Status Report

PRESENT SITUATION OF PESTICIDE RESIDUES AND BIOLOGICAL SUPPRESSION OF PESTS AND DISEASES IN CHINESE TEA GARDENS

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ABSTRACT

Several insecticides, germicides and herbicides which, are now prohibited, are still used in Chinese common tea gardens. Applied amounts of the pesticides with high toxicity and long time residues, such as methomyl, can not bypass certain limits in A-grade green food tea gardens. Pesticides are forbidden to be used in AA-grade green food tea gardens and organic tea gardens. Pesticide residues in a large number of merchant teas exceeded the national standard during 1998 - 2001. According to national standard, the number of samples exceeding standard percentage of 4200 output tea samples (including green tea, black tea. scented tea and oolong tea) in 2001 reached 6.55 %. However, the exceeding standard percentage was 0.4 % for 228 output tea samples in 2002. Safety time interval, half-life and MRL values of main pesticides used in Chinese tea gardens have been now introduced. The application of natural enemy insects, spiders and pathogenic microorganisms in biological control has also been summarized. 119 species of main natural enemy insects have been recorded. The joint application of insect semiochemicals and pathogenic microbes, the approach to chemical mechanism of tea plant resistance to pests and disease causing organisms by physiological and biochemical techniques, and tea breeding against pests and diseases by molecular biological techniques will be the key research fields of biocontrol of tea pests and diseases in China in the near future.

Keywords: *China; pesticide residue; biological control; natural enemy pests*

INTRODUCTION

The tea, *Camellia sinensis* (L.) O. Kuntze, is one of the major economic crops of southern China. Studies on tea pests and diseases have been conducted since 1950's. Till date around 800 tea pests and 133 tea diseases have been reported (Zhang and Han, 1999; Chen and Chen, 1989). Tea planting carried out before 1950 was more of sporadic and scattered nature and had only a few pests and diseases, including some Lepidopterous insects (e.g. tea bunch caterpillar *Andraca bipunctata)*, tea tussock moth (*Euproctis pseudoconspersa)*, tea xylorictrid (*Linoclostis gonatias)*, tea eucleid (*Iragoides fasciata)*, tea bagworm (*Cryptothelea minuscule)* and tea geometrid (*Ectropis oblique)*. Control was not necessary. Planting of tea in rows and fertilization were intensified during 1950-1960. Tea plants flourish with closed tree crown. Humidity and temperature are almost constant within the tea clumps that favor the occurrence of pests and diseases. Lot of DDT and benzene hexachloride had been applied during that period. Scale insects infested tea plants seriously in the southeastern Chinese tea growing area towards the end of 1950's; furthermore, leafhoppers and mites outbroke at the end of 1960's. The strategy of "Integrated Pest Control" was suggested in 1970's. However, it focused on "eradication" , i.e. "controlling insects in advance and in insects' infant period, and eradicating them completely" (Chen and Chen, 1999). "Integrated Pest Management" has been carried out since 1980's, which harmonized agricultural, chemical and biological measures to manage pests macroscopically. Sustainable control of tea pests has been advocated since 1990's. About 60 chemical insecticides have been applied

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to control tea pests since 1950's. DDT and Benzene hexachloride, the main two pesticides then used, were forbidden in 1972.

Organophosphorus insecticides have been widely employed in Chinese tea growing region since 1960's, and pyrethroids since 1970's. Carbamate insecticides, such as methomyl, were introduced in late 1980's. Meanwhile, dicofol is forbidden for use. Insect growth regulators, such as benrophenol ureas and buprofezin, are also used. Use of fenvalerate and esfenvalerate (Sumi-alpha) was forbidden in November 1999. The misuse of chemical insecticides has resulted in the serious "3R" questions since 1980's. Studies on natural enemies of tea pests and diseases were started on large scale in China in 1970's. Deployment of natural enemies has been cleared, and some insect pathogenic microbes and parasitic wasps have been bred and released.

MAIN PESTICIDES USED IN COMMON CHINESE TEA GARDENS AT PRESENT

Generally tea gardens are divided into organic tea gardens, AA-grade green food tea gardens, A-grade green food tea gardens and common tea gardens. Use of pesticides is not permitted in former two types of tea gardens. A-grade green food tea gardens produce merchant teas eligible to the green food standard of China and the MRL values of tea importing countries. So certain insecticides are prohibited in this type of tea gardens. The pesticides with high effectiveness, low toxicity and low residues are supposed to be used in common tea gardens. The pesticides allowed are listed below.

Insecticides: phoxim, malathion, fenitrothion, DDVP, phosemet, dimethoate, endosulfan, methomyl, decamethrin, cypermethrin, bifenthrin, cyhalothrin, permithrin, cartaphydrochloride , matrine, rotenone.
Acaricides: propargite, clofentezine.
Germicides: chlorothalonil, thiophanate-methyl, carbendazim.
Herbicides: glyphosate, paraquat, dalapon.

SAFETY INTERVAL, HALF-LIFE AND MRL OF PESTICIDES APPLIED IN TEA GARDENS

Several dozens of pesticides are applied in Chinese common tea gardens. Sun-shine can enhance their decomposition after these are sprayed onto tea plants. For example, several hours' sunshine may induce the most of phoxim to decompose. Rain and dew can wash and dissolve pesticides; however, their decomposing efficiency is less than that of sun light. Usually, tea plants grow in areas with temperature ranging between 15-40C. Therefore, the aerial temperature exerts little effect on decomposition of pesticides. Chen and Chen (2002) have studied the safety interval, half-life and MRL of some of the pesticides as are listed in Table 1.

Table 1. Safety interval, half-life and MRL values of pesticides in Chinese tea gardens

Pesticides	Safety Interval	Half-life	MRL	
			mg/kg	Year
DDVP	6	0.20	0.1	1984
Phoxim	3-5	0.20	0.5	1984
Malathion	10	0.22	1.0	1984
Fenitrothion	10	0.50	0.3	1984
Quinalphos	14	0.59	0.2	1987
Dimethoate	10	0.90	1.0	1984
Ethion	/	1.10	/	/
Phosemet	7	1.15	0.5	1984
Parathionuln	/	1.32	/	/
Permithrin	3	2.70	3.0	1987
Diflubenzuron	7-10	2.76	20.0	1997
Cypermethrin	7	2.90	20.0	1987
Alpha-cypermethrin	7	/	20.0	1987
Fenvalerate	/	3.10	2.0	1987
Decamethrin	5	3.20	10.0	1987
Bifenthrin	6	3.20	5.0	1987
Cyhalothrin	5	3.40	3.0	1989
Dicofol	/	3.85	/	/
Cartap hydrochloride	7	/	20.0	1989
Fenpropanate	7	/	5.0	1993
Buprofezin	10	/	/	/
Rotenone	7-10	/	/	/
Matrine	7	/	/	/
Propargite	10	/	/	/
Chlorothalonil	10	/	/	/
Thiophanate-methyl	10	/	/	/
Carbendazim	7-10	/	/	/
Lime sulphur	Forbidden in tea plucking period	/	/	/

REVIEW ON PESTICDE RESIDUES OF TEA IN CHINA

Sun-shine, rain, dew and aerial temperature can facilitate pesticides to decompose to some extent in the field. Some organophosphorus insecticides (e.g. phoxim, dibrom, DDVP, fenitrothion and malathion) as well as a carbamate insecticides (e.g. methomyl) could decompose 80 - 90 % within one day after being sprayed. Some other organophosphorus insecticides (e.g. quinalphos, dibrom, dimethoate, ethion, phosemet) decompose 50-80 % a day, while pyrethroids decompose not more than 30 %. Pesticides already absorbed by tea shoots are partly decomposed by enzyme; simultaneously, the tea shoots rapidly grow in size and cause diffusion of absorbed pesticides.

Tea processing also causes degradation of pesticides because of high temperature. Pesticides like DDVP, dibrom, fenitrothion, malathion and phoxim are decomposed to 70-80 %, dimethoate and parathionuln are decomposed to 50-60 %, and DDT, cypermethrin, decamethrin, bifenthrin, fenvalerate and dicofol are decomposed to 20-40 %.

Pesticide residues in tea seriously exceeded the standard several years ago. Pesticide residues of 4200 output tea samples in 2001 were listed in Tables 2 and 3 (Wang *et al*., 2003). The governments took effective action to control the pesticide residue, and the percentage of the pesticides residue in tea exceeding the standard reduced sharply in 2002 and 2003. Chinese government declared that Chinese teas are safe. According to Chinese national standard, the percentage of exceeding standard was 0.4 % from 228 output tea samples (Editorial Department of Tea economic Information, 2003).

Table 2 Pesticide residues in 4200 output tea samples in 2001

Detect rate ÿ%ÿ	Green tea	Black tea	Scented tea	Oolong tea
	32.2	36.4	62.1	71.2
Exceeding national standard	4.6	5.6	7.6	8.4
Exceeding European Union standard	21.1	26.4	44.8	50.4

Table 3 Pesticide residues in 4200 output tea samples in 2001

Detect rate ÿ%ÿ		Exceeding national standard	Exceeding European Union standard
DDT	7.4	2.7	2.7
fenvalerate	41.2	6.4	31.4
fenpropanate	23.1	3.6	7.7
buprofezin	18.4	4.4	7.1
Methamidophos	2.2	/	3.5
Thiodan	16.2	0	0
S-421	14.4	/	7.5

MEASURES TO OVERCOME PESTICIDE RESIDUES OF TEA

Most tea companies and farmers follow the government regulations and emphasize on biological control, use of bio-pesticides and an overall reduction in use of conventional pesticides. Pesticides are now used much less frequently and at an optimum time when the pest population crosses the threshold limits, following the right techniques to have good sprays.

Companies and farmers not following these guidelines are being corrected.

BIOCONTROL OF TEA PESTS AND DISEASES

Insect Pathogenic Microbes

Sixty nine species of viruses from 50 species of tea plant pests have been isolated and identified, including 59 species of Baculoviridae, seven species of Reoviridae, one species of Poxviridae, and two species of virus without inclusion body. Two species of pathogenic nematodes have been also identified (Han *et al*., 2003).

Spiders

There were recorded 290 species of spiders belonging to 27 families in Chinese tea gardens (Chen *et al*., 2000).

Other Predatory Natural Enemies

There are several species of frogs and lizards who prey on pests in Chinese tea gardens.

Insect Natural Enemies

Coccinellidae

1. *Coccinella septempunctata* L.
2. *Leis axyridis* (Pallas) var. *conspicua* Faldermann
3. *L. axyridis* (Pallas) var. *spectabilis* Faldermann
4. *L. axyridis* (Pallas) var. *novemdecimpunctata* Faldermann
5. *L. axyridis* (Pallas) ab. *bimaculata* Hemmelmann
6. *Adonia variegata* (Goeze)
7. *Calvia sicardi* Mader
8. *Chilomenes quadriplagiata* (Swartz)
9. *Chilocorus kuwanae* Silvestri
10. *Chilocorus rubidus* Hope
11. *Platynaspes maculosa* Weise
12. *Hyperspis repensis* (Herbst)
13. *Coelophora biplagita* (Swartz)
14. *Plopylaea japonica* (Thunberg)
15. *Plopylaea japonica* ab. *lineata* Kurisaki
16. *Plopylaea japonica* ab. *faliciae* Mulsant
17. *Plopylaea japonica* ab.dionea Mulsant
18. *Serangium japonicum* Chapin
19. *Serangium* (Neopullus) *yamata* Kamiya
20. *Scymnus* (Neopullus) *babai* Sasaji
21. *Verania discolor* (Fabricius)
22. *Scymnus* (*Pullus*) *sodalis* (Weise)

Cicindelidae

23. *Cicindela chinensis* DeGeer

Braconidae

24. *Apanteles heichinensis* Sonan
25. *Apanteles* sp.
26. *Apanteles* sp.
27. *Apanteles* sp.
28. *Apanteles* sp.
29. *Apanteles* sp.
30. *Bracon* sp.
31. *Chelouns* sp.
32. *Macrocentrus* sp.
33. *Phanerotoma flava* Ashmead

Aphidiidae

34. *Archaphidus* sp.
35. *Ephedrus* sp.

Ichneumonidae

36. *Xanthopimpla punctata* Fabr.
37. *Charops bicolor* Szepligeti
38. *Casinaria nigripes* Gravenhorst
39. *Coccygomimus disparis* (Viereck)
40. *C.luctuosus* (Smith)
41. *Goryphus basilaris* Holmgren
42. *Gotra octocinota* Ashmead
43. *Hyposoter* sp.
44. *Itoplectis naranyae* Ashmead
45. *Netelia ocellaris* (Thomson)
46. *Phaeogenes* sp.
47. *Temelucha philippinesis* Ashmead

Chalcididae

48. *Brachymeria excarinata* Gahan
49. *B.lasus* (Walker)
50. *Brachymeria* sp.

Callimomidae

51. *Podagrion* sp.

Eurytomidae

52. *Eurytoma monemae* Rusch

Encyrtidae

53. *Anicetus ceroplastis* Ishii
54. *Comperiella unifasciata* Ishii
55. *Anabrolepis bifasciata* Howard
56. *Anicetus beneficus* Ishii et Yasumatsu
57. *A.lindingaspidis* Tachikawa
58. *Anicetus howardi* Hayat
59. *Microterys flavus* Howard
60. *Microterys clauseni* Compere

Eulophidae

61. *Pediobius* sp.

62. *Pediobius* sp.
63. *Sympiesis* sp.

Tetrastichidae
64.*Tetrastichus leroplastae*
65. *Tetrastichus* sp.
66. *Tetrastichus* sp.
67. *Tetrastichus* sp.
68. *Tetrastichus* sp.

Aphelinidae
69. *Aphytis* sp.
70. *Coccophagus hawaiiensis* Timberlake
71. *Coccophagus scutellaris* (Dalman)
72. *Coccophagus* sp.
73. *Marietta picta* (Andre)
74. *Prospaltella smithi* Silvestri
75. *Pteroptorix* sp.

Scelionidae
76. *Telenomus* sp.
77. *Telenomus* sp.
78. *Telenomus* sp.
79. *Telenomus* sp.

Trichogrammalidae
80. *Trichogramma confusum* V.
81. *Trichogiamma dendrolimi* Matsumura
82. *Trichogramma evanescens* West

Chrysididae
83. *Chrysis shanghaiensis* Smith

Scoliidae
84. *Campsomeris annulata* F.

Larvaevovidae
85. *Carcelia* sp.
86. *Exorista sorbillans* Wiedmann
87. *Exorista* sp.
88. *Exorista xanthaspis* Wiedmann

Chrysopidae
89. *Chrysopa sinica* Tjeder
90. *Chrysopa formosa* Brauer
91. *Chrysopa septempunctata* Wesmael

Myrmeleantidae
92. *Dendroleon pantherius* F.

Hemerobiidae
93. *Hemerobius humli* L.

Coniopterygidae
94. *Coniopteryx pulverulenta* Enderlein

Reduviidae
95. *Agriosphodrus dohrni* (Signoret)
96. *Cydnocoris russatus* Stal
97. *Empicoris brachystigma* Horvath
98. *Harpactor fuscipes* (F.)
99. *Sirthenea flavipes* (Stal)
100. *Sphedanolestes impressicollis* (Stal)

Nadbidae
101. *Nabis stenoferus* Hsiao

Mantidae
102. *Mantis religiosa* L.
103. *Hierodula patellifera* Ser
104. *Paratenodera sinensis* Saussure
105. *Paratenodera* sp.
106. *Statilia maculata* Thunberg

Pentatomidae
107. *Arma custars* (F.)
108. *Picromerus lewisi* Scott

Syrphidae
109. *Epistrophe balteata* De Geer
110. *Melanostoma scalare* Fabricius
111. *Paragus quadrifasciatus* Meigen
112. *Sphaerophoria menthastri* Linne
113. *Sphaerophoria scripta* (L.)
114. *Syrphus corollae* F.
115. *Syrphus nitens* Zetterstedt
116. *Syrphus serarius* Wiedemann

Chamaemyzidae
117. *Leucopis puncticornis* Meigen

Asilidae
118. *Cophinopoda chinensis* F.

Vespidae
119. *Polistes chinensis* F.

Release of Microbial Formulations And Natural Enemy Insects To Control Tea Pests

Several insect pathogenic viruses and entomogenous fungi have been used for this (Han et al. 2003). From the mid 1970's to the mid 1980's, several species of Trichogrammatidae had been used to control *Adoxophyes orana* Fischer von Rosierstamm in some tea gardens on large scale. During the egg stage of *A. orana* 300,000-1,200,000 wasps per hectare were released, which were divided into 3 or 4 batches and at interval of 3 or 4 days. The parasite population of *Trichogramma ostriniae*, *T. closterae* and *T. dentrolimi* ranged from 60-70 %, while that of *T. confusum* was more than 85 % (Zhang *et al*., 1986) . If the larva density of *A. orana* was high, the formulations of *Beauveria bassiana* were released in morning, dusk or rainy day. The control effect could reach 80 %.

Natural Control Of Insect Pathogenic Microbes And Natural Enemy Insects To Pests And Diseases

Small and piercing sucking Homopterous insects such as scales and whiteflies infest in tea plants. However, there are plenty of pathogenic microbes and natural enemy insects in tea garden ecosystems, and many species of entomopathogenic fungi and parasitic wasps constantly alter hosts among the small pests, which come into being the complicated food web and chains and suppress these small pests effectively (Han, 2002). For example, *Aleurocanthus spiniferus* (Quaintance) broke out in 1989 in the southern tea area of Anhui Province. The field investigation from early spring to autumn showed that entomogenous fungi *Pleurodesmospora coccora* Samson, Gams *et* Evens, *Cladosporium* sp. and *Acremonium* sp., and parasitic wasps, *Prospaltella smithi* Silvestri, *Amitus hesperidum* Silvestri, *Amitus longicornis* Föster, *Encarsia* sp., *Trichaporus formosus* (Gah), *Comperiella unifasciata* Ishii and *Prospaltella ishii* Silverstri jointly controlled the pest and made its population to break down. The correlation of joint parasitic rate (y) to days (x) showed logistic curve.

$$y = \frac{100}{1+10.954244\, e^{-0.064555\, x}}.$$

Spiders, one group of important natural enemies, prey on pest insects directly or by web. For example, *Empoasca vitis* (Göthe), the most important pest in Chinese tea gardens, lacks effective natural enemies. In fact, only several species of spiders prey on them, such as *Misumenops tricuspidatus*, *Evarcha albaria* (L. Koch) and *Agelena labyrinthica* Clerck.

DISEASES CONTROL

Diseases seldom occur in Chinese tea gardens and these need hardly any control. Generally, *Exobasidium vexans* Massee infests the tea plants in high humidity conditions of Hannan, Yunnan, and Sichuan Provinces, while *Phyllosticta theaefolia* Hara occurs in tea gardens in high altitude mountains. For example, the sporadic occurrence of *P. theaefolia* in tea gardens in mountains made the merchant teas taste bitter. But no native resident considers that the teas could cure some diseases. We have isolated one group of *Bacillus* spp. named “Tea beneficial microbes” in collaboration with Chinese Agricultural University. If it is sprayed twice in every tea growth period, the tea yield will increase by 20-40 %. It is also antagonistic to *Guignardia camelliae* (Cooke) Butler. Its control effect could reach 30-50 % after two sprayings during disease period in the tea gardens (Han *et al.*, 1999).

PERSPECTIVE

Many factories breeding parasitic wasp or *Beauveria bassiana* were bankrupt at the end of 1980's, which affected biological control severely. Since 1990's only a few tea research institutes and large tea farms have produced NPV of *Ectropis oblique* Prout to control the pest, produced some *Beauveria bassiana* formulation to control tea beetles and *Adoxophyes orana* Fischer von Rosierstamm, and produced some *Aegerita weberi* formulation to control whiteflies. The breeding and release of parasitic wasps had been stopped.

Pesticide residues in tea seriously exceeded the standard during 1999–2001, and since then biocontrol has regained emphasis. Large tea farms use virus formulation to control tea geometrid (*Ectropis oblique* Prout) and tea tussock moth (*Euproctis pseudoconspersa* Strand), and Bt formulation to control tea bunch caterpillar (*Andraca bipunctata)* and *Adoxophyes orana* Fischer von Rosierstamm. We feel that the structure of insect communities in tea gardens is complicated, in which the pathogenic microbes are abundant. There are still more areas to be explored: selecting high toxic species or clones, developing effective application technique, such as strengthening the endemic to become epidemic, introduce entomogenous fungi into tea gardens, etc. (Pu and Li, 1996).

There are some reports on tea insect semiochemicals. For example sex pheromones of tea geometrid (*Ectropis oblique* Prout) and (*Adoxophyes orana* Fischer von Rosierstamm) have been isolated, identified and tentatively applied (Yin *et al*., 1993), and the chemical communication mechanism among tritrophic sytem, tea plant - pest insects - natural enemies, has been surveyed (Han and Chen, 2002; Zhao *et al*., 2002). Further applied study should focus on the combination of semiochemicals with pathogenic microbes. For instance, lure pests by semiochamicals, make them infected by pathogens, release them and then promote epidemic to prevail in pest population.

The national tea plant germplasm resource garden set up in our institute contains 2700 shares from all over the world. The preliminary investigations show that some of them are resistant to *Empoasca vitis* Göthe obviously (Zeng *et al.*, 2001). Therefore, such studies should be broadened to identify the chemical components to resist pests and diseases, mark related genes and breed new variety.

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