reared and described from ACP living on lemon leaves collected in the Punjab of Pakistan in 1921. The second parasitoid, *Diaphorencyrtus aligharensis*, was described in 1975 after it was reared from ACP collected from Alighar in the Punjab of India.

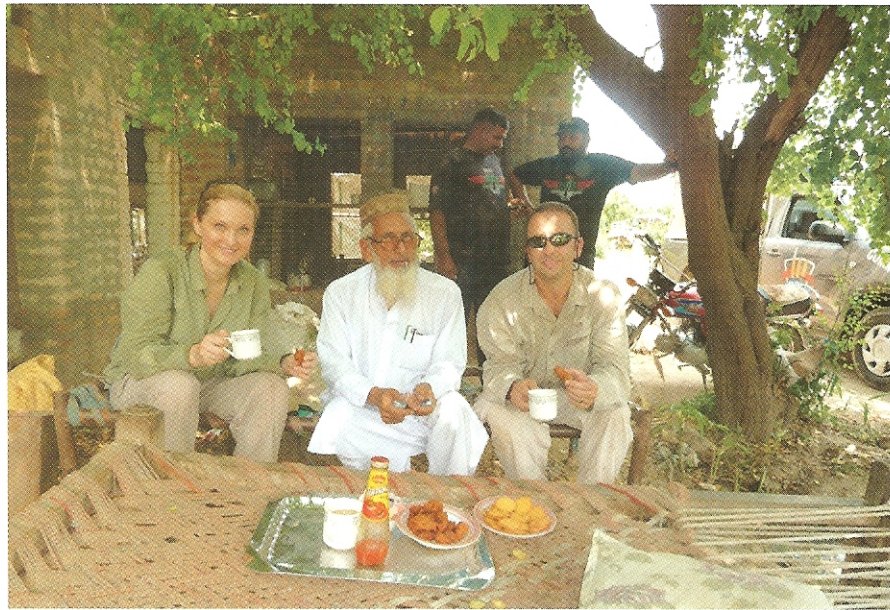
This lack of information on parasitoids associated with ACP in the Punjab of Pakistan raises several important and intriguing questions that need to be resolved: What are the other eight species of parasitoids attacking ACP in the Punjab of Pakistan? Is *D. aligharensis*

from India one of these eight species or is it an additional species that was not reared by Husain and Nath in Pakistan? What is the collective impact of this parasitoid guild on ACP in Pakistan? Is it great enough to reduce the pest status of this insect in citrus? Could the performance of some of these ACP parasitoids be greatly improved if they were imported into California without their hyperparasitoids?

To get a better handle on the ACP/natural enemy situation in Pakistan, Mark and Christina Hoddle visited the University of Agriculture in Faisalabad in Pakistan in September 2010. This trip was supported by funds provided to the California Department of Food and Agriculture (CDFA) by the Citrus Health Response Program (CHRP).

The major citrus variety grown in the Punjab region of Pakistan and India is 'Kinnow', a type of mandarin. 'Kinnow' was developed in 1935 by H.B. Frost, a citrus breeder at the University of California, Riverside. 'Kinnow' is a hybrid that was produced by crossing the 'King' and 'Willow leaf' citrus varieties. 'Kinnow' was exported to the Punjab Agricultural College and Research Institute in Lyallpur in Pakistan in 1943-1944. 'Kinnow' has performed exceptionally well in the Punjab, it appears to be extremely well adapted to the climate of this region, and perhaps more importantly, this cultivar appears to be tolerant to agents that collectively cause "citrus decline" in the Punjab. Citrus decline is a term that describes a combination of maladies (e.g., HLB, tristeza virus, citrus canker, and Phytophthora) that collectively reduce the productivity and vigor of trees without one culprit being pinpointed as the major cause.

In the Punjab of Pakistan, citrus orchards cover 195,000 hectares, and in the 2008-2009 growing season 2,132,000 tons of citrus were harvested. The Punjab produces 95% of Pakistan's citrus, and 'Kinnow' makes up more than 75% of production in this region. 'Kinnow' accounts for 90% of Pakistan's citrus exports which primarily go to the United Arab Emirates. Further, Pakistan is amongst the world's top ten 'Kinnow' producing and exporting nations. There are 28 'Kinnow' processing plants in Pakistan located in Sargodha and Karachi which have the capacity to move 5-10 metric tons of fruit per hour. Discussions with faculty at the



Punjabis pride themselves on offering exceptional hospitality. Christina and Mark Hoddle share tea and local foods with a 'Kinnow' orchard owner after sampling for Asian citrus psyllid.



Many farmers in the Punjab are not well trained in the appropriate and proper use of pesticides, and accidental poisonings are not uncommon. Most farmers are unable to afford safety equipment and clothing to protect themselves from pesticides. Photo by Mark Hoddle.

University of Agriculture in Faisalabad indicated that 'Kinnow' acreage in the Punjab is expanding; there are plans for developing more processing plants; seedless 'Kinnow' varieties are under consideration; and efforts are being made to develop disease-free planting materials for growers.

What was lacking from these discussions with faculty was immediate concern over managing ACP and HLB, and that research efforts were directed at much more pressing issues, in par-

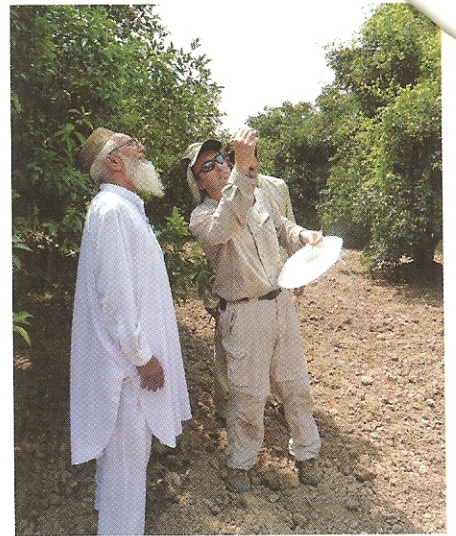
ticular production of arable crops and protection of stored grains from arthropod pests.

This lack of research activity suggests that diseases afflicting citrus, in particular HLB mortality of 'Kinnow', a major source of vitamin C for many struggling people, is not an overly important issue in Pakistan. This fact may be supported indirectly by several lines of evidence.

The first and most obvious is the result of a natural field experiment that



'Kinnow' is the primary type of citrus grown in the Punjab of Pakistan. It is well adapted to local growing conditions and has flourished in the Punjab since its initial introduction into Faisalabad 66 years ago. Weed control is typically via discing, and orchards are flood irrigated. The Punjab of Pakistan is reportedly one of the largest artificially irrigated agricultural areas in the world. Photo by Christina Hoddle.



A 'Kinnow' orchard owner inspects a vial containing Asian citrus psyllid specimens and parasitoids. This grower is a trained engineer who also farms chickens.

has been ongoing in Pakistan since 1944. During this 66-year period, 'Kinnow' has performed exceedingly well under ACP and HLB pressure in the Punjab (even on the Indian side of the Punjab), and it is a highly sought-after fruit when it is in season and not a small, sour, nasty orange that no one wants to buy or eat if trees were suffering from HLB!



Psyllid nymph with exit hole chewed by a parasitoid when it emerged. Photo courtesy of Marjorie Hoy, University of Florida.

Kinnow is the preferred variety, and other types of citrus like oranges and lemons are not grown, either because they are not adapted to the climate of the Punjab or, perhaps more likely, they can't tolerate the ACP/HLB combination and they quickly become unpro-

ductive. Further, 'Kinnow' acreage is expanding—we visited multiple new orchards—and plans for additional processing facilities are being considered. Finally, University of California Riverside field entomologists, untrained in plant pathology, were expecting to see acres of skeletal trees with thin crowns and small misshapen fruit in the Punjab because of severe ACP/HLB infestations. This was not the case. In fact, the opposite landscape dominated: very large trees with dark green foliage, thick crowns, lots of developing fruit, and we were even able to collect ACP off these trees!

Field trips in the Punjab

of Pakistan indicated that citrus, in particular 'Kinnow', has not gone extinct in the presumed area of origin for ACP and HLB. This has led to some tentative conclusions. First, perhaps the mandarin parents of 'Kinnow' or perhaps 'Kinnow' itself, under the environmental conditions in the Punjab, is tolerant of ACP feeding and HLB infection. If this is true, then plant breeding may offer some effective and long-term protection against HLB.

It should be noted that other factors could influence ACP/HLB interactions in 'Kinnow' in the Punjab of Pakistan. These factors may include the rootstock selections that affect the 'Kinnow' scion's ability to tolerate ACP/HLB. Additionally, perhaps the extreme climatic conditions in the Punjab where intense hot periods and prolonged cold spells are common may greatly moderate or

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diminish the effects of ACP and HLB on 'Kinnow'. These possibilities need serious investigation in the Punjab to determine their contributions to 'Kinnow' production. Second, if there is some level of host plant, rootstock, or environmental resistance to ACP/HLB that can be exploited or manipulated, then ACP natural enemies may be another regulating layer that could further limit the damage caused to citrus by maintaining ACP levels at densities that citrus can tolerate.

Third, the reason ACP/HLB has recently jumped to such high prominence in the worlds of citrus production and research is because this problem is now invading major production areas that grow citrus cultivars that are highly susceptible to HLB and possibly to ACP as well. In the absence of the parasitoid guild from Pakistan, ACP populations reach densities that greatly aggravate the disease situation. Finally, as HLB takes its toll on the citrus varieties and cultivars we are most familiar with (e.g., types of Valencias), they may be gradually replaced with other varieties, perhaps yet to be developed types, per-



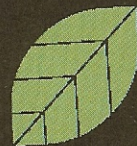
Farmers and local kids were extremely interested in collecting insects from 'Kinnow'. It was not unusual for crowds of enthusiastic helpers to appear out of nowhere to help find Asian citrus psyllids, a good team effort!

haps originating from Frost's 'Kinnow', and citrus production will emerge with a host of new and consumer-acceptable cultivars for juicing and eating.

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