RESEARCH ON RICE VIRUS DISEASES IN CHINA

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ABSTRACT

As a result of investigations, a total of 11 virus and virus-like diseases of rice, namely, yellow dwarf, dwarf, transitory yellowing, black-streaked dwarf, stripe, grassy stunt, bunchy stunt, ragged stunt, orange leaf, tungro and gall dwarf have been described. Among them, the causal agents of transitory yellowing and bunchy stunt were first identified and confirmed in China. The former occurred seriously in Taiwan, Yunnan, Guangxi, Guangdong, Fujian, Jiangxi, Hunan, Hubei, Zhejiang, Jiangsu, Shanghai, Anhui and Sichuan provinces, and the latter occurred only in some parts of Fujian, Jiangxi, Hunan and Guangdong provinces in China. As far as the distribution and the damage caused by these diseases are concerned, transitory yellowing and dwarf are the most important. This report also deals with the advances and problems in the ecology, variety resistance and integrated control of rice virus diseases in China, and outlines some of the aspects which should be emphasized in the future.

Introduction

Virus diseases of rice were recorded long ago in China. However, it was not until the early 1960s that the diseases were comprehensively studied when transitory yellowing and black-streaked dwarf occurred seriously in the south, the southwest and the east of China respectively. Since then, a series of spectacular results have been obtained in the investigations on disease incidence, etiology, ecology, variety resistance and integrated control. This report deals with the progress made in the research into rice virus diseases in China.

Occurrence of the diseases

Up to the present, a total of 16 virus and mycoplasma-like diseases of rice have been recorded in the world, 11 of which, namely, yellow dwarf, dwarf (RDV), transitory yellowing (RTYV), black-streaked dwarf (RBSDV), stripe (RSV), grassy stunt (RGSV), bunchy stunt (RBSV), ragged stunt (RRSV), orange leaf (ROLV), tungro (RTV) and gall dwarf (RGDV), have been observed in China. It should be pointed out that the diseases were gradually recognized due to the large number of investigations carried out by many scientists. Some of the diseases, such as those caused by RBSV, RRSV, ROLV and RGSV, were not studied until they became epidemic and caused considerable loss. The diseases appear to show geographic limits. The geographic relation between China and her neighboring countries or districts, especially those in South and Southeast Asia, and the similarity of insect vectors should be considered in the investigation of rice virus diseases regarding their distribution.

It is anticipated that new viruses are likely to be introduced into China with the long distance migration of viruliferous insect vectors. In addition, some particular viruses may appear due to the large area under rice cultivation, the cultivation of many kinds of crops, the complexity of the cropping systems, geographical conditions and ecological environment in China. Therefore, it is necessary to further promote investigations on rice virus diseases in China.

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Diagnosis of the diseases

The diagnosis of the diseases was mainly based on biological tests with inoculation experiments. Meanwhile, electron microscopy and serological tests were employed to supply further evidence in the analyses and conclusions reached. In detail, the diagnosis of the above-mentioned 11 diseases was primarily based on the symptoms of rice plants, modes of transmission, species of insect vectors and particles of viruses. Some of them were comparatively diagnosed by studying the resistance of the virus *in vitro,* host range and serology. However the number of biochemical experiments was somehow limited.

Both bunchy stunt and dwarf were found to be caused by spheroidal virions, and could be transmitted by *Nephotettix cincticeps* and *N. virescens.* They were persistent. RBSV, howeer, did not display transovarial transmission in its insect vectors, and could not be transmitted by *Recilia dorsalis,* one of the vectors of RDV. In addition, RBSV was not serologically related to RDV (Xie *et al.,* 1981), and had a very narrow host range. Among the 18 species of gramineous plants tested, only rice plants were infected, while *Echinochloa crusgalli, Alopecurus aequalis, Poa annua, Leersia hexandra, Setaria viridis, Paspalum thunbergii* and so on, the hosts of RDV, were immune to RBSV (Xie *et al.,* 1982b). The dilution end point of RBSV ranged between 10^{-4} and 10^{-5} for the sap of diseased leaves, between 10^{-3} and 10^{-4} for the extract of viruliferous insects.

The thermal inactivation point ranged between 60 and 70°C for 10 minutes. The virus *in vitro* remained infectious for 4—5 days at 4°C, and for 2—3 days at 22°C. Such properties of RBSV, especially the thermal inactivation point and longevity *in vitro* were apparently different from those of RDV (Xie *et al.,* 1983b).

Gall dwarf, ragged stunt and black-streaked dwarf appeared with some similar symptoms, but differed in the symptoms on the outer surface of vein swellings and respective insect vectors (Faan *et al.,* 1983; Xie *et al.,* 1980). Results of tests using immunoelectron microscopy and ELISA showed that RRSV in China was similar to that observed in the Philippines, as far as the morphology and serology are concerned (Milne *et al.,* 1981).

Tungro and transitory yellowing appeared with little difference in symptoms in the fields and could hardly be differentiated *in situ.* Both could be transmitted by *N. virescens* and *N. cincticeps,* but RTV also had another insect vector, *R. dorsalis,* and RTV did not persist and multiply in its insect vectors, while RTYV did. In addition, they were different in their morphology and serology (Xie *et al.,* 1982a). Thus, it is easy to distinguish them based on the characteristics described above.

Orange leaf was generally considered to be caused by a virus or by a MLO. With electron microscopic scanning and the response to tetracycline, it could be demonstrated that the disease was caused by a virus (Lin, *et al.,* 1983).

The morphology of RSV and RGSV has not been studied extensively in China. Wilted stunt had been reported in Taiwan, China and has recently been found to be caused by a virus similar to RGSV 2 (Hibino, 1983). Based on its biological characteristics and other data, we believe that the virus may be a strain of RGSV.

Ecological studies on the diseases

As far as double-cropping of rice in China is concerned, the occurrence of some main diseases in the 2nd rice crop appears to be more serious than that in the 1st rice crop. In general, little damage is caused by the diseases in the 1st rice crop (Xie *et al.,* 1980, 1982b, 1983a). Such a situation indicates that virus infection is related to ecological factors. All the rice viruses found in China are transmitted by leafhoppers or planthoppers. The infection and pathogenicity of the viruses require a relatively high temperature. The older the rice plants, the lower their susceptibility to viruses (Chen *et al.,* 1981; Lin *et al.,* 1983; Milne *et al.,* 1981; Ruan *et al.,* 1982; Xie *et al.,* 1980, 1981, 1982b, 1983a). Although rice plants in the seedling and green recovering tiller stages are quite susceptible to virus infection, the temperature at this time is unfavorable to the infection, multiplication and pathogenicity of the virus, and very few insect vectors can emerge also due to the lower temperature in the 1st rice crop. Whereas, as the temperature is higher in the 2nd rice crop, the total number of leafhoppers and planthoppers or the number of viruliferous insect vectors becomes much higher than that in the 1st crop. When the host rice plants are infected, the multiplication and pathogenicity of the virus are promoted and the diseases may even become epidemic at this time. Thus, the forecasting and control of rice virus diseases should focus on the 2nd rice crop in South China.

Here, the first problem is the virus source. Generally, there are two sources of rice viruses: infected plants and viruliferous insect vectors. Regarding the host, some viruses may infect many plant species, for instance RBSDV has been known to infect 28 plant species, with 16 of them being found in China including the newly-recorded *Polypogon fugas*; 37 plant species were found to be the hosts of RSV, 8 of them being found in China; 39 plant species were known to be the hosts of RDV, 28 of them, including 23 newly-recorded species, being found in China (Rue *et al.*, 1982). But other viruses, e.g. RBSVand ROLV, appeared to infect rice plants only. However, there may be some host plants which have not been identified due to the lack of research or virus variation. For instance, with the exception of rice plants, no other host plants of RTYV had been detected (Faan *et al.*, 1980) until *Panicum maximum* and *Leersia hexandra* were confirmed recently also to be the host plants in China. In addition to the 7 species of host plants of RRSV reported (Milne, 1982), 7 others were also recently confirmed (Lin *et al.*, 1984). Thus, it is necessary to gain more information on the host range of the viruses, as well as on how the viruses overwinter and multiply in their hosts. As regards the insect vectors, a total of 11 viruses found in China are transmitted by leafhoppers or planthoppers. They are frequently "the hosts" of most viruses except one. The viruses may multiply and even become transovarial in their insect vectors. They are both "the store-sources" and transmission vectors of the viruses. The viruliferous insect vectors are considered to be the only source of infection if perennial plants are not the overwintering hosts of some viruses in large rice cultivation areas, especially in those places where rice ratooning and annual weeds can not overwinter. Obviously, vectors as the hosts of viruses are frequently affected by viruses. This phenomenon is characterized by the following aspects: 1) cytological distortion often takes place in the tissues of viruliferous insects so that the life-span of the insects becomes shorter, and fewer ova are produced; 2) viruliferous offsprings from infective females often die in the nymphal stage. This fact may explain why some viral diseases could hardly become epidemic year after year in the same area.

The second problem is transmission. In China, one insect or at least two insect species may transmit 5 viruses or 6 viruses. Even so, the compatibility of a given virus with different insect vectors is different. For instance, the transmission rate of *N. virescens* for RTV was highest, *N. cincticeps* moderate and *R. dorsalis* the lowest in China (Xie *et al.*, 1982a). The insect vector of a virus may be different depending on the virus strains or the biotypes of the vector. EDV, for example, which was not transmitted by *N. virescens* in Japan, has been found to be one of the important vectors of RDV in China. The transmission efficiency of a given insect for a virus may vary with the age or sex or the insect. For instance, RTYV was transmitted more efficiently by the nymphs or females of *N. cincticeps* than by the adults or males. Some viruses, e.g. RDV and RSV, may display a different infectivity due to the vectors which may originate from various regions, such as diseased and non-diseased rice areas. But the other viruses, e.g. RTYV and RBSV did not show such differences, and once their insect vectors acquire the viruses, the transmission efficiency would very high (Xie *et al.*, 1984). This suggests that it is possible at present for the diseases to spread and become epidemic as long as the insect vectors encounter relevant virus sources in the so-called non-diseased rice areas. Thus, we must be alert for the possible outbreak of the diseases in the non-diseased rice areas where the vectors of the viruses swarm.

Besides, a series of studies on the biotic and abiotic factors influencing the multiplication, activity and transmission of insect vectors has been carried out in order to identify the key factors responsible for the epidemiology of some important virus diseases together with ways for forecasting, preventing and controlling the diseases. All these led to good results in field disease control. In testing the percentage of viruliferous insect vectors by serological methods ELISA is especially sensitive and specific, and the correlation with the rate of viruliferous vectors of RDV reached more than 92.7% (Xu *et al.,* 1983). This made the forecasting more exact and timely.

The modification of the cropping systems usually results in a change in the ecology of insect vectors, and promotes the occurrence or outbreaks of virus diseases. The outbreak of RBSDV in Shanghai in 1966 was considered to be closely related with the presence of large areas devoted to wheat cultivation. Since 1970, along with the promotion of triple cropping from double cropping, barley took the place of wheat and the acreage under wheat cultivation has decreased while the acreage under barley and highland barley planting has expanded. Thus, RBSDV was checked and is no longer epidemic because large numbers of planthopper vectors failed to emerge and migrate in time, and were either wounded or killed.

The major factors associated with insect activity and disease epidemic are the schedule of crop sowing and transplanting. For instance, the occurrence of RTYV in the fields where seedlings were transplanted during the hot season was more serious than that in the fields where seedlings were transplanted at the beginning of autumn in Guangdong, Guangxi, Hunan, Hubei, Anhui, Jiangxi and Zhejiang provinces in China. Observation in Fujian province showed that the rice plants transplanted in the early part of July were more frequently infected by the disease than those transplanted in mid-July.

Research on the resistance of rice varieties

For the past 10 years, more than 10,000 varieties/line/hybrid combinations of rice have been tested in accordance with their resistance to the major viruses and their vectors, and a stock of resistant varieties/sources has been selected in China (Ruan *et al.,* 1984; Xie *et al.,* 1982c, 1983a). Among the selected varieties, Chikuai 3 was resistant to RTYV, RDV, RSV, RTV and *N. cincticeps;* Cuba 154 and Kaladumai were resistant to RTYV, RDV and *N. cincticeps;* Boluoai, Baikeai, 691, Guangerai 5, Banna 2, Chaiyeching 8, Shuihum, Cuba 198, IR 29, IR 1110-20, Siyou 4 and Shanyou 4 were resistant to RTYV; Tetep, IR 26, IR 36, IR 880, etc. were resistant to RDV; Baotaiai and Zhenlong 13 were resistant to RBSV; Chikuaixuan and Sannong 3 were resistant to RRSV; IR 30 and Zhenlong 13, etc. were resistant to *N. cincticeps,* many of which, such as Boluoai, Chikuaiai 3, Banna 2, Minwan 6, Siyou 4, Shanyou 4 and Shanyou 30, etc., have been disseminated for large scale production in the diseased rice areas.

The investigations (Xie *et al.,* 1982c) showed that the resistance of most rice varieties to various viruses was not identical, reflecting their control by various genes. Thus, it is very important to keep in mind the reaction of major viruses in specific local areas, and avoid hit and miss so as to breed and exploit the resistant varieties.

The differentiation of virus pathogenicity is also an important cause of the breakdown of the resistance of a plant variety. A study on the differentiation of RDV pathogenicity in Jiangxi province (Shyu *et al.,* 1979) indicated that Cuba 154 and Hongkenuo were resistant in comparison with the strains from Changsha, Anging, Kunming, Sha country and Nanchang, but rather susceptible to the strain from Shangrao. Also, Tetep had been tested and found to be resistant to RDV in several Fujian areas for several years, but the results of the experiments in 1983 showed that it was not resistant to the strain from Ningde of Fujian. Thus, efforts must be made to identify the developing tendencies of virus strains in exploiting the resistant varieties and breeding for resistance.

In breeding for resistance, emphasis must be placed on breeding for resistance to several diseases and pests in accordance with the achievements of rice yield. In spite of the difficulties, such undertakings are possible so long as the researchers can select suitable materials and combine them step by step with those useful resistance genes together with the rice plants.

Integrated control of the diseases

Since 1973, studies on the ecology of the major viruses of rice plants and their vectors have been undertaken. Experiments on integrated control were promoted on a large scale in the whole country. A set of technical measures for integrated control under the concept of "Agricultural control as a basis, preventing diseases from controlling pests in time" has been gradually developed. These measures have played an important role in the management of the diseases and improvement of rice yield. According to the incomplete statistics from Hunan, Hubei, Zhejiang, Yunnan, Anhui and Fujian proviences, the total acreage of 90,000,000 mu under integrated control results in a harvest of more than 600,000,000 kg. The primary measures for integrated control are: 1) Long-term and short-term forecasting of the diseases was carried out intensively in accordance with the ecological systemic characteristics of the major viruses and their vectors as well as natural enemies in the respective regions; 2) Rice varieties which are resistant to diseases and pests and are also high-yielding and adaptable to the local environment were planted; 3) The arrangement of rice crop and the time of sowing and transplanting were adjusted so as to avoid the migration peak of insect vectors; 4) A given variety was grown in pieces together, and cultivation techniques were improved; and 5) Chemicals were employed to control insect vectors when it was necessary, especially in the overwintering stage, the period between summer harvesting to transplanting or seedling to green recovering tiller stage.

In order to achieve effective control of the diseases, further research on integrated control relating to the ecological system of the viruses should be carried out. Much work has to be done in the development of techniques for integrated control. For instance, better coordination of control measures, emphasis on the key measures and improvement by learning the successful experience gained in various areas. Aside from the most serious virus diseases and their vector(s), trials including the resistance to other diseases and pests such as blast, bacterial leaf blight, sheath blight, leafhoppers and planthoppers of rice, as well as the characteristics of potential high yield must be considered in the selection, breeding and dissemination of rice varieties. If the time of sowing and transplanting is well regulated, the migration peak of insect vectors can be avoided and the last heading time can be guaranteed. Chemicals employed to control insect vectors effectively should at the same time not be too harmful to the natural enemies. Such measures must be taken into consideration if the success of integrated control of rice virus diseases in China is to be achieved.

References

1) Chen, C. C. and Chiu, R. J. (1981): Rice ragged stunt and its effect on the growth of rice plant. Plant Prot. Bull. (Taiwan), 23(2), 67-75.
2) Faan, H. C. and Pui, W. Y. (1980): A preliminary investigation on the primary source and transmission of rice yellow stunt in Kwangtung. Journal of South China Agricultural College, 1(1), 3-20.
3) Faan, H. C., Zhang, S. G., He, X. Z., Xie, S. D., Lin, C. Z., Zhou, L. G., Liu, X.R. and Zhu, D. (1983): Rice gall dwarf - a new virus disease epidemic in the west of Guangdong Province of South China. Acta Phytopathologica Sinica, 13(4), 1-6.
4) Hibino, H. (1983): Rice grassy stunt virus 2: Current research and future plans. A paper presented at the IRRC, 18-22 April 1983, p.1-5.
5) Lin, Q. Y. and Xie, L. H. (1983): Studies on rice orange leaf disease. Journal of Fujian Agricultural College, 12(3), 195-201.
6) Lin, Q. Y. and Xie, L. H. (1984): On the host range of rice ragged stunt virus. Acta Phytopathologica Sinica, 14(4), 247-248.
7) Milne, R. G., Luisoni, E., Zhou, L. K. and Ling, K.C. (1981): Morphological and serological similarities of rice ragged stunt virus samples from China and the Philippines. Int. Rice Res. Newsl., 6(1), 11-12.

8) Milne, R. G. (1982): Rice ragged stunt virus. CMI/AAB Descriptions of Plant Viruses, No. 248, 1-5.
9) Ruan, Y. L., Tin, D. D. and Lin, R. F. (1982): On rice dwarf virus disease III. Host range. Acta Phytopathologica Sinica, 12(1), 1-6.
10) Ruan, Y. L., Lin R. F. and Chen, S. X. (1984): Studies on the integrated control of rice yellow stunt and rice dwarf disease in China. Scientia Agricultura Sinica, (1), 75-78.
11) Shyu, C. Y. and Wei Yu. N. (1979): A preliminary study on the difference in virulence of rice dwarf virus. Acta Phytopathologica Sinica, 9(2), 143-146.
12) Xie, L. H. and Lin, Q. Y. (1980): The ragged stunt disease, a new record of rice disease in China. Acta Phytopathologica Sinica, 10(1), 59-60.
13) Xie, L. H., Lin, Q. Y. and Chen, Z. X. (1981): Rice bunchy stunt, a new virus disease. The paper presented at the IRRC 1981, Los Banos, Philippines, p.1-7.
14) Xie, L. H. and Lin, Q. Y. (1982a): The occurrence of rice tungro disease (spherical virus) in China. Journal of Fujian Agricultural College, 11(3), 15-23.
15) Xie, L. H., Lin, Q. Y. and Zhu, Q. L. (1982b): On the bunchy stunt disease of rice. II. The distribution, loss, host and overwintering of rice bunchy stunt. Acta Phytopathologica Sinica, 12(4), 16-20.
16) Xie, L. H. and Lin, Q. Y. (1982c): Studies on the resistance of rice varieties to viruses. Journal of Fujian Agricultural College, 11(2), 15-18.
17) Xie, L. H., Lin, Q. Y., Zhu, Q. L. Lai, G. B., Chen, N. Z., Huang, M. L. and Chen, S. M. (1983a): On the occurrence and control of rice tungro in Fujian. Journal of Fujian Agricultural College, 12(4), 275-284.
18) Xie, L. H. and Lin, Q. Y. (1983b): On the bunchy stunt disease of rice. III. Stability in vitro and distribution in host of rice bunchy stunt virus. Acta Phytopathologica Sinica, 13(3), 15-19.
19) Xie, L. H., Lin, Q. Y., Xie, L. M. and Nai, G. B. (1984): On the bunchy stunt disease of rice. IV. The experiments of occurrence, development and control of rice bunchy stunt. Acta Phytopathologica Sinica, 14(1), 33-38.
20) Xu, W. J. and Hsiung, L. M. (1983): The pathogens of some virus diseases of cereals in China. XI. Application of ELISA to the determination of the percentage of active individuals in a population of insect vectors transmitting the rice dwarf disease. Acta Biochimica et Biophysica Sinica, 15(4), 367-371.

Discussion

Ishikura, H. (Japan): As you may know, agricultural authorities from China and Japan are engaged in a collaborative research project on the long-range flight of the brown planthopper and white backed planthopper which was initiated in 1981. This year two brown planthoppers released from China were detected in Japan. The information you presented on the virus-vector relationship is most important as there is a possibility in future of incidental introduction of viruses that occur in China but not in Japan through the migrations of insect vectors such as leaf-and brown planthoppers.

Saito, Y. (FFTC)*: Your report is most informative because your country lies betwen the tropics and the temperate zone.

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