Soil-Borne Plant Diseases and Their Pathogens in Japan

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Historical view

From old times Japan's agriculture made rapid progress centering around the cultivation of rice, and barley, wheat, rape and certain vegetables were cultured in paddy fields after the drainage as the second crops of rice. It is probable that there were few serious diseases of root under such a condition because the build-up of pathogenic microorganisms in the soil must have been inhibited by the repeated flooding and drainage of soil.

In the 18th century, the dry land farming of tobacco, cotton and mulberry and the intensive cultivation of garden truck were propagated in the central part of Japan, being attended with an increase of root diseases in this region. According to the agricultural classics published in those days, the well known disease of tobaccos and eggplants was the wilt which corresponds to the current bacterial wilt which is known to be caused by *Pseudomonas solanacearum*.

Though the farmers were ignorant of the pathogenic microorganisms at that time, they believed from their experience that the disease was caused by inadequate crop sequence or sick soil and took measures to tackle the problem.

Japan's plant pathology dated from the last decade of the 19th century, and pathologists at that time were interested in two root diseases—the violet root rot of mulberry plants and soil-sickness due to inadequate crop sequence and monoculture. The pathogen of the former has been identified as *Helicobasidium mompa* and studies on this disease are still going on at present.

There is much argument about the cause of soil-sickness. The sickness is caused by *Pseudomonas solanacearum* in the eggplant and by *Fusarium oxysporum* f. *lini* in the flax, respectively. The soil-sickness of upland rice can be prevented by a short-term flooding, which suggests that the occurrence of this disease has relation to the accumulation of toxic substances as well as the changes of microflora and/or nutritional conditions in the soil.[3] But the etiology of the disease can not completely be explained now.

The following were serious soil-borne plant diseases in the past but are minor ones at present: (1) The take-all of wheat formerly did serious damage in the regions of volcanic ash soil, deficient in phosphorus, but it has been decreased by improved fertilization practice. (2) The bunt of wheat is scarcely observed to cause damage after the propagation of resistant varieties. (3) The stripe disease of wheat caused by *Cephalosporium gramineum* first occurred in Okayama Prefecture and spread to various places and was one of the most important diseases of wheat in the past. But now it has become a local disease as a result of the good practice of crop sanitation and a decrease in wheat acreage in infested areas.

Present state

In Japan the agricultural zone is now making a change with industrialization, resulting in the reorganization of upland crop zones, as the coastal areas of the Pacific Ocean in the middle and southern parts of Japan for the intensive cultivation of vegetables, and the other parts especially the northern parts for the production of field and forage crops. Under the circumstances, the cultivation of a certain crop has increased in frequency in an area with increased troubles of soil-borne diseases.

In 1970, a questionnaire was sent to each plant pathologist in various agricultural experiment stations throughout this country to get information on the kinds of important soil-borne pathogens now widely distributed in Japan and on the host plants of the pathogens. The information obtained is summarized in Table 1.

Among these pathogens the ones which have especially risen in importance recently are those causing damage to various vegetables. *Phytophthora melonis*, *P. parasitica*, *P. capsici*, *F. oxysporum* f. *lycopersici* and *F. oxysporum* f. *cucumerinum* are important pathogens attacking garden trucks such as tomatoes, green peppers and cucumbers which are forced during the season from autumn to spring in the southern parts of Japan for supplying throughout the country.

Ecology

Helicobasidium mompa, *Rosellinia necatrix*, *Armillaria mellea* and *Rhizoctonia solani* are soil fungi native in forests infecting the roots of various plants, and some of them survive in soil as saprophytes, colonizing such organic substances as litter.[9] The violet root rot caused by *H. mompa* frequently attacks sweet potatoes, apple trees and mulberry trees in a new upland farm made by clearing forest land or in a field adjacent to a forest. But in such a field the disease ceases 20 to 30 years after clearing the forest, and the white root rot caused by *R. necatrix* becomes dominant in the soil. The decline of violet root rot has some relation to a change in dominance of microorganisms from bacteria to fungi and that in composition of humus substances in soil. *Rosellinia nectarix* is a good competitive saprophyte and grows vigorously colonizing organic

Table 1. Important soil-borne pathogens and their host plants in Japan

Causal microorganisms	Host plants
Erwinia aroideae (*E. carotovora*)	Vegetables (Chinese cabbage, lettuce, etc.) tobacco, konnyaku*
Pseudomonas solanacearum	Vegetables (tomato, eggplant, etc.), tobacco
Agrobacterium tumefaciens	Fruit trees
Plasmodiophora brassicae	Vegetables (crucifers)
Phytophthora spp.	Vegetables (cucumber, pepper, watermelon, etc.)
Pythium spp.	Seedlings of various vegetables, etc.
Armillaria mellea	Conifers (Japanese larch)
Helicobasidium mompa	Sweet potato, mulberry, pear, apple
Rosellinia necatrix	Pear, apple, mulberry, tea
Fusarium oxysporum f. spp.	Vegetables (Solanaceae, Cucurbitaceae, Crucifers)
Fusarium solani f. spp.	Beans, etc.
Rhizoctonia solani	Vegetables and various crops
Sclerotium rolfsii	Leguminous (peanut, soybean, etc.), flowering plants, konnyaku*
Verticillium albo-atrum	Eggplant

* *Amorphophalus konjac* KOCH

substances in soil.[7]

Therefore, the white root rot disease becomes serious where a heavy amendment of brush wood was made in the soil of a pear plantation to supply organic matter for the purpose of improving soil.[1]

The *Armillaria* root rot is one of the most important diseases in Japanese larch plantations in the northern part of this country. It causes severe damage to the plantation on a mountainside where the soil is temporarily or seasonally very humid after the thawing of snow, because a high moisture level of soil makes the roots of larches susceptible to the invasion of the fungus.[5]

Rhizoctonia solani causes the seedling damping-off in many plants and the foliage blight of various crops, especially of leguminous crops in a humid summer climate. In the sugar beet zone of this country, the crop suffers heavily from the crown rot caused by the same fungus. *Rhizoctonia* in Japan is classified into six groups according to the cultural type and their pathogenicity.[10]

The Fusarium yellows of Japanese radishes caused by *Fusarium oxysporum* f. *raphani* do lighter damage in the so-called 'Kuroboku' soil (ando soil-black) than in others because 'Kuroboku' soil is unfavorable for the survival and build-up of the fungus.[2]

A severe injury of seedlings after the amendment of green manure is a phenomenon generally observed in northern regions, and it has been made clear that the primary cause of the injury is attributed to a burst of *Phythium* sp., mainly *P. ultimum*, at the beginning of the decomposition of green manure applied.[6]

Pseudomonas solanacearum is surviving deep in the sub soil where antagonistic microorganisms are very rarely found. When host roots reach the sub soil, the bacteria begin to multiply in the rhizosphere of the host plants and then invade the roots.[4]

Erwinia aroideae (*E. carotovora*) multiplies at first in the rhizosphere, but later in the phyllosphere. The bacteria show a marked increase in number in a part of the surface soil where Chinese cabbages come into contact with the soil by petioles of the outermost leaves in the wrapping stage, because the bacteria multiply utilizing amino acids and sugars which are exudated from the host plants and markedly higher in concentration there than in other parts of the surface soil. In addition, that part of the surface soil is shaded by the leaves of Chinese cabbages and maintains a moisture level suitable for the growth of bacteria.[8]

Control

Among the cultivating techniques developed in Japan, there are useful for the control of root diseases. The cultivation of fruit vegetables, as tomato, cucumber and eggplant, by means of grafting, the cultivation of vegetables in paddy fields after the harvest of rice, especially the cultivation in winter in simple greenhouses with plastic film—so-called vinyl houses which are set up every year in paddy fields after the drainage in warm districts, the paper tube transplanting system used for the cultivation of sugar beets in the northern parts.

The use of grafted seedlings is an excellent method for the prevention of the vascular wilt disease caused by such a highly specialized parasite as *Fusarium oxysporum*.

For this purpose resistant or immune varieties or related species are used as stocks for scions from susceptible varieties to be cultivated. Good examples of such stock-scion combinations are: white-flowered gourd or white gourd-water melon; squash-cucumber; resistant melon-musk melon; *Solanum integrifolium*-or *S. acuteatissium*-eggplant. The last combination is in use for protecting eggplants against the bacterial wilt caused by *P. solanacearum* as well.

The regions south of the isothermal line of 5°C in winter, that is, the coastal regions of the Pacific Ocean south of the middle part of Japan are the principal places of truck farming from autumn to spring.

In these regions, vegetable cultivation is economically so valuable that rice culture has

been considered to be of secondary importance being rather a measure for destroying soil-borne pathogens.

But contrary to expectation, the pathogens can not completely be destroyed by such a short period of flooding, and the level of inoculum increases every year as a result of the repeated cultivations of the same vegetables. There are many examples showing that soil fumigation is necessary in recent years even in the vinyl houses.

The steam sterilization of soil is not yet in wide use and soil fumigation with chloropicrin or methyl bromide is mainly practised. The use of grafted seedlings is sometimes necessary to be adopted in combination with soil fumigation because of the rapid recovery of *Fusarium* and *Pseudomonas* in the fumigated soil.

Sugar beets are cultivated only in Hokkaido, and more than half of them are planted by the paper tube transplanting system there as follows: Seeds are sowed in the soil treated with PCNB or Dexon and contained in paper tubes. Seedlings are grown in frames in early spring when the temperature is still low. When the seedlings have reached their proper growth, they are planted in the field with a transplanting machine as they are in the tubes.

Though this system principally aims at starting the cultivation of beets as early as before the thawing of snow to prolong the growing period of beets, it enables us to control adequately the damping-off of best seedlings as a result of soil treatment with chemicals. It also keeps diseased seedlings from coming into the field.

In addition, it reduces the attack of nematodes on the seedlings because of the use of nematode-free soil. Actually, northern root knot nematodes now show a remarkable decrease in population in the soil of a field where they were very densely populated before.

Conclusion

In Japan, until 10 to 20 years ago studies on plant diseases were mainly carried out in rice plants and enabled us to control the rice blast, etc. with the development of excellent fungicides and new controlling techniques. Foliage diseases can be controlled now in various crops as well. It is said, accordingly, that among the plant diseases which are caused by fungi and bacteria a group of diseases left uncontrolled are soil-borne ones.

As mentioned in the paragraph on control, we have succeeded to a certain extent in controlling this group of diseases mainly in intensive crops and seedlings until now. For the control of soil-borne plant diseases in field and plantation crops, integral methods should be considered on the basis of the biology of respective root diseases and the fundamental ecological knowledge of the pathogens or related soil organisms as well as the production of disease-resistant cultivars. And we are confident that if studies are continued as mentioned above, the results will be applied to the control of these diseases.

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