水稻抗旱育种手册

K.S. Fischer, R. Lafitte, S. Fukai,
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译 者 的 话

水稻是全世界半数以上人口的主食，同时，水稻生产容易受干旱影响，是农业生产中的用水大户。为了从根本上改变水稻需水甚多与世界水资源短缺的现状，许多国家都先后开展了水稻的抗旱育种研究，积累了许多值得借鉴的宝贵经验。2003年12月，美国洛克菲勒基金会在泰国Khon Kean University举行的“水稻抗旱育种”国际学术讨论会上，基金会粮食安全部副主任John O' Toole博士介绍该基金会正在资助国际水稻研究所编著“Breeding rice for drought-prone environments”一书，这是首部有关水稻抗旱育种的工具书。为了将它介绍给中国更多的抗旱研究人员，促进水稻抗旱育种工作在中国的开展，本人表示了将该书翻译成中文的愿望。随后，在John O'Toole博士的协助下征得了本书作者及国际水稻所的同意进行翻译。

针对干旱环境的多变性和水稻抗旱的复杂性，本书着重于介绍如何确定培育耐旱品种的目标环境（Target population of environments），以及通过产量直接选择和抗旱性状间接选择，提高干旱地区水稻产量的育种方法。除了在理论上进行阐述外，本书的显著特点就是具有很强的可操作性，对于我国水稻抗旱育种工作是一本极具价值的指导手册。相信本书译本对我国其他作物抗旱育种研究也有一定的参考价值。

参与翻译的人员是上海市农业生物基因中心的老师和研究生们。林榕辉博士及梅捍卫博士对全文进行了校译，最后本人对译稿进行了审定。本书的翻译基本忠实于原著，只是其中个别专用词结合我国实际情况进行了改动。

藉此向 John O’Toole 博士、本书作者及国际水稻所的支持表示谢意。

罗利军

2005.4.8

Introduction to Chinese Version of "Breeding Rice for Drought-Prone Environments", edited by K.S. Fischer, R. Lafitte, S. Fukai, G. Atlin and B. Hardy

Throughout the past 7,000 to 10,000 years of Chinese history, rice has been a pivotal aspect of societal development and security. From the earliest records of rice domestication, irrigation water management has preoccupied Chinese populations from rainfed peasant farmers to the mightiest emperors. The ancestors knew well that adequate water was essential for proper growth and yield of this tasty grain upon which so many Asian societies were to become dependent for food security. However, the ancestors never guessed there would be so many Chinese people to share the fresh water of the 21st Century. In addition to population growth the requirements for limited-market economic growth and policies as well as concerns for the environment are placing additional pressure on fresh water quautity and quality. In brief, the thousands of years' long era of traditional "flooded field" irrigation practices for rice may be coming to a close for vast areas of China. The genetic modification of rice to cope with this reality is a very significant scientific and technical challenge.

Many scholars and development experts believe the scarcity of water for rice production will eventually become pan-Asian in scope. However, the magnitude of the challenge to rice geneticists and breeders is nowhere greater than in the Peoples' Republic of China (hereafter China). As it enters the 21st Century, China, with its history and future inextricably tied to rice production and food security of its 1.3 billion people, faces a monumental task. The Chinese phrase "water-saving rice culture" describes the goal of producing equal or more rice with less water. In practice this task will fall to three groups of researchers and technicians; irrigation water engineers/managers; agronomists to deal with the challenges of soils no longer anaerobic but alternating or continuously aerobic; and rice geneticists and breeders to create, test and disseminate new varieties suitable to the new "water-saving rice culture".

It has been many years since the agricultural research establishment and economic and planning development communities of China realized that given the desired path toward a limited-market economy within China and its global trading partners, fresh water was a salient issue. However, my first introduction to the magnitude and practical implications of this challenge was a workshop in which rice breeders from throughout China, the International Rice Research Institute (IRRI), Philippines and officers and consultants from the Rockefeller Foundation gathered to access the potential for genetic modification of rice to fit into China's future water-scarce cropping systems.

This workshop was a landmark, creating a common perspective on the future of rice and water between national and international participants. Prof. Lu Liangshu, Member of the Presidium of Chinese Academy of Engineering delivered an excellent presentation (in Chinese) along with an English language companion document entitled "Development of Agriculture, Drought Tolerance and Water-Saving Culture of Rice in China". Prof. Lu provided a clear explanation of the driving forces impacting "Chinese agriculture and rural economy (CARE)" for the past decade: increased interaction of CARE and the global economy; close linkages between CARE and the state/provincial economic evolution from urban-rural to increasingly urban; changing factors constraining agriculture — alternative demands and environmental concerns; emergence of a "mixed economy"; and last but not least, the uncertainty regarding the potential of science and technology to respond to future rice production constraints .

Prof. Lu's presentation left no doubt that current water use by agriculture, approximately 70% of the country's annual fresh water consumption, could not continue as in the past with rice using 60% to 70% of agriculture's total. His talk raised important questions regarding the potential of breeding to not only continue to increase the yield ceiling of rice production but to do so in the face of ever increasing scarcity of water for irrigated rice and the continuing "normal" scarcity (droughts) in upland and rainfed lowland rice regions of China.

That workshop in Hainan Island, March 2000, set the stage for a number of very significant collaborative research ventures linking those in various regions of China, the IRRI and participants in a newly initiated pan-Asian program of the Rockefeller Foundation entitled "Resilient Crops for Water-Limited Environments". The workshop's outcome forged not only scientific linkages but also established cooperation for shared resources (financial, physical and human) between the Rockefeller Foundation and various entities such as: Chinese National Rice Research Institute, Hangzhou; Huazhong Agriculture University, Wuhan, Hubei and the Shanghai Academy of Agricultural Sciences which eventually established the

Shanghai Agrobiological Gene Center with substantial funding commitments directed to the solution of this problem — rice and water scarcity in China's future.

The book that follows, "Breeding Rice for Drought-Prone Environments", published by the International Rice Research Institute in late 2003, is a significant contribution from many individuals who, over the past two decades, learned and practiced the art and science of rice breeding for target regions where water was not assured. The editors are to be congratulated for their painstaking efforts to collect those experiences from practitioners as distant as Brazil, Philippines and Thailand. They succeeded in providing the reader with the primary tools now available: breeding/genetic theory; the latest field screening/phenotyping techniques; statistical and field design aides; physiological insights into yield reduction due to drought; the potential use of molecular markers and much more. Additionally, the editors have coaxed authors to share their hard-learned knowledge of breeding for drought tolerance in a number of target regions through the "case studies" section. This section is truly an inspiration to those interested in the long-term contribution of drought tolerance in rice and its role in stabilizing rice yield and production. The eventual impacts of this research will be to provide greater year-to-year stability of food security and income for the household economies of farmers as well as stabilizing the production functions of entire provinces, regions or nations over time.

Finally, my sincere appreciation goes to Dr. Lijun Luo, Dr. Ronghui Lin, Dr. Hanwei Mei, Dr. Hongyan Liu, Dr. Songping Hu, Ms. Guihua Zou and Ms. Guolan Liu for taking on the task of translating this book from English to Chinese. By accomplishing this goal they have rendered an incalculable service to their fellow Chinese rice breeders and deserve our hearty congratulations and thanks for such a fine job in a short time period.

John C. O'Toole
The Rockefeller Foundation
New York, New York USA
April 20, 2005

K.S. Fischer，R. Lafitte，S. Fukai，G. Atlin & B. Hardy 所著“Breeding Rice for Drought-Prone Environments”一书中译本的出版

在中国七千至一万年的历史长河中，水稻一直是社会长治久安的基石。远从水稻被改良栽培起，灌溉便始终受到上自帝王、下至稻农的关注。先民们深知提供适当的水分是这种可口的谷物生长及结实不可或缺的基本条件，正是依赖水稻生产，许多亚洲国家才得以保证粮食充足。然而，先民们绝不会预料到21世纪时，竟然有如此众多的中国人要使用淡水。除了人口增长之外，经济市场和政策的发展以及对环境的要求，都加强了在量和质上对淡水需求的压力。简言之，千百年来对水稻进行灌溉的“水田”耕作传统，可能将在中国广袤的土地上终结。为应对这一现实，如何在遗传学上对水稻进行改造，已对科学及技术提出了十分重要的任务。

许多学者及专家均认为水稻生产缺水的问题，最终将遍及整个亚洲。不过对中国的水稻遗传学家和育种家来说，要应对的挑战更为严峻。在步入21世纪之际，中国的历史及未来，无可避免地受到水稻生产及13亿人民的粮食安全所制约。中国正面临着一项非同寻常的任务。她提出“水稻节水栽培”一词，便表明了消耗更少的水，但水稻产量不减或增产的目标。为实现此任务，需要有三类研究人员和技术人员的参与，即：水利工程师及管理人员；能在交替或连续性的好氧土壤环境下，而不是在厌氧的土壤环境下栽培水稻的农学家；以及培育、测试及推广适合“水稻节水栽培”新品种的水稻遗传学家及育种家。

自从中国的经济计划发展部门及农业研究机构了解到必须走国内以及全球贸易合作的市场经济道路以来，淡水供应一直是一个突出的问题。在中国一次全国性的水稻育种工作研讨会上，我第一次向他们介绍了这个问题的重要性以及实践中可能面对的挑战。当时菲律宾国际水稻研究所（IRRI）的代表及官员们，洛克菲勒基金会的顾问们聚集一堂，共同探讨水稻通过遗传学改造后，适应中国未来节水耕作制度的可能性。

这个研讨会是一个里程碑，它对水稻利用及水稻生产的前景作了讨论，为中国及国际与会代表们勾画出共同的蓝图。中国工程院院士卢良恕教授在会议上作了题为“中国农业发展及水稻耐旱和节水栽培”的出色报告，对中国的农业与农村经济(CARE)过去十年来的推动力作了清晰的阐述，包括增进CARE和全球经济之间的互动；加强在城市化过程中，CARE与各省及地区之间经济发展的紧密联系；农业可持续发展中条件的变化——从需求的改变以及环境上的考虑；“混合型”经济以及在保持未来水稻的稳产上、种子及技术的不确定性等。

卢教授的报告明确无误地指出：现在农业上的用水约占全国年用水总量的70%。以前水稻用水占农业总用水量的60%～70%的状况将难以为继。他的报告还指出：育种所面临的重要问题，不仅是产量的持续增长，还需面对水稻灌溉用水日益匮乏，以及在旱地及雨育低地稻区被认为是“正常”的持续性缺水。

2000年3月海南岛举行的研讨会，促成了在中国不同地区、IRRI及与会者之间许多十分有意义的合作研究项目。洛克菲勒基金会启动了一个新的、被称为“节水灌溉下作物的重建”的泛亚洲计划。在这一研讨会上，洛克菲勒基金会与不同的机构如中国水稻研究所（杭州）、华中农业大学（武汉），以及上海市农业生物基因中心（上海市农业科学院）等建立了科研上的联系，也同时建立了资源（经费、物资及人员）之间的协作，在持续的研究经费支撑下，致力于解决中国未来水稻及缺水的问题。

2003年年底，由国际水稻研究所出版的《Breeding Rice for Drought-Prone Environments》一书，是过去20年来许多在难以保证水分供给的目标地区进行探索和实践的工作者的重要贡献。我们感谢编者从世界各地，如巴西、菲律宾、泰国等地辛苦地收集资料。他们成功地为读者提供了适合当前应用的基本手段，包括育种及遗传学理论；最终的田块筛选及表型鉴定技术；统计及田间设计；因干旱减产的生理学研究及应用分子标记的可能性等等。感谢编者动员作者们在“研究实例”一节中，将他们在许多目标地区进行耐旱育种所得来的宝贵经验与读者共享。该节将对那些关心水稻耐旱的远景及它在稳定水稻产量作用的人，是一种激励和启发。这一领域的研究最终将会使作物安全的稳定性、农户的经济效益以及整个地区或国家生产上的稳定性能逐年增长。

最后，我诚挚地感谢罗利军博士、林榕辉博士、梅捍卫博士、刘鸿艳博士、胡颂平博士、邹桂花女士及刘国兰女士将此书翻译为中文。他们为共同进行水稻育种的同行们作出了难以估量的贡献。同时也衷心地祝贺他们能如此高效、完美地完成此项工作。

John C. O'Toole
洛克菲勒基金会
纽约 · 美国
2005年4月20日

缩　写

开花至吐丝间隔期	ASI	(anthesis-to-silking interval)
国际玉米小麦改良中心	CIMMYT	(International Maize and Wheat Improvement Center)
加倍单倍体	DH	(doubled-haploid)
干物质	DM	(dry matter)
干旱响应指数	DRI	(drought response index)
基因型	G	(genotype)
基因型与环境互作	GEI	(genotype × environment interactions)
基因型与地点互作	GL	(genotype × location)
绿叶期	GLD	(green leaf duration)
基因型与地点、年份互作	GLY	(genotype × location × year)
基因型与年份互作	GY	(genotype × year)
遗传率	H	(heritability)
收获指数	HI	(harvest index)
国际水稻信息系统	IRIS	(International Rice Information System)
红外测温仪	IRT	(infrared thermometer)
最小显著差数	LSD	(least significant difference)
叶水势	LWP	(leaf water potential)
标记辅助选择	MAS	(marker-assisted selection)
多点试验	METs	(multiple-environment trials)
均方误差	MSE	(mean square error)
近等基因系	NILs	(near-isogenic lines)

渗透调节	OA	(osmotic adjustment)
穗收获指数	PHI	(panicle harvest index)
数量性状位点	QTL	(quantitative trait loci)
完全随机区组	RCB	(randomized complete block)
快速加代法	RGA	(rapid generation advance)
重组自交系	RILs	(recombinant inbred lines)
辐射利用率	RUE	(radiation-use efficiency)
相对含水量	RWC	(relative water content)
水分供给	S	(supply of water)
选择环境	SE	(selection environments)
单粒传法	SSD	(single-seed descent)
蒸发水量	T	(water transpired)
目标环境	TPE	(target population of environments)
水分利用率	WUE	(water-use efficiency)
年份	Y	(year)

彩 图

1 当干旱持续一段时间后，在田间很容易对各种品种的枯叶值进行评分。图中显示的是在高温旱季断水26天后的叶片干枯情况（日平均温度28℃，日平均水分蒸发蒸腾5.9mm）。
图片提供：R. Lafitte。

2 IR61907和Moroberekan间不同干旱反应对比。IR61907是具有高渗透调节水平的雨育低地稻（左），Moroberekan是具有深根性的旱稻品种（右）。在胁迫开始时，IR61907的叶面积较小，并迅速停止了叶片生长；Moroberekan已形成了较大的叶面积，在胁迫加重后，表现严重的叶片枯死。这两种品种在长时间的胁迫处理下产量都不变。
图片提供：R. Lafitte。

3 用地下水管和自制张力计监测土壤水分条件。
图片提供：R. Lafitte。