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Prospect for Integrated Pest Management in Tea Cultivation in Japan

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Abstract

Tea plant is perennial and evergreen, and leaves are stratified into 2 layers. The bush below the plucking surface is very important as a refuge for natural enemies because of minimal artificial effects. The ecosystem of tea field is the most complex and most stable among the Japanese agroecosystems. Most of the tea pests are polyphagous and complete their life cycle in tea fields Since the effects of natural enemies on the population of insect pests are pronounced even under insecticidal control because of the complexity of the ecosystems, excessive insecticide application is not recommended and conservation and utilization of indigenous natural enemies should be promoted in the control system of tea pests. A tentative IPM system for tea cultivation in Japan was proposed. In the system, both natural enemies and insecticides are used complementarily.

Discipline: Insect pest/Tea industy
Additional key words: agroecosystem, economic injury level, insecticide resistance, natural enemy

Introduction

Tea plants are subjected to the attack of more than 100 species of insect pests. At present, the control of insect pests tends to depend on insecticide spraying. On the other hand, many kinds of natural enemies occur in tea fields and some of them control the pest density adequately even under insecticidal control[1]. Moreover, sex pheromones[8] and granulosis virus[7] have recently become available for the control of tortrix. From the viewpoint of safe use of agricultural chemicals in ecosystems and the possible development of resistance, insecticide applications must be kept at a minimum, and integrated pest management (IPM) system should be considered. For the IPM system, the characteristics of the ecosystem of the field should be analyzed. In this paper, the author describes the characteristics of tea pests and the ecosystem of tea fields, and suggests the adoption of the IPM system in Japan.

Ecological characteristics of tea fields in Japan

Tea plant is perennial and evergreen. New shoots sprout several times per year after plucking. Tea plant develops into a characteristic shape (Fig. 1). Leaves grow thick around the plucking surface, and thin below the plucking surface. Leaves are stratified into 2 layers.

The effects of artificial management including insecticide application are negligible on the bush below the plucking surface. Since insecticide application is mainly conducted above the plucking surface, a substantial amount of insecticides is deposited around the plucking surface, while the deposition on the bush below the plucking surface is negligible (Fig. 1). The bush below the plucking surface is very important

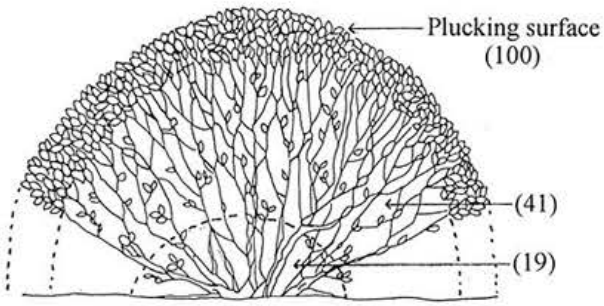

Fig. 1. Cross section of tea plant
Numerals in parentheses indicate the relative deposition of insecticides sprayed over the plucking surface[3].

as a refuge for natural enemies. For example, the population densities of several natural enemies of *Tetranychus kanzawai* are high at the bush below the plucking surface even under insecticidal control (Fig. 2).

Stability of agroecosystems depends on crops, cultivation methods, environmental conditions, etc. Kiritani[2] classified the agroecosystems in Japan according to their stability and stated that the ecosystem of a citrus field is the most stable since citrus is an evergreen perennial crop. Since tea is also an evegreen perennial crop and the effects of artificial management including insecticide application are negligible on the bush below the plucking surface, the ecosystem of the tea field is more complex and more stable than that of a citrus field.

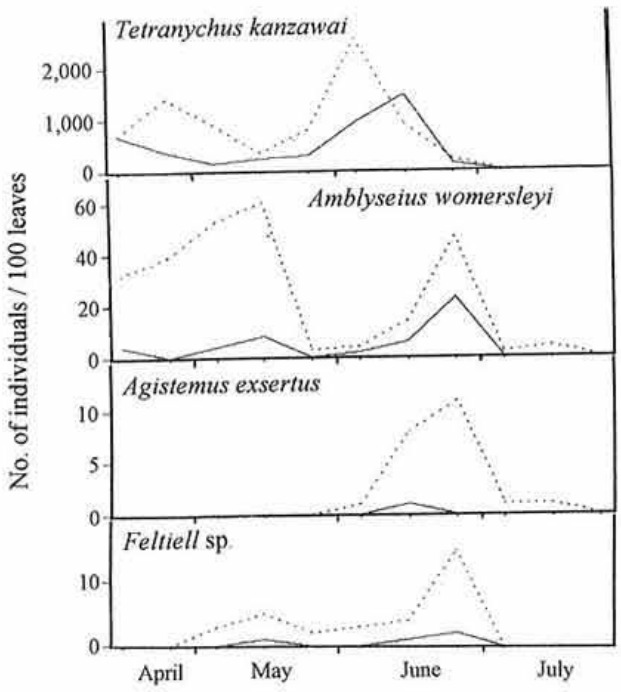

Fig. 2. Seasonal prevalence of *Tetranychus kanzawai* and its natural enemies at the plucking surface and the bush below the plucking surface of tea field under insecticidal control[6]
—— : at the plucking surface.
···· : at the bush below the plucking surface.

Characteristics of tea pests

Major insect pests of tea plant in Japan are listed in Table 1. Four species infested the new shoots to be harvested, and other species infested other parts of the tea plant. Most of the tea pests are polyphagous, but all the pests except for *Ascotis selenaria* infest throughout the year and complete their life cycle in the tea field. Since most of the tea pests are residential, their degree of insecticide resistance is correlated with the frequency of sprays with respective insecticides in the past. Both diapause and non-diapause species are considered to be important tea pests.

The economic injury level (EIL) is very low for the pests infesting the new shoots since their injury directly affects both the yield and quality of tea (Fig. 3). On the other hand, EIL is high for the pests infesting other parts of tea plant because their injury affects the growth of the new shoots of the next crop and light injuries do not affect the yield and quality.

Table 1. Major insect pests of tea in Japan

Scientific name	Common name	Plant part attacked[c]	Ecological traits[d]
Tetranychus kanzawai	Kanzawa spider mite	L	R, D, P
Caloptilia theivora	Tea leaf roller	Sh	R, N, O
Homona magnanima	Oriental tea tortrix	L	R, N, P
Adoxophyles sp.	Smaller tea tortrix	L	R, N, P
Pseudaulacaspis pentagona[a]	Mulberry scale	St	R, D?, P
Toxoptera aurantii	Black citrus aphid	Sh	R, D, P
Scritothrips dorsalis	Yellow tea thrips	Sh	R, N, P
Empoasca onukii	Tea green leafhopper	Sh	R, N, P?
Ascotis selenaria	Mugwort looper	L	M, N?, P
Heptophylla picea[b]	Chafer	R	R, D, P

a): Occurrence of damage is occasional, but severe.
b): Damage occurring in restricted area by the pest.
c): L; Leaves, Sh; Shoots, St; Stems, R; Roots.
d): R; Residential, M; Migratory, D; With diapause, N; Without diapause, P; Polyphagous, O; Oligophagous.

Methods of control of tea pests

1) Insecticides

At present, insecticide spraying is the principal method of insect pest control for tea in Japan. However the problem of insecticide resistance has recently become important for *T. kanzawai, Homona magnanima, Adoxophyles* sp., *Scritothrips dorsalis* and *Empoasca onukii*. For the pests infesting new shoots, the density increased rapidly along with the growth of new shoots, and the effect of natural enemies on the population was minimal. When the size of the injured shoots decreased, the effects of injury became more pronounced (Fig. 3). Therefore, insecticide spraying is essential for these pests in the bud-opening period. On the other hand, for the pests infesting other parts of the tea plant, the effects of natural enemies are substantial. Insecticide spraying is restricted only when the pest density exceeds EIL, and the effects on the natural enemies are considerable for the selection of chemicals.

2) Sex pheromones

Communication disruption using sex pheromones of *H. magnanima* and *Adoxophyles* sp. is effective[7]. However the application area is very small because of high cost and limited control effect under high population density. When the use of insecticides decreases, the effect of indigenous natural enemies becomes more conspicuous and the density of insect pests decreases. Consequently, sex pheromones will become more important for controlling the 2 species of tortrix moths in the future.

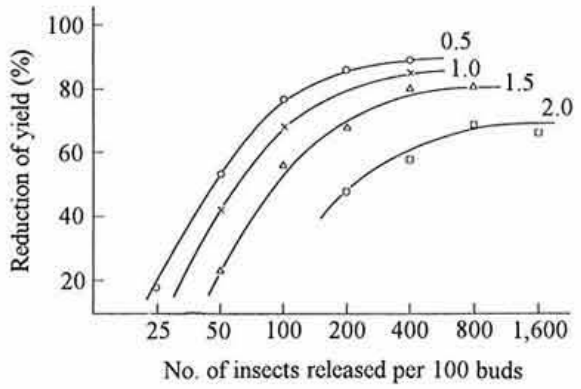

Fig. 3. Relationship between the density of *Empoasca onukii* released and yield of tea[4]
Hundred buds were covered with a cheesecloth and nymphs of *E. onukii* were released on it. Numerals in the figure indicate the number of opened leaves of the bud when the pest was released.

3) Natural enemies

As stated before, many kinds of indigenous natural enemies operate efficiently in tea fields under insecticidal control, and conservation and utilization of indigenous natural enemies is essential for biological control in tea fields. Especially, *Amblyseius womersleyi* controls effectively the population density of *T. kanzawai*. When the population of *T. kanzawai* increased at the bush below the plucking surface, the population of *A. womersleyi* also increased subsequently. Consequently, the population of *T. kanzawai* decreased at the bush below the plucking surface, and it did not increase at the plucking surface (Fig. 4). Recently, *A. womersleyi* has become resistant to many kinds of insecticides (Table 2), and this insecticidal resistance enhances the control effect of *A. womersleyi* under insecticidal control. The LC_{50} value of the resistant strains is 10 to 100 times that of the susceptible strains, while the value is the same as or slightly lower than the commercially used concentration of chemicals[1,5]. The effects of insecticides on the population on the plucking surface are serious, while those on the population on the bush below the plucking surface are negligible, and consequently *A. womersleyi* effectively controls the population density of *T. kanzawai* under insecticidal control because of the ecological characteristics of tea fields. Many other natural enemies are considered to affect the density of tea pests. It is

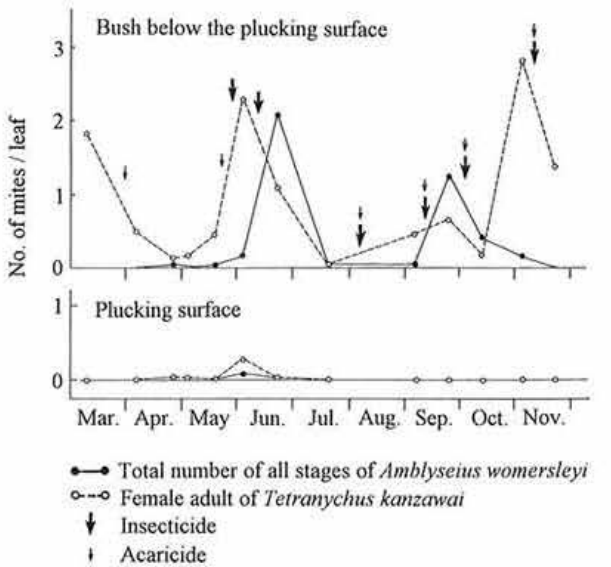

Fig. 4. Seasonal prevalence of *Tetranychus kanzawai* and *Amblyseius womersleyi* in tea field under insecticide application[1]

Table 2. Susceptibility of 2 strains of *Amblyseius womersleyi* to several insecticides

Chemicals	LC_{50} (ppm)		Resistance ratio
	R strain[a]	S strain[b]	
Organophosphorus insecticides (Hamamura, 1985)[1]			
Methidathion (400)	30.3	0.3	118.5
Phenthoate (500)	39.8	1.4	29.2
Carbamate insecticides (Hamamura, 1985)[1]			
Methomyl (450)	105.4	0.8	129.3
Carbaryl (850)	308.4	13.0	23.7
Pyrethroid insecticide (Mochizuki, 1990)[5]			
Permethrin (100)	301.9	8.8	34.3

a): R; resistant strain collected in a tea field in Shizuoka Pref. in Japan.
b): S; susceptible strain.
Numerals in parentheses indicate the concentration used in tea fields in Japan.

important to examine the effects of the indigenous natural enemies and to utilize them.

Granulosis viruses (GV) of *H. magnanima* and *Adoxophyles* sp. are practically used[7]. When GV are sprayed in spring, they are able to control effectively the 2 species of tortrix moths until autumn, but the viruses do not persist in winter. The use of GV could become an effective method of control in IPM system.

4) Cultural control

By plucking, skiffing and pruning, not only new shoots but also insect pests on the shoots are removed. These operations are assumed to strongly affect the population of insect pests on new shoots. It is, therefore, necessary to examine the effects of these operations on the pest population.

Prospect and conclusion

The ecosystem of tea fields is complex and stable, and the effects of natural enemies on the population of insect pests are substantial even under insecticidal control. Since excessive insecticide application reduces the effects of natural enemies and causes the resurgence of insect pests, conservation and utilization of indigenous natural enemies should be promoted in the control system of tea pests. However, it is impossible for commercial production of tea to control all the insect pests only by conservation

Table 3. Tea production system in Japan

Crop	Plucking month	Yield[a] (t)	Price[b] (Yen/kg)
First	Apr. - May	47,240(100)[c]	2,543(100)[c]
Second	Jun.	28,100(59)	962(38)
Third	Jul. - Aug.	4,310(9)	662(26)
Autumn	Sep. - Oct.	6,770(14)	279(11)

a): Yield of crude tea (1994).
b): Price for crude tea in Shizuoka Pref. (1994).
c): % to the value of first crop.

Table 4. Tentative integrated pest management system in tea cultivation in Japan[a]

Crop	Density of insect pests	Activity of natural enemies	Management system	
			Pest of shoots	Pest of leaves
First	Low	Low	Not necessary[b]	Not necessary
Second	Medium	Medium	Insecticide spraying[c]	Natural enemies[d]
Third	High	High	Natural enemies	Natural enemies
Autumn	High	High	Natural enemies	Natural enemies

a): For tea field, only first and second crops are harvested and third and autumn crops are not harvested.
b) Usually control is not necessary, but in case of high density, insecticide spraying is necessary.
c): Insecticide spraying is necessary from the bud opening period.
d): Conservation and utilization of indigenous natural enemies are essential, but when the pest density exceeds the EIL, insecticide spraying is necessary.

and utilization of natural enemies.

Considering the pest management system for tea field, the production system of tea is very important as well as the ecological characteristics of tea field. New shoots grow several times per year, but not all the new shoots are harvested. Harvest of new shoots is conducted 2 to 4 times per year and non-harvested shoots are cut off after maturity. Since the price of the first crop is very high, that of the second crop is about one-third and that of the other crops is very low, third and autumn crops are not harvested in most fields (Table 3). Both population density of insect pests and activity of natural enemies are low on the shoots of the first crop, and they are high during summer and autumn (Table 4).

Based on the ecological characteristics of tea fields and production system of tea, a tentative IPM system in tea cultivation in Japan was proposed (Table 4). In the system, both natural enemies and insectides are used complementarily. Insecticides are mainly used for the pests on new shoots in early summer, and natural enemies effectively control the pests on mature leaves and in other seasons. Sex pheromones and granulosis virus are also effective in IPM system.

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