水稻病毒：病理学与分子生物学

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序

我的科研兴趣始自大学三年级（1957），当时有幸被分配到省外的一个地方国营农场进行为期3个月的生产实习。在按实习大纲要求，并以技术员助手身份参加水稻生产、管理的过程中，遇到的一个突出问题就是稻瘟病。那些成片的水稻，虽然经过了严格的种子消毒，以及生长期中多次喷药，但仍然发病严重，几乎所有品种都不能幸免。期间，我注意到，在同一品种、同一病田中总能找到一些完全没有发病的健康植株，这些健株往往是长在耙地不平而露出水面的较高土块上，或是施肥不匀的长势“较差”（叶不披、色不黑）的稻株。这个现象似可说明在水稻栽培和田间管理过程如能做到适度控水、控肥，让植株长势适中，则有可能达到控瘟的效果；此外，我不得不怀疑自己所学的，也就是一些教材所写的有关此病防治的提法——“以消灭菌源为前提，以选用抗病品种为基础，以耕作防治为中心，以喷施药剂为保证”——的可靠性和科学性。很明显，稻瘟病菌越冬易、来源多、传播快、发病（面）广，要彻底消灭很不现实；选用抗病品种无疑是最经济有效的，但当时抗病品种不多，能抗病又高产的更少，且多数抗病品种易受气候、土壤和肥水条件左右；耕作防治牵涉面广，针对性差；喷施药剂问题更大，一是当时所用农药西力生、赛力散均系剧毒有机汞剂，二是早稻保穗施药关键时期均系南方雨季，难以实施。针对这些问题，结合农民生产经验和自己亲身感受，我写了《试论水稻的抗瘟性问题》（即后来的《论稻瘟的免疫》），提出“栽培免疫是迅速解决当前稻瘟问题的主要途径”，此文后被收入我国第一本《植物免疫学》统编教材中的第九章（农业出版社出版，1961）。20世纪60～70年代我有两次（各3年）长驻农村参与水稻生产的机会，充分运用这一“栽培免疫”理论，取得了很大的成功：既节省了农药、劳力成本，又确保了水稻丰收。特别是稻瘟病大发生的1971年，整个三明地区损失严重，而我们驻扎管理的整个大队（110多公顷）在不施或很少施用农药的情况下，却被摘去了历史上的“稻瘟病窝”帽子，获得了空前的高产，引起了附近数县农民的关注。

20世纪50～60年代生产上的另一突出问题是小麦秆锈病，在福建仅1950～1965年，就大发生过5次，其中1958年为大流行年，重者颗粒无收，轻者减产4～5成。于是我主动参加了这项研究，搞了许多田间调查和品种抗性鉴定。根据当时的普遍看法是小麦秆锈病菌在福建不能越夏，在东北（春麦区）不能越冬，福建沿海是主要越冬区，越冬菌源于每年3～4月随东南风经闽北—江西—浙江—淮南—淮北—胶东—东北麦区。这样，只要找到越冬基地，使其南下的越夏菌原难以立足，就有可能解决我国小麦秆锈病问题。问题是：越冬基地在哪里？通过1959～1960年、1963～1965年的实地调查，发现福建最早发病的地区既不是在福建最南部的几乎无冬的诏安，也不是在福建南部的基本无冬的漳州、泉州，而是在福建中部的靠近福州的莆田。其主要原因是这里有极早播的“八月麦”（年糕麦），这些麦田往往于10底

至11月初即有发病中心，至12月上中旬已普遍发生。莆田以南地区虽气候暖湿，更加有利发病，但因播期明显推迟，南下菌原未有合适的寄主。因此，我提出不种“八月麦”，以切断菌原越冬桥梁的设想，得到了当地领导的支持，并付诸实施。从1967年后，30多年来我国小麦秆锈病未出现大面积流行，而福建省也未见有损产量的小麦秆锈病，特别是近10年来，此病已几无踪迹。

20世纪60～70年代，水稻病毒病肆虐我国南方稻区，给水稻生产造成严重威胁。为了对付这类病害，我国先后成立了华东地区水稻病毒性矮缩病协作组和全国水稻病毒病科研协作组，在有关部门的支持和老一辈植病学家的指导下，大家齐心协力，取得了很大的成绩。

我于1972年开始从事水稻病毒病的研究，并积极参加了一年一度（1972～1979）的全国水稻病毒科研协作会议，每次会议都能得到许多老先生和同行的鼓励、教诲和帮助，确实获益不小。自1973年以来，我和我的课题组及研究生们，前后深入我国南北稻区的22个省（市、区）和福建的63个县（市、区），开展了水稻病毒病的系统调查和研究，取得了如下主要成绩：

1. 通过病原鉴定和病原生物学-病毒病理学研究，弄清了我国发生的水稻病毒有10种，其中水稻簇矮病毒（RBSV）是一种新病毒，水稻齿矮病毒（RRSV）、水稻东格鲁球状病毒（RTSV）和水稻东格鲁杆状病毒（RTBV）系中国新记录，并发现二点黑尾叶蝉（*Nephotettix virescens*）是水稻矮缩病毒（RDV）的一种新介体。

2. 弄清了上述10种病毒在我国的地理分布和几种主要病毒病害的流行特点，建立了可于发病前40～50天和90～100天针对国内两种经济损失最大病毒［RDV和水稻暂黄病毒（RTYV）］的监测体系，从而使监测工作直接为病害综合防治服务。这一结果已被国家农业部采纳作为全国县级中心测报站推广使用。

3. 确立了水稻病毒病的一个实用的监控技术对策——结合病情预测，坚持抗、避、除、治的“四字原则”。其中仅抗性品种即鉴定出抗病、抗虫品种和抗源材料25个。

这些成绩，尤其是对我国水稻病毒病理学的系统研究，和RBSV及RDV新介体的发现，为国内外同行所关注，前后三次应邀参加国际学术会议作特邀报告（其中两次被选为会议主席），有关论文被ICTV和VIDE数据库及多种病毒学、植物病理学专著、教科书及重要学术刊物引用，获得了多项科技成果，产生了重要的社会影响和经济效益。

4. 近年来，我们主要集中在水稻条纹病毒（RSV）、水稻草矮病毒（RGSV）和RDV的分子生物学特性研究上。先后完成RSV和RGSV的部分基因组全序列分析，对CP、SP基因功能和表达调控有了比较深入的研究；比较全面系统地研究了我国RSV的分子演化及其与寄主水稻和介体灰飞虱的互作关系；培育出抗RDV、RGSV和RSV的转基因工程水稻，部分植株表现高抗，且单株后代抗性遗传稳定。

5. 推动了学科博士点和博士后流动站的建设，培养了一批高层次人才。

21世纪是科学技术突飞猛进的世纪，是人与自然不断协调的世纪，在农业生产和经济建设中新的问题将层出不穷，只有不断学习，积极探索，才能跟上时代的需要。

本书收集的论文，基本上反映了我和我的课题组及研究生们近30年来有关水稻病毒病理学与分子生物学的研究工作。本书的出版是应学校党政领导的盛情邀约，作为母校65周年华诞的一个纪念。几十年来，在我的教学与科研工作中，始终得到各级党政领导的关怀与支持，

以及校内外老前辈和同行的鼓励与帮助；在本书编辑出版过程中，福建农林大学学报编辑部蒋元霖副编审等许多同志做了大量工作，谨此一并致以衷心的感谢！

谢联辉

2001年9月1日

PREFACE

It is in my college junior year in 1957 that I developed an interest on scientific researches from the time when I had a field practice for three months in a local government-owned farm. During that time, I participated in the work as a technical assistant, and met an important problem, rice blast. In a very large area, almost all varieties of rice suffered from this disease though there were strict seed-sterilization and several sprays of fungicides during rice growth. I noticed, however, that there were some rice plants free of disease as these plants were almost grown on some patches with higher soil level due to uneven plow, or that received less fertilizer growing relatively poor (light green, and straight leave). These phenomenons indicated that it might be possible to control rice blast by applying a good management of water and fertilizer usage during rice growth in a field. Meanwhile I had to question what I had learned about the control of rice blast, which was described in some textbooks. I wondered if there was scientific standing and real practical application in terms of the strategies: "To eliminate pathogen sources as a prerequisite, to use resistant varieties as a basis, to have good farming practice as a foundation, and to spray chemicals as a supplement. "It was apparent that rice blast pathogen was easy to go over winter, spread fast and the disease normally occurred in a large scale of fields. Therefore, it was impossible to control this disease completely. Of course, the most effective and economic way is to use resistant varieties for disease control. However, there were then not many varieties available, and even fewer varieties with resistant and high yield, of which the majority was easily affected by climate, soil condition, and water and fertilizer management. In terms of farming practice, it covered so many factors that it was hard to find which factor was more useful. In terms of chemical control, it had a lot more problems, such as the chemicals Ceresan (Ethylmercuric chloride, EMC) and Agrosan (Phenylmer-curicacetate, PMA) that are organic compound of mercury. Not only were they very toxic, but also were there little effect for preventing rice heads from infection due to raining season in the south. Upon these problems, and in combined farmer's experience with my knowledge, I wrote a paper "Opinions on current problems of rice blast"i. e. later "The immune to rice blast". In which, I proposed, "It was main approach to control rice blast by using good cultivation management." This paper was later published in the nationwide-adapted textbook (National Agriculture Press, 1961). In 1960—1970's, I had twice opportunities to work in countryside for three years each. By applying "the immune from field practice" theory, we were very

successful in control of this disease, i. e. not only did it reduce pesticide usage and labor costs, but also did it guaranty a great harvest. Especially in 1971, rice blast caused severe losses in the whole Sanmin city, Fujian, China, except the village where I lived because the application of my theory. We had a historical high yield harvest with a little usage of fungicides, and got rid of the nickname of "rice blast village", and caught farmers' attention in several neighbor counties.

In the 1950 — 60's, another key problem was wheat rust. During 1950 — 1965, the disease had been epidemic for 5 times, especially, in 1958, it caused 40% — 50% yield reduction, and some even up to 100%. Therefore, I participated in the research, working on field investigation and screening for resistant varieties. There was a popular hypothesis that wheat rust fungi did not go through summer in Fujian, and winter in Northeast (Spring wheat), but survived along the coast of Fujian during winter. During March to April, the pathogen source then spread from Northern Fujian to Jiangxi province then further north to Zhejiang province, Huainan, Huaibei, Jiaodong, and finally reach to wheat growth region in Northeast of China. Therefore if we could find out where the pathogen survived during the winter in Fujian, and eradicate the resource for its surviving, we would be able to solve the wheat rust problems. After field investigations in 1959 — 1960 and 1963 — 1966, we found that the disease did not occur first in the so-called no winter county Shaoan, and in almost no winter cities, Zhangzhou, and Qunzhou, but in the Central Putian city near Fuzhou. The main reason was that there was early growing cultivar called as "August Wheat", and initial disease center appeared in the end of October to early November, and the pathogen spread out in December. In the region to the South of Putian, though it was warm with high humidity favored by the pathogen, the pathogen didn't have host plants because of late sowing of wheat. Therefore, I proposed that it is essential to cut off the pathogen winter source by stopping growth of "August Wheat", and which was carried out with official support. Since 1967, the wheat rust has not been epidemic for more than 30 years, and caused little yield loss in Fujian, especially in recent 10 years.

In the 1960—1970's, rice virus disease were widely spread in the south China, causing severe losses of rice production. To control these diseases, we organized a workshop research on rice dwarf in eastern China, and nation-wide collaboration research on rice virus diseases. With official support and the guidance of pioneer plant pathologists, we coordinated our efforts, and achieved our primary goals.

I began my research on rice virus diseases in 1972. I actively participated annual conference of nation-wide collaboration research on rice virus diseases in 1972 — 1979. Each meeting, I benefited a lot from many pioneers, including their encouragement, support and instructions for my career goals. Since 1973, our research group has systemically conducted investigation and researches on rice virus diseases, which covered 22 provinces of rice growing area in China, and 63 counties in Fujian province. Our results are as following:

1. Being conducted research on identification and biological characterization of rice viruses, we identified 10 kinds of rice viruses in China, one of them, *Rice bunchy stunt virus* (RBSV) was a new virus in the world, and *Rice ragged stunt virus* (RRSV) and *Rice tungro spherical virus* (RTSV) were new records in China, and leafhopper (*Nephotettix virescens*) was a new vector for *Rice dwarf virus* (RDV).

2. Found out the distribution of the above-mentioned 10 kinds of viruses and their epidemic characteristics of some important viruses, in addition, established monitoring systems for 40—50 days, and 90—100 days, respectively, before the occurrence of these virus diseases, which greatly assisted the integrated management of these virus diseases, and was adopted by Agriculture Ministry for the usage of all county forecasting centers.

3. Set up a practical monitoring protocol that emphasizes on resistance, escape, eradication, and control- "Four word rules" in combined with disease forecasting. Just on screening for resistance, we identified 25 virus-resistant or insect-resistant varieties.

All these results, especially our systemic research on the pathology of rice viruses, and the new discoveries of RBSV and a new vector of RDV, caught an attention of colleagues in the world. I was invited to attend international conferences for keynote speaking for three times, two of which I was appointed as a chair of the meetings. Our papers were cited by ICTV and VIDE databases, and several virology and plant pathology journals, and some other professional Journals or textbooks. We, therefore, were granted several scientific awards. It was also so important that our results generated a great social impact and economic benefits.

4. In recent years, we focus on molecular biology of *Rice stripe virus* (RSV), *Rice grassy stunt virus* (RGSV) and RDV. We sequenced major parts of RSV and RGSV genomes, and conducted extensive research on gene expression, regulation and function of CP and SP genes of these viruses, and extensive research on the molecular evolution of RSV, the interactions between virus and host, and between virus and vector. We also generated RDV, RGSV and RSV transgenic rice plants; some of them were resistant, and stable in subsequent generations.

5. Our research achievements strengthened our authorization for Ph. D candidates and postdoctoral training, and a group of students graduated with advanced degree.

Twenty-first century will be the century of fastest growing ever for science and technology, and of better adaptation between human and nature environments. There will appear all different kinds of problems in the coming agricultural and economic processes. One has to continue his or her efforts to learn, to explore and to research so that he or she will meet new challenges.

Papers collected in this book reflect our researches on rice virus diseases and their molecular biology in the last 30 years. The publication was for the invitation of our university in celebration of her 65 years anniversary.

In the past decades, my research and teaching always benefited from official support, pioneer's guidance, and encouragement and help of colleagues.

I am indebted to Jiang Yuanlin, deputy editor of Journal of Fujian Agriculture and Forestry University, and his group for their critical review and editing works.

Lianhui Xie
September 1, 2001

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