Bacterial Diseases of Fruit Trees Found in Japan

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Introduction

It is generally accepted that bacterial diseases of plants are caused by six genera of bacteria, i.e., *Agrobacterium*, *Corynebacterium*, *Erwinia*, *Pseudomonas*, *Streptomyces* and *Xanthomonas*. However, diseases of fruit trees caused by genus *Corynebacterium* and genus *Streptomyces* have not been described yet in Japan. In addition, any disease caused by new realms of pathogens such as mycoplasma-like organism, spiroplasma, xylem limited bacteria, and phloem limited bacteria has fortunately not been found with certainty[10]. Bacterial diseases of fruit trees and their pathogenic bacteria, compiled in the book "Common name of economic plant diseases in Japan, Vol. 3 (2nd ed. 1984)" and later supplemented by Annals of the Phytopathological Society of Japan, are shown in Tables 1 to 4. The outline of them will be presented in this paper.

Diseases caused by *Agrobacterium*

As shown in Table 1, crown gall is recorded to have occurred on 20 kinds of fruit trees. Its occurrence on kiwifruit was observed, but not yet recorded. Being a soil-borne disease, the pathogenic bacteria inhabiting in soils make infection through wounds at the time of grafting, etc. Therefore serious damage is found when the nursery plants are produced on soils once infested with the pathogen. As there is no effective control method, nurserymen have much trouble by this disease.

Recently, new cultivars such as Kyoho, Kaiji, etc. which have a part of the genotype of European grape (*Vitis vinifera*) have won popularity, but a problem came out that some of these cultivars suffer from crown gall. The pathogenic bacteria spread and multiply in grapevines and cause systemic infection. Hence a large number of galls are formed not only on the basal portion of trunks, but also on the entire portion of trunks and canes resulting in decline of tree vigor followed by death. If canes carry the pathogenic bacteria symptomlessly, infected nursery plants are produced by using these canes as scions. Therefore, to prevent the spread of the disease, it is necessary to secure healthy mother plants free from pathogenic bacteria, and produce clean nursery plants by using scions derived from the above mother plants as in the case of the control of virus diseases.

The pathogenic bacteria isolated from crown

Table 1. Fruit tree diseases found in Japan caused by bacteria of the genus *Agrobacterium*

Causal bacteria	Diseases	Fruit trees affected
Agrobacterium tumefaciens	Crown gall	Apple, Apricot, Blambles, Cherry, Chestnut, Citrus, Currant and Gooseberry, Fig, Grape, Japanese apricot, Loquat, Mango, Olive, Papaya, Peach, Japanese pear, Japanese persimmon, Plum, Quince, Walnut.
Agrobacterium rhizogenes	Hairy root	Apple.

galls of stone fruit trees belong to biovars 1 or 2[1], but those from grapevine galls are regarded as biovar 3[9]. In Japan, a large number of biovar 3 isolates, showing strong pathogenicity to grapevines are obtained[11]. Effectiveness of agrocin 84 differs by biovars, and agrocin 84 is regarded not effective to biovar 3. Development of an effective method of control for biovar 3 is needed. The search for resistant rootstocks was begun with peach and grapevines.

Hairy root caused by *A. rhizogenes* occurs on apple trees without any actual damage, and the occurrence is quite rare.

Diseases caused by *Erwinia*

Table 2 shows five diseases caused by bacteria which belong to genus *Erwinia*. Bacterial shoot blight of pears was found for the first time by Tanii in Hokkaido in 1981[24].

The main symptoms are blackening of clusters, expanding young leaves, and wilting to death of spurs and twigs. Pathogen of the disease has similar bacterial characters to that of fire blight on apple and pear, however, it has strong pathogenicity only to pear, but never to apple. Therefore, the pathogen of bacterial shoot blight of pear was considered to belong a different pathovar, and identified as *Erwinia amylovora* (Burrill) Winslow et al. pv. *pyri* pv. nov.[25].

Erwinia nigrifluens was isolated from the lesion which could not be distinguished from the symptom of bacterial shot hole of peach trees caused by *Xanthomonas campestris* pv. *pruni*, and its pathogenicity was recognized. However, this pathogen has been isolated so far only in limited areas, and never detected in major peach producing areas[17].

Erwinia rusty canker of Japanese pears was found for the first time in Chiba Prefecture in 1985[25]. A part of the bark of trunks and branches changes into black and water-soaked appearance, and vicinity of cambium just under the bark lesion shows browning. From the bark-splits formed on such lesions, the sap bleeds out, and it looks rusty when dried. Wasps and other insects come together to get the sap. The possibility of their role as insect vectors is suggested. When the affected part spreads around the branch, the top portion of branch beyond that part dies back. Once the disease occurs, it causes great damage of trees. However, the outbreak in wide areas has never happend. Two kinds of pathogen were detected, i.e., *E. chrysanthemi* pv. *chrysanthemi*, and *E. carotovora* subsp. *carotovora*, which were isolated at high and at low frequency, respectively.

Diseases of pineapple[23] and mango[27] caused by bacteria which belong to genus *Erwinia* have been recorded only in Okinawa Prefecture.

Diseases caused by *Pseudomonas*

As shown in Table 3, it has been considered that in the genus *Pseudomonas* the pathogenic agents are five identified and one unidentified pathovars of *P. syringae*. However, recently two other species were added as the pathogens to blossom blight of kiwifruit[3].

The disease which has been known from long ago is canker of loquat. Formerly, two diseases, i.e., canker and bud blight were reported as different diseases. However, Okabe

Table 2. Fruit tree diseases found in Japan caused by bacteria of the genus *Erwinia*

Causal bacteria	Diseases	Fruit trees affected
E. amylovora pv. *pyri*	Bacterial shoot blight	Japanese pear, Pear
E. ananas pv. *ananas*	Marbled fruit disease	Pineapple
E. carotovora subsp. *carotovora*	Fruit rot	Mango
E. chrysanthemi pv. *chrysanthemi*	Erwinia rusty canker	Japanese pear
E. carotovora subsp. *carotovora*	Erwinia rusty canker	Japanese pear
E. nigrifluens	Bacterial shot hole	Peach

Table 3. Fruit tree diseases found in Japan caused by bacteria of the genus *Pseudomonas*

Causal bacteria	Diseases	Fruit trees affected
P. syringae pv. *castaneae*	Bacterial canker	Chestnut
P. syringae pv. *eriobotryae*	Canker	Loquat
P. syringae pv. *morsprunorum*	Bacterial canker	Japanese apricot, Plum
P. syringae pv. *morsprunorum**	Bacterial canker	Kiwifruit
P. syringae pv. *myricae*	Bacterial gall	Wax myrtle
P. syringae pv. *syringae*	Bacterial shot hole	Peach
P. syringae pv. *syringae*	Blossom blight	Japanese pear
P. syringae new pathovar	Blossom blight	Kiwifruit
P. marginalis	Blossom blight	Kiwifruit
P. viridiflava	Blossom blight	Kiwifruit

* As it differs in pathogenicity from the causal bacteria of stone fruit diseases, its pathovar is expected to be altered in the near future.

(1955) found that these two names were given to different symptoms of the same disease, and proposed that they should be unified with the name of pathogenic bacteria as *P. eriobotryae* (present name: *P. syringae* pv. *eriobotryae*)[7]. The causal bacteria are divided into three groups according to their pathogenicity. The three groups show some difference each other regarding regions of their occurrence, variety and plant portions to be infected. Namely, according to Morita (1988), the group A was mainly isolated from twig canker and also from bud blight. No marked difference in resistance was observed between varieties Tanaka and Mogi. The group B was mainly isolated from leaf necrotic lesions with halo, and Mogi is more susceptible than Tanaka. The group C was isolated only from twig canker and showed strong pathogenicity to Tanaka[5]. At present, it is recommended as control measures to cut off the parts of lesions and their surroundings and to apply streptomycin paste containing some kind of insecticide to the cut surface after the removal of lesions or after pruning. Agricultural chemicals more effective and easy to apply are desired.

Bacterial canker occurred on mature trees of Japanese apricot causes severe damage of fruit. When young trees are infected, spring canker of shoots occurs severely followed by the dieback of shoots. Therefore, the sufficient number of fruit bearing shoots can not be obtained, or the tree form is disturbed. Thus, the adverse effect of the disease lasts for long.

This disease was named and recorded by Kishi et al.[2], and later Tominaga et al. identified *P. syringae* pv. *morsprunorum*[22] as the pathogen. The causal bacterium, which invades latently in the lenticel etc. of shoots, and overwinters, begins to reproduce just before the blooming, and produces spring canker. The spring canker acts as the primary infection source for the occurrence of blossom blight and the disease development on new shoots and young fruits. Almost all the causal bacteria of such bacteriosis of Japanese apricot trees are *P. syringae* pv. *morsprunorum*, and no *Xanthomonas campestris* pv. *pruni* is isolated[10].

The present author found that bacterial canker caused by *P. syringae* pv. *morsprunorum* occurs on plum trees, too[19]. Symptoms of the disease on leaves and branches are similar to, and not distinguished from those of black spot caused by *Xanthomonas campestris* pv. *pruni*, but symptoms on fruit is obviously different from those of black spot. Therefore, the disease was recorded as a different one. Namely, the lesions on fruit are brown to blackish brown in color, raised and have the rough surface of rind. As the diseased tissue ceases its growth, while the healthy tissue continues to grow, the diseased fruit becomes malformed with a concavity. However, the plum orchard where the bacterial canker occurs singly is seldom found, but the

bacterial canker is observed together with black spots in many cases[19].

From a few lesions of bacterial shot hole on peach leaves, *X. campestris* pv. *pruni*, which has so far been recorded as the major causal bacterium is not isolated, but only another kind of bacterium which develops white colony on nutrient bloth agar was isolated. A kind of these bacteria was identified as *P. syringae* pv. *syringae*, and the other as *E. nigrifluens*. However, both of them caused the same symptoms on leaves, branches and fruits as those caused by *X. campestris* pv. *pruni* by spray inoculation. Therefore, unlike the case of plum, the plural kinds of causal bacteria were listed for the same disease[17].

From branches of stone fruits in the overwintering period, a large number of epiphytes were detected. All these isolates belong to the group of *P. syringae*, and from any kind of trees the same pathovar as the causal bacteria of bacterial canker of respective kind of trees was detected as the dominant species. Therefore, these epiphytes were considered as the major infection source. There was no case that *X. campestris* pv. *pruni* was detected from the solution used to rinse the same pieces of branches. Namely, it was not recognized that *X. campestris* pv. *pruni* is epiphytic[18].

Bacterial canker on kiwifruit was reported[12], and the causal bacterium was identified as *P. syringae* pv. *morsprunorum*[21]. However, the isolates of *P. syringae* pv. *morsprunorum* from kiwifruit showed weak pathogenicity to many kinds of stone fruit trees and those from stone fruit trees showed no pathogenicity to kiwifruit. This fact suggests the difference of pathover between these two groups of isolates. Therefore, there is a possibility that the pathover of causal bacterium of kiwifruit will be altered in the near future.

Opgenorth et al. reported bacterial canker of kiwifruit caused by *P. syringae* pv. *syringae* in California[8]. As it is suggested that the disease in Japan and that in U.S.A. are the same ones, comparative examination on the causal bacteria is desirable. The characteristics of the disease are as follows: the causal bacteria which infected kiwifruit trees in autumn multiply and spread in trees in winter. In the next spring, the bacteria ooze out through splits of trunk epidermis or a nodal portion of canes since the time before budding. They are mixed with tree sap and flow down. When dried, this mixture looks like iron-rust. Later, the new buds, already developed, begin to wilt or the whole cane dies back without budding. These changes closely resemble the symptom suggestive of tree damage caused by freezing in cold spring. On the other hand, in the growing stage, small necrotic lesions with yellow halo are produced on young leaves. When this symptom of leaves begins to be observed, the disease occurrence of the canes becomes gradually conspicuous, and soon the trees die. Therefore, attention is necessary to find out lesions with halo on leaves in unaffected orchards of kiwifruit. As the countermeasures to disease development in winter, the possibility to control the disease by injecting antibiotics such as streptomycin products into trees is under study from the viewpoint of effectiveness and nothing of residue of antibiotics, in addition to the prevention of infection in autumn.

Furthermore, kiwifruit suffers from bacterial blossom blight and the causal bacteria are found to belong to the group of *P. syringae*, but its pathovar still remains undetermined[4]. Recent study on the pathogen made clear that although *P. syringae* is the main causal bacterium, *P. viridiflava*, *P. marginalis*, and other bacteria identified as close to them are highly possible to cause the disease[3]. In addition, in orchards with bacterial canker, blossom blight occurs by the pathogen of bacterial canker. Therefore, the blossom blight is considered as the syndrome caused by plural paghogens.

In Shiga Prefecture a new disease of chestnut trees was found. On overwintered shoots, knob-like swelling occurs, and epidermis of the swelling comes to show the canker appearance. From this part, the causal bacteria are released, and the shoots die back. This disease was named bacterial canker of chest-

nut trees[13]. Its causal bacteria resemble closely that of loquat canker in bacteriological characters and pathogenicity, but are different from the latter as to the point that the former produces the gall on chestnut trees. Thus, the former was considered as a new pathovar, and the name, *P. syringae* pv. *castaneae* pv. nov. was proposed for it[20]. In addition to the symptoms stated above, this disease causes bud blight and produces black, necrotic lesions and galls on petioles, flower spikes, and young twigs. Application of an excessive amount of nitrogen makes plants apparently more susceptible to this disease. Reasonable nitrogen application is recommended, and its effectiveness of preventing the disease is recognized.

The disease, bacterial gall, which produces rough galls on the surface of trunks and twigs of wax myrtle (*Myrica rubra* S. et Z.) was reported, and the pathogen was identified as *P. syringae* pv. *myricae* pv. nov.[6]. This pathogen infected only wax myrtle and produced galls, but no gall was formed in 38 kinds of woody plants tested.

Diseases caused by *Xanthomonas*

The four kinds of diseases shown in Table 4 are caused by *Xanthomonas campestris*, and two pathovars are recorded: pv. *pruni* which widely infects stone fruit trees, and pv. *citri* infecting citrus trees. The disease on stone fruit trees caused by pv. *pruni* is named bacterial shot hole of peach and apricot, based on the symptom on leaves, and blackspot of plum, based on characteristics of the symptom on fruit. The resistance of the host plants to the disease is apricot > peach > plum.

From the leaf lesions of those plants, *X. campestris* pv. *pruni* is isolated at a quite high frequency, showing that this kind of bacterium is undoubtedly the most important pathogen of the disease. The infection which leads to the primary infection source occurs as follows: in late autumn, the pathogen enters into plants though lenticel of branches or leaf scars newly formed at the time of typhoon etc. and over-winters latently. In the next spring, the pathogen produced, before the flowering stage of host plants, the lesions with water-soaked appearance, so called spring canker, and the lesions act as the primary infection source[16].

Three kinds of virulent phages of *X. campestris* pv. *pruni*, isolated from peach, plum, and apricot are obtained. These virulent phages are considered to be in the relation of host range mutant of the same species from morphological and biological characteristics as well as serological affinity, and named pp_1, pp_1h_1 and pp_1h_2, respectively.

The pp_1 was isolated from peach and apricot, and it took causal bacteria isolated from these trees and also derived from quite a few plum trees as its host, while pp_1h_1 was all isolated from plum, and took causal bacteria isolated from plum and quite a few peach trees as its host. The pp_1h_2 was isolated from plum at a low frequency, and it took all the bacterial strains isolated from plum and a few peach trees as its host. The size of all plaques produced by pp_1h_2 was larger than 1 mm, whereas the other two phages produced small plaques (< 0.5 mm)[16].

Chemicals effective to this disease are very few, i.e., only a few kinds of organic compounds and antibiotics are used at present. In addition, development of a tolerant strain to streptomycin products was found out. In view of such situation, an experiment to use the Bordeaux mixture (which had been con-

Table 4. Fruit tree diseases found in Japan caused by bacteria of the genus *Xanthomonas*

Causal bacteria	Diseases	Fruit trees affected
X. campestris pv. *citri*	Canker	Citrus
X. campestris pv. *pruni*	Bacterial shot hole	Peach, Apricot
X. campestris pv. *pruni*	Black spot	Plum

sidered not usuable to stone fruit trees in the growing season because of its toxicity) before leaf fall in autumn for preventing the infection leading to the primary infection source (spring canker) was carried out. It was shown that the Bordeaux mixture was usuable without causing phytotoxicity to matured leaves. Then, in some prefectures such as Fukushima, application of Bordeaux mixture (4–12: 0.4% $CuSO_4$ + 1.2% CaO) in late September (the best time to prevent autumn infection to branches) was recommended, and obtained fairly high effectiveness.

Citrus canker is caused by *X. campestris* pv. *citri*. Among the bacterial diseases of fruit trees in Japan, this disease has the greatest accumulation of research regarding ecology of the disease occurrence, and physiology and ecology of the causal bacteria. On the basis of these research results, the early screening for resistant cultivars was made possible, and many of the cultivars recently developed are resistant to this disease. Regarding the citrus canker, M. Koizumi is expected to publish his paper on JARQ, so that the detail of this disease is omitted in the present paper.

References

1) Keane, P. J., Kerr, A. & New, P. B.: Crown gall of stone fruit II. Identification and nomenclature of *Agrobacterium* isolates. *Aust. J. Biol. Sci.*, **23**, 585–595 (1970).
2) Kishi, K. & Takanashi, K.: A new disease, bacterial canker of Japanese apricot. *Ann. Phytopath. Soc. Jpn.*, **35**, 112 (1969) [In Japanese].
3) Miyoshi, T. et al.: Studies on the blossom blight of kiwifruit trees (1) A blossom blight syndrome by some pathogenic organisms. *Ann. Phytopath. Soc. Jpn.*, **54**, 378 (1988) [In Japanese].
4) Morita, A. & Hayashida, S.: Occurrence of blossom blight on kiwifruit trees. *Ann. Phytopath. Soc. Jpn.*, **50**, 103 (1984) [In Japanese].
5) Morita, A.: Studies on the grouping of the *Pseudomonas syringae* pv. *eriobotryae* and the varietal resistance against loquat canker. *In* Special Bull. of the Nagasaki Fruit Tree Exp. Sta., 1–58 (1988) [In Japanese with English summary].
6) Ohgimi, C. & Higuchi, H.: Bacterial gall of Yamamomo (*Myrica rubra* S. et Z.) caused by *Pseudomonas syringae* pv. *myricae* pv. nov. *Ann. Phytopath. Soc. Jpn.*, **47**, 443–448 (1981) [In Japanese with English summary].
7) Okabe, N.: Bacterial plant diseases in Japan V. A study of loquat bacteriosis, canker and bud blight caused by *Pseudomonas eriobotryae* (Takimoto) Dowson. *Bull. Fac. Agr., Shizuoka Univ.*, **5**, 100–106 (1955).
8) Opgenorth, D. & Lai, M.: Pseudomonas canker of kiwifrut. *Plant Disease*, **67**, 1283–1284 (1983).
9) Panagopolus, C. G., Psallidas, P. G. & Alivizatos, A. S.: Studies on biotype 3 of *Agrobacterium radiobacter* var. *tumefaciens*. *In* Proc. 4th. Int. Conf. Plant Path. Bact., Angers 1978, 221–228 (1978).
10) Phytopath. Soc. of Japan: Common name of economic plant diseases in Japan. Vol. 3 Fruit trees (2nd ed.), Jpn. Plant Protect. Assoc., Tokyo, 1–190 (1984).
11) Sawada, H., Ieki, H. & Takigawa, Y.: Biovars in organisms isolated from crown gall of grape vine in Japan. *Ann. Phytopath. Soc. Jpn.*, **54**, 379 (1988) [In Japanese].
12) Serizawa, S. et al.: A new disease, bacterial canker of kiwifruit. *Ann. Phytopath. Soc. Jpn.*, **51**, 53 (1985) [In Japanese].
13) Shimizu, K. et al.: Studies on the bacterial canker of chestnut tree. (1) Disease occurrence and their symptom. *Ann. Phytopath. Soc. Jpn.*, **51**, 342 (1985) [In Japanese].
14) Karnijianarat S. et al.: Bacteriological characteristics of Pseudomonade isolated from blossom blight of kiwifruit. *Proc. Assoc. Plant Prot. Kyushu*, **31**, 229 (1986) [In Japanese].
15) Suyama, K. et al.: Causal organisms of Erwinia rusty canker of Japanese pear. *Ann. Phytopath. Soc. Jpn.*, **53**, 71 (1987) [In Japanese].
16) Takanashi, K.: Ecological studies on bacterial shot hole caused by *Xanthomonas pruni* (E. F. Smith) Dowson. *Bull. Fruit Tree Res. Sta.*, **A5**, 1–71 (1978) [In Japanese with English summary].
17) Takanashi, K.: Two newly found pathogenic bacteria of peach bacterial shot hole. *Bull. Fruit Tree Res. Sta.*, **A12**, 101–114 (1985) [In Japanese with English summary].
18) Takanashi, K.: Epiphytic survival of *Pseudomonas syringae* pv. *syringae* and pv. *morsprunorum* on twigs of some kinds of stone fruit trees during winter season. *Bull. Fruit Tree Res. Sta.*, **A12**, 115–124 (1985) [In Japanese with English summary].

19) Takanashi, K.: Bacterial canker of Japanese plum caused by *Pseudomonas syringae* pv. *morsprunorum*. *Bull. Fruit Tree Res. Sta.*, A15, 117–125 (1988) [In Japanese with English summary].
20) Takanashi, K. et al.: Studies on the bacterial canker of chestnut tree. (2) Identification of the causal organism. *Ann. Phytopath. Soc. Jpn.*, **51**, 342 (1985) [In Japanese].
21) Takigawa, Y. et al.: Identification of the organism causing bacterial canker of kiwifruit. *Ann. Phytopath. Soc. Jpn.*, **51**, 53 (1985) [In Japanese].
22) Tominaga, T. et al.: Identification of the organism causing bacterial canker of Japanese apricot (*Prunus mume* S. et Z.). *Ann. Phytopath. Soc. Jpn.*, **49**, 627–632 (1983) [In Japanese with English summary].
23) Tamori, M., Higashi, S. & Yamauchi, S.: Diseases and pests of pineapple in Okinawa Prefecture. *Plant Protection*, **25**, 443–448 (1971) [In Japanese].
24) Tanii, A., Tamura, O. & Ozaki, M.: Occurrence of fire blight like disorder of pear (*Pyrus* sp.). *Ann. Phytopath. Soc. Jpn.*, **47**, 102 (1981) [In Japanese].
25) Tanii, A.: Identification of the organism causing bacterial shoot blight of pear (*Pyrus* sp.) and their pathogenicity to pome fruit trees. *In* Proc. of 12th. Conf. Plant Bact. Dis. Phytopath. Soc. Japan, Niigata 1988, 18–23 (1983) [In Japanese].
26) Umemoto, S. & Nagai, Y.: Occurrence of Erwinia rusty canker of Japanese pear. *Ann. Phytopath. Soc. Jpn.*, **50**, 83 (1984) [In Japanese].
27) Watanabe, T.: Diseases of fruit trees and crops in the tropics. Yōkendo, Tokyo, 1–308 (1977) [In Japanese].

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