PROSPECTS OF BIOLOGICAL CONTROL OF CITRUS INSECT PESTS IN PAKISTAN

Riaz Mahmood, Abdul Rehman and Mushtaq Ahmad*

ABSTRACT

Citrus is attacked by a number of insect pests in Pakistan. The list includes citrus psylla Diaphorina citri; leaf miner Phyllocnistis citrella; white flies Aleurocanthus woglumi Aleurocanthus husaini, Aleurotuberculatus citrifolii, A. jasmine, Amurrayae, Aleurolobus niloticus, Aleurotrachelus sp, Dialeurodes citri and D. elongata; scale insects Aonidiella aurantii, A. citrina, and A. orientalis; mealy bugs Nipaecoccus vastator, Ferrisia virgata, Planococcus citri, Pseudococcus filamenetosus, Spilococcus sp, and Rastrococcus spinosus; coccids Coccus hesperidum and Pulvinaria psidii; margarodids Drosicha stebbingi and Iceryia egyptiaca; fruit flies Bactrocera zonata and B. dorsalis and butter fly Papilio melinus. At present farmers rely on pesticide sprayings in orchards to control pests and diseases. These practices have not only worsened the pest status over time but also have created the risks of pesticide residues in produce. If present plant protection practices continue, Pakistani growers may have a setback in exporting their produce. Consumers, especially in the developed world, being health conscious force their governments to protect them from ill effects of pesticides. The need of the time therefore is to shift from the present pesticide based plant protection to integrated pest management based on bio-ecological principles to reduce the use of pesticides in crops particularly in horticulture. In the paper, status of key pests of citrus in Pakistan is reviewed and possibilities of their management by non-chemical measures have been discussed.

KEYWORDS: Citrus sinensis; insect pests; fruit flies; Psylla, Aleyrodids; leaf miner; mealy bugs; scale insects; biological control; integrated pest management; Pakistan.

INTRODUCTION

Citrus is one of the most important fruits and is grown in more than 52 countries around the world. Brazil and China are the largest producers of citrus worldwide producing about 45 million tons (MT) of citrus fruit together,
followed by USA, India, Mexico and Spain with a production of 10.7, 8.6, 7.2 and 5.5 MT, respectively (1). Pakistan also occupies a prominent position in citrus production and is among the top 15 citrus-producing countries in the world. In Pakistan, citrus is cultivated over an area of 194,000 hectares with an annual production of 2.2 MT (2). Among citrus, ‘Kinnow’ has gained special significance and has monopolized the citrus industry in Pakistan. It is commercially cultivated because of its better adaptation to soil and environmental conditions and it has not only excelled in area, production and quality relative to other mandarin cultivars but has also surpassed the sweet orange cultivars in the country. ‘Kinnow’ occupies about 70% of Pakistani citrus production (2). The average yield of citrus in Pakistan is just 9 tons per hectare, while in many other citrus-growing countries it is much higher (30). Besides meeting local requirements, Pakistan can substantially increase citrus exports provided export constraints are adequately addressed. However, there are compliance issues emanating from globalization of trade especially those pertaining to product quality and hygiene. The growers want to export their produce as much as possible. This ensures them attractive prices of their produce. This could be possible only when they have a mindset for adopting good agricultural practices (GAP). The increasingly strict pesticide residue regulations and insect contamination (mainly fruit flies and scale insects) are the major trade barriers for export of citrus and mango to USA, Japan, and European markets.

A number of insect pests attack citrus in Pakistan. To control these pests, farmers mainly rely on pesticides. Indiscriminate use of synthetic chemicals results in residual toxicity endangering human and animal health apart from causing environmental degradation. It is estimated that as much as 17% of pesticides are used in fruits and vegetables in Pakistan (2). In studies carried out during 1980’s and 1990’s by different national institutes in Pakistan, it was found that 422 out of 1059 samples of fruits and vegetables were found contaminated with pesticide residues and 71 samples of these had residue levels exceeding the limits set by the FAO/WHO Codex Alimentarius Commission (45). The European markets are conscious about food safety and the importers (superstores) have therefore imposed restrictions of Maximum Residue Limits (MRLs). The products are rejected if these do not conform to the prescribed MRLs. To meet these challenges concerning health issues at national and international levels, the possibilities of biological management of controlling key insect pests in citrus have been discussed in this paper. This paper is based on the findings and experiences gained from several projects on pests and natural enemies conducted by CABI CWA over three decades

1. **Insect pests**
The key pests on citrus in Pakistan include fruit flies (*Bactrocera zonata* (Saunders) and *B. dorsalis* (Hendel); citrus psylla (*Diaphorina citri* (Kuway); leaf miner (*Phyllocnistis citrella* Staint); white fly (*Aleurocanthus woglumi* Ashby); mealy bug (*Drosicha stebbingi*) (Green); scale insects *Aonidiella aurantii* (Mask.) and *A. citrina* (Coq.) whereas minor pests include butter fly (*Papilio demoleus* L.); scale insect (*Aonidiella orientalis* Newst.); mealy bugs (*Nipaecoccus vastator* (Mask.)); *Rastrococcus spinosus* (Robinson), *Planococcus citri* (Risso) and *Ferrisiavirgata* (Ckll.); margarodid *Ceryia egyptiaca* (Dougl.); *coccids Coccus hesperidum* and *Pulvinariapsidii* Mask and white flies *Aleurocanthus husaini* Corbett, *Aleurotuberculatus citrifolii* Corbett, *A. jasmine* Takahashi, *A. murrayae* Singh, *Aleurolobus niloticus* Priesner & Hosny, *Aleurotrachelus* sp, *Dialeurodes citri* (Ashmead) and *D. elongate* Doziere (32,35).

### 1.1 Fruit flies (Diptera: Tephritidae)

Fruit flies are pests of prime importance in citrus. They do direct damage to the fruit and losses done are irreversible. Where citrus is grown adjacent to other fruits such as mango and guava, sometime 80% of the crop is lost due to fruit flies (42,43). They have gained more importance recently, as the fruit importing countries need certification of presence/absence of fruit fly species of quarantine importance and also the documentation of management practices in line with international standards.

**Bactrocera zonata** (Saunders) and **B. dorsalis** (Hendel)

Fruit flies *B. zonata* and *B. dorsalis* have been recorded from citrus in Pakistan. Of these *B. zonata* is dominant on the plains and *B. dorsalis* in the foothills (42, 43).

**Hosts:** Both fruit flies are highly polyphagous. From Pakistan they have reported about 18 host fruits. Main hosts include mango, guava, citrus, plum, peach, pomegranate, pear, guava, persimmon and loquat (4).

**Seasonal abundance:** In Pakistan Syed et al. (42, 43) reported seasonal abundance of these flies in different areas of Pakistan. At Sargodha flies were observed breeding from March and their populations were at peak in August-September. In winter, from December to February they underwent hibernation (4).

J. Agric. Res., 2014, 52(2)
Biological control: There is a long history of attempts to use parasitoids for the biological control of fruit flies. Clausen (13) reviewed the classical biological control methods in the world for controlling fruit flies. Since 1912 about 50 species of parasitoids were introduced in Hawaii against fruit flies from Brazil, Philippines, Indo Malaya, India, Pakistan, South China, Australia, Africa and South America. Six of these have proved to contribute substantially to population regulation of fruit flies throughout the state (31,44). One of the main control methods currently under investigations in Hawaii and elsewhere is the augmentation of existing opine parasitoids in conjunction with other control measures (31). In Pakistan, CIBC (5, 7) reported eleven species of parasitoids associated with fruit flies of economic importance. In 1970s parasitism in fruit flies in guava and mango were reported as high as 44%, however, in recent surveys done by CABI (5) the parasitoids population levels were extremely low (1-4%) (3).

Integrated pest management: Biological control alone is not good enough in controlling fruit flies to tolerable limits. This has to be supplemented with other control measures impact. In view of extremely low tolerance levels of fruit losses and to ensure fruit production in pesticide free environment, strategies for controlling fruit flies are changing worldwide from relying on one control measure to integrated pest management (IPM).

CABI did a series of experiments for controlling fruit flies in mango at Multan and in guava at Sharqpur in 2003-04. The results of these are described here that are also applicable in citrus and need further testing. The impact of IPM measures, including crop sanitation, male annihilation technique (MAT) using dorsa lure and spot sprays of bait protein hydrolysate (BAT) was tested in 2002 and 2003 on mangoes at Multan. In 2003 these measures were applied together from May on an isolated patch of mango orchards (200 hectares) at Basti Lar, Chak 5 Faiz, Bahawalpur Road, Multan and a patch of 40 hectares on a wide spread mango belt at Kabirwala. These measures when applied together were effective in controlling fruit flies. At Basti Lar only 0.1-0.3% damage by fruit flies was recorded in June - August whereas at Kabirwala where there were fair chances of incursions of fruit flies from adjoining areas the infestations were in range of 1-5%. In the control (Boson Road) where no fruit fly management measures were applied the damages were in the range of 4-20% (Fig 1).
Guava is a long duration crop and also the main host on which fruit flies breed and disperse to other fruits. Farmers spray pesticides 6-10 times on this crop for controlling fruit flies. This has made the fruit flies issue worse over the years because of weakened natural control. The option for controlling fruit flies through augmentation and conservation of naturally existing parasitoids was tested in 2003.

At Taridewali (Sharaqpur) about 71,300 laboratory reared Trybliographa daci Weld. and 27,700 Diachasmimorpha longicaudata (Ashmead) were released in early March and in third week of July. This resulted in increase of parasitism in fruit flies up to 53% compared with 9% in control, where parasitoids were not released (Fig. 2). The fruit fly damage to guava also decreased to one half in orchards where parasitoids were released as compared with orchards where parasitoids were not released.

1.2 Citrus psylla

*Diaphorina citri* (Kuway) (Hemiptera: Psyllidae)

Citrus psylla has become a very serious pest in all citrus growing areas of Pakistan. It attacks all parts of the plant above ground. It is a known vector of the disease ‘citrus greening’. The insect excretes honey which accumulates on the plant leaves and twigs. Sooty molds develop on the honey and the plant becomes black interfering with photosynthesis of the plant thus indirectly affecting plant yield. Insect feeds on plant sap and under high populations plant start dying (17).
Distribution: It is widely distributed in south east Asia and South West Asia and is also known from Mauritius and Reunion in Africa, Brazil in South America (8) and has expanded to Caribbean (17).

Hosts: D. citri is mainly a pest of Citrus spp. and is also known to attack Murraya koenigii and M. paniculata (17) and Clausena lanisium (19).

Seasonal Abundance: Hussain and Nath (25) studied its biology in Punjab. The pest completed its life cycle in 15-74 days and had 9 generations a year in the Punjab. All stages were found throughout the year and no hibernation occurred in any particular stage. Adults live long, sometimes up to 189 days. In current observations at Faisalabad citrus psyllid was found most abundant in February, March and September.

Biological control: In Pakistan CIBC (6) conducted surveys for natural enemies of D. citri and recorded six species of parasitoids including Tetrastichus sp. Tetrastichodes sp., Psyllaephyagus spp. Aphycoides ssp. and Achrysochara ssp. In addition to the above mentioned parasitoids CABI CWA, recorded Tamarixia radiata (Waterson) in recent survey from Punjab. Moreover seven species of predators including Coccinella septempunctata

J. Agric. Res., 2014, 52(2)
L., C. repanda Thunb., Menochilus sexmaculatus (F.) Chilocorus nigritus F. Brumus suturalis (F.), a syrphid and Chrysopa sp. were also recorded.

Biological control of D. citri was successfully attempted in Reunion by imported parasitoid Tamarixia radiata (Waterson) from India in 1978 when nearly 4600 adult parasitoids were released. This controlled the pest. This parasitoid was also introduced in Guadeloupe in 1999. About 1000 T. radiata were released all over Guadeloupe islands. Just a little more than one year after release the parasitoid established and psyllid populations were decreased considerably. Quite favorable biological characteristics play a great part in explaining the excellent effectiveness of T. radiata in biological control programs against D. citri. T. radiata was sent from Pakistan to Florida in 2008 and Texas in 2009. It has established there and is giving substantial control of the pest (11).

D. citri in Pakistan is a self created problem resulting from indiscriminate use of pesticides in orchards. There exists a good natural enemy complex in Pakistan therefore by adopting farmer friendly techniques of conservation of natural enemies and integration with other measures can give sustainable solution of the problem.

1.3 Aleyrodids (Hemiptera: Aleyrodidae)

White flies damage citrus plant by sucking nutrients from foliage. They excrete honeydew on which sooty molds develop causing them to appear black. Sooty molds can severely impair leaf respiration and photosynthesis thus impacting indirectly on plant yield.
**Aleurocanthus woglumi Ashby**

**Distribution:** It is widely distributed in south east and west Asia, Kenny, Seychelles, South Africa and Tanzania in Africa, Central America and South America and from Mexico, Texas and Florida in North America (9).

**Hosts:** Citrus black fly is known to infest over 300 host plants, but citrus is the preferred host for large-scale population development.

**Seasonal abundance:** Hussain and Khan (24) recorded its two generations for a year in the Punjab. The adults of first generation emerged during March- April and of second generation during July - October.

**Biological control:** Clausen (13) reviewed the attempts of biological control of this pest in different parts of the world. Three parasitoids *Eretmocerus serius* Silv., *Prosptaletta opulent* Silvestri. and *P. clypealis* Silv. have been used to control this pest in different parts of the world. *E. serius* has been very successful in Netherlands Indies, Barbados, Bahamas, Cuba, Mexico South, east Africa, Jamaica, Seychelles and some parts of Mexico. In drier parts of Mexico *E. serius* has not been effective and another parasitoid *P. opulent* was most effective in controlling the pest.

In Pakistan CABI conducted surveys for natural enemies of *A. woglumi* in 1960s and recorded six species of parasitoids including *Trioxy ssp.* *Amitus aleurolobi* Mani, *Prosptaletta ishii* Silv., *P. smithi* Silv., *P. divergence* Silv. and *Prosptalatta* sp. (15). The parasitoids like *Eretmoserus serius* *Prosptalatta opulenta* and *P. clypealis* should be introduced for controlling this pest (32).

**Other aleyrodids**

The white flies *Aleurocanthus husaini* Corbett, *Aleurotuberculatus citrifolii* Corbett, *A. jasmine* Takahashi, *A. murrayae* Singh, *Aleurolobus niloticus* Priesner & Hosny, *leurotrachelus* sp. *Dialeurodes citri* (Ashmead) and *D. elongate* Doziere. have been recorded on *Citrus* spp. and are under natural control (32).

**1.4 Leaf miner**

**Phyllocnistis citrella** Staint (Lepidoptera: Gracillariidae)

The citrus leaf miner damages by mining the inner under side of young citrus leaves. Larval feeding results in leaf deformation and leaf drop. This ultimately results in reduction in plant photosynthesis. It may also provide entry point for a number of plant pathogens. Mining of spring flush is more...
damaging than fall flush since the spring flush is primarily responsible for supporting fruit development. Trees of three years of age or less are especially susceptible to leaf miner damage.

**Distribution:** It is widely distributed in Asia and is also found in Australia, Florida, in USA, Honduras in Central America, Cyprus, Italy, Spain, and Turkey in Europe (10).

**Hosts:** It is mainly a pest of citrus spp, however, other known hosts are *Atlantia* (40), *Loranthus* spp. (38), *Aeglemarmelos*, *Alseodaphneseme carpifolia*, *Jasminum sambac* and *Murraya koenigii* (4).

**Seasonal abundance:** It is a major pest of citrus throughout Pakistan. Pena et al. (34) and Pandey and Pandey (33) reported from India that this species had ten generations a year. In Pakistan young nursery plants suffer the most. The pest is most active in spring and the populations dwindle in summer. Life cycle seems to be completed within two weeks, although it can sometimes take two months depending on the temperature.

**Biological control:** In survey conducted in 1960s in Pakistan CABI recorded *Ceratoneuromyia* sp. and *Cirrospilu* sp. parasitizing larvae (32). About 39 species of parasitoids have been reported from citrus leaf miner from Southeast Asia, Japan, Australia, and USA (18, 14, 27, 41). Several eulophid parasitoid species, already present in Florida shifted to this new invading pest on citrus (18, 27, 34). *Ageniaspis citricola* Loginovskaya and *Cirrospilus ingenuus* Gahan were introduced from Australia into Florida in 1994 (21). Both these parasitoids have established here and are giving substantial control of the pest (20-23). The introduction of the above mentioned parasitoids may be considered for trial against this pest in Pakistan.

1.5 Mealy bugs and scale insects

The mealy bugs and scale insects suck the plant sap and highly infested plants become weak, shoots dry and thus indirectly affects the plant yield. The mealy bugs secrete honey dew which deposits on leaves and twigs. Sooty mold develops on the honey and the plant become black thus interfering with photosynthesis. The infested leaves and twigs overtime dry because of direct feeding of the insect.

**Mealy bug (Drosicha stebbinji Green)**

**Distribution:** This is known from India and Pakistan (36, 37)
Hosts: It is highly polyphagous species and more than 100 plants have been reported as its hosts in Pakistan. It is one of the major pests of citrus.

Seasonal abundance: Rasheed et al. (37) reported its phenology at Lahore. Its nymphs started coming out of soil in January and settled on plant twigs and leaves. It was most abundant in February. Population started decreasing in March and April. In May mature females came down from trees and entered soil. In June only ovipositing females and egg masses were found in soil.

Integrated pest management: In Pakistan farmers mostly dust insecticide powder on soil around tree trunks or put sticky bands on tree trunks to check the climbing of nymphs on tree. In India the researchers such as Lakra et al. (26) and Sandhu et al. (39) and in Pakistan Rahman & Latif (36) studied the effectiveness of various types of bands put around tree trunks for checking the climbing of the bug nymphs on trees. Mahmood & Mohyuddin (28) studied the biology and ecology of the bug and its natural enemies and devised methods for controlling the pest in different situations. They also developed methods for conservation of a host specific predator Sumnius renardi Weise. By combination of cultural control that included hoeing of soil under trees, three times from June to December and conservation of predator Sumnius renardi by providing protection measures to congregating adults from June to December obtained control of the mealy bug within tolerable limits.

Other mealy bugs

The Pseudococcids Nipaecoccus vastator (Mask.), Ferrisia virgata (Ckll.) Planococcus citri, Pseudococcus filamenetosus Ckll., Spilococcus sp. (6, 28), Rastrococcus spinosus (Robinson) (16); Margarodids Iceryia aegyptiaca (Dougl.) (28).

Scale insects

Aonidiella aurantii (Mask.) & A. citrina (Coq.)

Aonidiella spp. are common pests of Citrus spp. in the plains. They suck the plant sap and highly infested plants become weak and the shoots dry and indirectly affect the plant yield. Aonidiella aurantii was most dominant however A. citrina and A. orientalis were also found in invariable numbers in infestations together with A. aurantii. The population trends of scale insects were studied at Peshawer in 1976-77. Every month from March, 500 leaves
in sample were collected to count the number of scale insects per leaf and the predator *Pharoscymnus flexibilis* Muls. The scale insects were recorded on citrus throughout the year. Their population started building up from April and the trend in increase of population continued through July and reaching their peak in August (Fig. 3). The numbers of the scale insects started decreasing in September as the predator, as described below, became maximum. The population of the scale insects further decreased in October but increased in November probably because of the released impact of the predator (Fig. 3). In December the population decreased because of slowing down of the scale insects breeding and onwards through January and February next year.

**Biological control:** Biological control of *A aurantii* has been quoted as one of successful example of biological control of insect pests worldwide. In California and other countries a number of predators and parasitoids were obtained from the oriental region including Pakistan, India and China (13). In Pakistan it has good natural enemy complex and was found abundant only in conditions where insecticides were profusely used. In the present studies it was found abundant at Peshawer where the natural enemies were rare probably because of adverse impact of pesticides sprayed in the orchard. The only predator *Pharoscymnus flexibilis* Muls. was recorded in more or less numbers from July and its population became maximum in September after a month when the scale insects were maximum in August (Fig. 3). Two
species of parasitoids Aphytis melinus DeBach and Comperiella bitasciata were recorded almost throughout the year but their numbers were extremely low.

Other scale insects of minor importance known from citrus in Pakistan include the Diaspidids Aonidiella orientalis (Newst.), Chrysomphalus aonidum (Ashm.), Lepidosaphes conchiformis (Gmel.), Pinnaspis strachani (Cooley) and Coccids Coccus hesperidum L.

1.6 Papiliodemoleus L.

It attacks Citrus spp. unlike most swallow tail butterflies it does not have a prominent tail. The butterfly is a pest and invasive species from the Old World which has spread to the Caribbean and Central America. In Pakistan it has become a pest of major importance overtime. The larvae feed on leaves eating from the edge right up to midrib. Seedlings and young plants are completely defoliated. Depending upon season a generation takes about weeks to four months. There are 5-6 overlapping generations a year. It overwinters as pupa (35).

**Distribution:** It is a common butterfly. It is perhaps the most widely distributed swallow tail in the world. The butterfly can be found in Oman, UAE, Saudi Arabia, Kuwait, Bahrain, Qatar, Iran, western and possibly eastern Afghanistan, western Pakistan, Sri Lanka, India (including the Andamans), Nepal, Burma, Thailand, the Philippines, Kampuchea, southern China (including Hainan, Guangdong province), Taiwan, Japan (rare strays), Malaysia, Singapore, Indonesia (Kalimantan, Sumatra, Sula, Talaud, Flores, Alor and Sumba), Papua New Guinea, Australia (including Lord Howe's island), Hawaii and possibly other Pacific Ocean islands. Formerly absent from Borneo it is now one of the commonest papilionids in Sabah and Sarawak in Malaysian Borneo, Kalimantan (Indonesian Borneo) and in Brunei. In recent years the butterfly has spread to Hispaniola Island (Dominican Republic) in the Western Hemisphere, and subsequently to Jamaica, and Puerto Rico. The Dominican population originated from Southeast Asia but how the butterfly reached there is not known.

**Biological control:** Larval parasitoids (Erycia nymphalidophaga Baron off,Cantheconidea furcellata (Wolff), Pupal parasitoid (Brachymeryia sp. Pteromalus puparum Linnaeus from Thailand , and an encyrtid egg parasitoid and a chalcidoid parasitoid have been reported from Jamaica. A number of parasitoids including Apanteles spp. including Apanteles

J. Agric. Res., 2014, 52(2)
Prospects of biological control of citrus insect pests in Pakistan  241

papilionis, Braconhebetor and egg parasitoids (Ooencyrtus malayensis Ferriere, Tetrastichus sp.) from India (13). Predators including predatory pentatomids, reduviid bugs, birds, spiders, sphecid wasps and chameleons have also been reported from Thailand (13). In Pakistan the parasitoids Pteromalus sp. Pteromalus bengalensis and Bugnetia musca P.&D. are known attacking butterfly larvae (6).

CONCLUSION

Insect pests on citrus in Pakistan have rich natural enemy complexes and mostly are under natural control. The white flies are well under natural control and need no measures to be applied against them. Some of the pests such as mealy bug Drosicha stebbinji, fruit flies Bactrocera spp., butterfly, leaf miner, scale insects Aoinidiella spp. and citrus psylla need to be addressed on priority. All these pests too have good natural enemies complexes, however some of the agricultural practices impact on natural enemies that need to be identified. There is need to develop techniques which encourage natural control. Parasitoids associated with fruit flies are their main mortality factors, therefore, biological control through augmentation and conservation of parasitoids integrated with other non-pesticide measures need to be tested with holistic approach in citrus, guava and mango on area wide basis. This conclusion is further supported by the fact that fruit flies are flying insects, and there are frequent chances of their incursions from one orchard to the other orchard. As such there is no hard line for fixing size of the area size for application of this approach, however, a minimum area of 500 ha may be considered practicable. Many of the natural enemies exported to USA from Pakistan and other countries have established there and are giving substantial control of the citrus pests. On analogy of the same, some of the parasitoids have been identified in the paper for introduction in Pakistan to improve the existing natural enemy fauna of the pests. Citrus is a perennial crop therefore all negative approaches of applying insecticides should be avoided.

REFERENCES


J. Agric. Res., 2014, 52(2)

*J. Agric. Res.*, 2014, 52(2)
Prospects of biological control of citrus insect pests in Pakistan


*J. Agric. Res., 2014, 52(2)*


