中国大豆

耐逆研究

Research on Tolerance to Stresses in Chinese Soybean

林汉明　常汝镇　邵桂花　刘忠堂　主编

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编写人员名单

主　　编　林汉明　常汝镇　邵桂花　刘忠堂

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序

《中国大豆耐逆研究》专著即将问世，主编林汉明和常汝镇先生嘱为作序，欣然命笔。遍查我国的大豆专著，未见专门写耐逆研究的，因此本书的出版乃是应时、应需之举。

大豆生产和其他作物一样，产量和品质具有很好的遗传潜力，但是实际生产中所获得的产量和营养成分含量往往没有预想的好，原因是生长环境没有完全满足基因型的需要。大田中作物的生长环境是变化多端的，人们可以通过栽培技术来调节生长环境使之适合作物的要求，但这种调节是有限度的，有些条件是可控的，有些条件是难以控制的。这些不易控制的就构成了作物生产的“逆境”，是有待人类想办法来控制的。通常“逆境”是指非生物性的环境因子，包括空气和土壤的各种环境因子，称为非生物逆境。广义的逆境还包括了生物性的环境因子，包括病、虫、草等，称为生物逆境。本书从广义的逆境出发，包含了大豆非生物和生物逆境两方面的研究内容。对于大范围的非生物逆境，作物难以左右，一般通过耐受机制去抗衡，这种机制称为耐逆性；对于生物逆境，作物在受到生物攻击时一些物质对于攻击者有害，能抑制有害生物的攻击，这种机制称为抗病（虫）性，但也有的对攻击者并无抑制机能而只有单纯的忍耐，称为耐病（虫）性。

非生物和生物环境是相互关联的整体。以往在常规的生产水平上，非生物和生物环境的胁迫保持相对稳定，人们经过数千年的实践已经有所掌握。但近年来，随着人口的增加，人类活动的干扰，地球生存环境正不断加速变化。现代工业的无序发展更加剧了环境的恶化，二氧化碳排放量猛增，温室效应加剧，气候变暖，海平面上升，海水倒灌，盐渍土面积扩大，干旱、洪涝、冰雪风暴灾害频繁发生，既干扰了人类的生境，又严重影响了农业生产的维持和发展。另一方面，气候条件的动荡还改变了人类和农作物的生存环境，加上高强度的农作使植物病原物和有害昆虫越冬量剧增，生物种群结构改变，病虫草害加剧。无论非生物逆境还是生物逆境给农业生产不仅已经造成巨大的危害，而且有更大的潜在威胁。因而面向未来，加强农作物应对环境胁迫的研究愈益重要。要判明作物生产潜在的重要环境胁迫因子，要研究控制这些胁迫因子的策略、方法和技术，要明确作物对这些胁迫因子的耐受性及其遗传潜力，从而培育耐受

性品种。对于作物是如此，对于大豆当然亦复如此。

我国大豆生产遍布全国，包括有北方春豆、黄淮春夏豆、长江中下游春夏豆、中南春夏秋豆、西南春夏豆和华南四季大豆等栽培区域。各地区地理、季节条件不同，非生物和生物逆境各不相同，有些有共性，有些有特殊性。大致北方地区干旱是普遍性问题，南方可能有季节性干旱的问题；内陆地区干旱还带来土壤盐碱化问题，而沿海地区盐土本来就是首要的问题；南方酸性土壤的铝离子毒性是大豆生产的关键问题，而全国各地都因长期耕作而存在营养元素亏缺的问题。近年来，大气逆境中，苗期低温、花期高温、风暴冰雪在不同地区是肆虐作害的重要因子。大豆生物逆境的病、虫、草问题种类繁多，有一些是全国性的，有一些是地方性的。以往已将大豆胞囊线虫和大豆花叶病毒作为全国性病害对付，东北的灰斑病和南方的锈病都是重要的地区性病害，近年来一些检疫性病害正在悄然发展。虫害中，豆秆黑潜蝇在关内广大地区普遍发生，食叶性害虫是南方的重要害虫，食心虫和豆荚螟分别是东北和关内的重要钻蛀性害虫，近年来东北的蚜虫已成为新的重要虫害。大豆的逆境因子之多难以一一枚举，而且随着时代的变迁常有变化。本书选择最重要的十个逆境因子的有关研究作讨论，其中还把大豆重迎茬本身看作为一个逆境因子处理，这是大豆的特殊问题。

在对付大豆逆境胁迫的策略中，治理环境这是一个方面，需要大量的人力物力投入，为了根本的治理，这是必需的。另一个方面是增强大豆本身对于逆境的抗性和耐性，具有抗、耐性的品种一旦育成，便不需其他人力物力的投入，因而是一种经济有效的策略，这也就是为什么现代育种研究快速发展的原因。抗、耐逆境育种的基础是发掘出抗、耐性基因，这些有利基因散布在浩如烟海的种质资源中，有待人们去鉴别出来。因而种质资源研究是现代抗、耐逆育种的基础性工作。本书在讨论了各种逆境因子问题的基础上，特别有一章专门讨论耐逆资源的评价利用问题。

本书主编特地邀请了各领域从事专业研究的有关专家参加编写，以便将读者带到各个研究领域的前沿。相信这部专著的问世将能促进我国大豆耐逆研究的进一步发展，从而改变我国大豆产业的面貌。

2009.7.6

Preface

In response to the invitation by the chief editors Prof. Hon-Ming Lam and Prof. Ruzhen Chang, it is my pleasure to write a preface to this book "Research on Tolerance to Stresses in Chinese Soybean". Monographs specialized on stress tolerance in soybean were previously absent in Chinese scientific publications. The release of this book timely filled this gap.

Like other crops, soybean has an excellent potential in yield and quality that is often not fully expressed in the actual production process. It is mainly due to the sub-optimal environmental conditions that do not fulfill the requirements of genotypes. Crops grown on fields are subjected to a dynamic environment. Through various cultivation technologies, human can partially manipulate the environment to facilitate crop production. This kind of adjustment is limited because some conditions are beyond our control. These adverse conditions constitute the "stress" in crop production. "Stress" often refers to "abiotic stress" that involves abiotic environmental factors, including atmospheric and soil conditions. A broader definition of "stress" would cover biotic factors, including pathogens, pests, and weeds that constitute "biotic stress". This book encompasses the contents of both abiotic and biotic stresses. In extensive regions suffered from abotic stresses, crops may deal with this situation via various adaptive mechanisms, known as stress tolerance. When attacked by harmful organisms, crops may produce phytoalexins to counteract. This mechanism is known as pathogen/pest resistance. There are also situations that crops do not have abilities to inhibit the invaders. Survival solely by tolerating these attacks is known as pathogen/pest tolerance.

Abitoic and biotic stresses are integral parts of the same production system. They maintained at a relatively steady level under the regular production mode in the past. Human has learnt the stress occurrence patterns via agricultural practices over the past few thousands years. Currently, the living world is facing accelerating changes due to the growing human population and interference of human activities. Increase in carbon dioxide emission intensified the "greenhouse effect" which aggravated the situation of global warming, leading to rise of sea level, backflow of sea water, expansion of saline lands, and escalating incidents of drought, flooding, and ice storm. This situation not only affects our living environment, but also severely hampered the maintenance and development of agricultural production. On the other hand, the fluctuating climatic conditions have brought a profound change to the environments for human living and agriculture. Intense agricultural activities exacerbated problems of pathogens and pests by facilitating the "over-winter" ability of pathogens and pests, and changing the genetic structure of their populations. Both abiotic and biotic stresses have already caused damages to agricultural production. The potential threats could be much more severe. Therefore, researches to understand the response of crops toward environmental stresses are important topics for our future. There is an urgent need to delineate important underlying environmental stress factors affecting crop production for developing strategies, methodologies, and technologies to combat these stress factors; and to understand the genetic potential of crops contributing to tolerance of these stress factors for breeding of stress tolerant varieties. The same principle should apply to all crops including soybean.

Soybean is widely cultivated in China, including spring soybean in the north, spring-summer soybean in southwest, Huanghuai region, mid- and down-stream regions of Yangtsz river, spring-summer-autumn soybean in the mid-south, and all-season soybean in the south. Abiotic and biotic stresses could be different under diversified geographical and seasonal conditions. There may be both common and unique characteristics. Drought is a common problem in northern part of China while seasonal drought will also occur in the south. Salinization, the primary problem affecting coastal regions is also a problem in dry and semi-dry inland regions. Aluminum toxicity of acidic soils is a key issue of soybean production in the south. Nutrient deficiency is observed in most fields that have been subjected to prolonged agricultural practices. In recent years, low temperature at seedling stage, high temperature at flowering stage, and ice storms in different regions are major disturbances. The types of pathogens, pests, and weeds affecting soybean are manifold. Some are wide-spread throughout the whole country while some are restricted to particular regions. Soybean cyst nematode and soybean mosaic virus have been enlisted as national pathogens while Frogeye leaf spot in northeast and soybean rust in the south are important regional pathogens. In recent years, some quarantine diseases have been gradually expanding. Soybean pest is also an important issue. The soybean agromyzid fly *Melanagromyza sojae* affects a large area in the Guannei region. Leaf-feeding insects are important to the south. Soybean borer and *Maruca vitrata* (F.) are the major borers affecting northeast and Guannei regions, respectively. Currently, aphids have become a new important pest in northeast. It is difficult to cover all stress factors affecting soybean, especially due to the ever changing environment. This book included ten most important stress factors for in depth discussion. In particular, continuous cropping of soybean which is listed as a stress factor should be considered as a unique soybean problem.

Among different strategies to combat stresses affecting soybean, environmental management and restoration are essential to provide the ultimate solution but require a huge amount of inputs from human and other resources. One economically efficient tactic is to increase the resistance and tolerance of soybean toward stresses. Successful breeding of new tolerant varieties could eliminate the need of additional inputs. This advantage accounts for the rapid development of researches in modern breeding. The basis of stress resistance and tolerance breeding is to identify the corresponding functional genes. These important genes embedded in the tremendous amount of germplasm resources await identification and discovery. Therefore, germplasm study is the foundation of modern breeding for resistance and tolerance. In conjunction to the discussion of various stress factors, a unique chapter on stress tolerance germplasm evaluation and utilization was included in this book.

The chief editors have invited relevant experts to participate in composing this book. It will bring the readers to the frontier of each research field. I believe that the publishing of this book will contribute to the further development of studies in the soybean stress tolerance, and signify a new stage of soybean production in China.

Junyi GAI

July 6, 2009

前言

作物生产过程中会遇到各种各样的环境条件，风调雨顺的年景终归是少数。中国地域广阔，不同地区，不同年份作物生产都会遭遇不同的逆境。只是遇到逆境的种类、时期、程度有所差异。逆境包括生物逆境和非生物逆境，植物病虫害属生物逆境，其发生需要一定的环境条件；干旱、盐碱、水涝、低温等属非生物逆境，多受天气状况的影响，如降水少了受旱，降水多了受涝。农业生产就是不断与逆境斗争的过程，受旱要力争灌水，受涝要排水，发生病虫害要采取措施予以防治。研究作物与逆境的关系，了解逆境发生的过程和规律，对减轻逆境对农业生产造成的影响十分重要。

大豆是我国重要农作物，种植面积 900 万 hm^2 左右，居水稻、小麦、玉米之后列第四位。大豆是高脂肪高蛋白作物。大豆的蛋白含量在 40%左右，是主要作物中蛋白含量最高的，是人类食物和畜禽饲料植物蛋白的主要来源。大豆油是主要植物油脂之一，富含不饱和脂肪酸，是优质食用油。大豆还含有多种有益于健康的生物活性物质如大豆异黄酮、大豆皂苷、维生素 E、低聚糖等。由于上述特性，对大豆的需求不断增长，年需求量已接近 5 000 万 t，进口量已超过 3 000 万 t，国产大豆中只有 1 600 万 t 左右。我国大豆单产较低，这和逆境影响有一定关系，因而大豆生产中要采取一系列先进的栽培技术，包括防治病虫害、防旱排涝等，品种本身的耐逆性和大豆的产量尤其是稳产性和适应性有重要关系，耐逆性强的品种往往适应性好，产量稳定，农民愿意选用。

我国大豆研究中，对于相关的生物逆境主要是病害研究较多，近些年对非生物逆境如耐盐、抗旱、耐酸铝等也开展了研究，为进一步更深入地研究大豆耐逆性，有必要在总结前人研究的基础上结合自己在相关领域的研究进展，撰写一部专著，为大豆耐逆研究提供参考。最早由邵桂花研究员、刘学义研究员等人提议，开始邀请相关科技工作者参与编写。2006 年 3 月在哈尔滨召开了大豆耐逆研究书稿撰写启动会，邀请各章撰稿人参加，明确书稿写作的要求、初稿完成的时间、审稿人的安排等。2007 年 5 月初稿基本完成，当年夏天经过初审，书稿返回各章作者，按审稿要求进行修改，修改稿又经

主编再次审阅，并再经作者修改，修改后的稿件最终由主编修改定稿，2008年底全书稿件完成统稿。

全书包括12章，第一章“干旱”由刘学义撰写，第二章“盐碱”由邵桂花、林汉明、彭翠虹、郑镇潮、王福玲撰写，第三章“酸铝毒害”由年海撰写，第四章“大豆胞囊线虫”由卢为国撰写，第五章“大豆花叶病毒病”由智海剑撰写，第六章“大豆灰斑病”由马淑梅、刘忠堂撰写，第七章“大豆锈病”由单志慧撰写，第八章“大豆食心虫”由王克勤、张匀华撰写，第九章“大豆食叶性害虫”由孙祖东撰写，第十章“重迎茬”由刘忠堂、何志鸿、魏丹、王玉峰撰写，第十一章“抗逆性大豆种质资源的评价和利用”由常汝镇、邱丽娟撰写，第十二章“中国大豆生产逆境研究的展望”由林汉明、邵桂花、彭翠虹撰写。每章后面附有详细的英文摘要，图表以中英文双语表达，撰写及翻译工作由林汉明及彭翠虹完成。

除作者撰稿之外，若干人员对本书稿的组织和审校做了大量工作。香港中文大学林汉明数次来京商讨书稿撰写，并审阅了全部书稿，提出了修改意见。中国农业科学院作物科学研究所邵桂花研究员在全书撰写的组织、书稿审阅方面投入了不少精力，为成书做出了贡献。黑龙江省农业科学院刘忠堂研究员、中国农业科学院油料作物研究所周新安研究员审阅了部分书稿并提出了修改意见。中国农业科学院作物科学研究所常汝镇研究员负责全书统稿，全部书稿审阅修改三遍，终于成书。中国农业出版社编辑对书稿做了认真细致的审校。著名大豆遗传育种及生物统计专家盖钧镒院士为本书作序。在本书出版之际，谨向所有参加本书编写、审阅修改和出版的各位同事表示衷心的感谢。书中不足之处，敬请读者批评指正。

编　者

2009年4月

Forward

Crops are seldom grown under optimal conditions. They are always facing different kinds of challenges or stresses. China, with her vast geographical span, poses a multitude of adversities. These adversities vary by region and by year. Crop production is simply a series of efforts to overcome the adversities - irrigation upon drought; drainage upon floods; control of disease and pests. Study of the relationship between crops and adversities is to ameliorate their negative impacts on crop yield.

Soybean is an important crop in China. It is being cultivated in about 9 million hectares of scarce land, ranking number four, after rice, wheat, and maize. Soybean is rich in lipid and protein. Its protein content is about 40%, the highest among staple crops, and it serves as the primary source of plant proteins in human as well as animal diet. Soybean oil is rich in unsaturated fatty acids, thus a high quality food oil. It also contains a number of bioactive substances such as isoflavones, saponins, vitamin E, and oligosaccharide that are good for health. Consequently, the demand for soybean has been ever increasing. Annual demand in China has risen to nearly 50 million tons, of which over 30 million tons are imported. Local production stands at around 16 million tons only. Unit production of soybean in China is toward the lower end, in part due to environmental stresses. Apart from improving cultivation techniques like irrigation and drainage systems, identification of varieties that exhibit stress tolerance and of good adaptability and stable yield is also an important strategy to improve soybean production.

In the past, soybean research in China has focused primarily on biotic stresses. Recently, much emphasis is placed on the study of abotic stresses - tolerance to salinity, drought, and aluminum toxicity. To build upon the edifice of the pioneers of soybean stress tolerance study, a compendium of research would be extremely useful. Researchers Guihua Shao and Xueyi Liu initiated this undertaking and started to invite members of the soybean research community to participate. In March 2006, the first meeting on the compendium took place in Harbin. The first working draft of the book was basically completed by May 2007. After a few rounds of back and forth editing, the manuscript was finally ready at the end of 2008.

The entire compendium is divided into eleven chapters. The first chapter titled "Drought " was written by Xueyi Liu. The second chapter titled "Salinity" was co - authored by Guihua Shao, Hon - Ming Lam, Tsui - Hung Phang, Chun - Chiu Cheng, and Fuk - Ling Wong. Chapter three titled " Aluminum toxicity " was written by Hai Nian. The fourth chapter about "Soybean cyst nematode (SCN)" was written by Weiguo

Lu. The fifth chapter "Soybean mosaic virus (SMV)" was written by Haijian Zhi. Chapter six "Frogeye leaf spot" was written by Shumei Ma and Zhongtang Liu. The seventh chapter titled "Soybean rust" was written by Zhihui Shan. Chapter eight "Soybean borer" was authored by Keqin Wang and Yunhua Zhang. Chapter nine "Leaf - feeding insects" was written by Zudong Sun. The tenth chapter "Continuous cropping and partition crop rotation" was written by Zhongtang Liu, Zhihong He, Dan Wei and Yufeng Wang. Chapter eleven "Evaluation and utilization of soybean germplasm in China" was written by Ruzhen Chang and Lijuan Qiu. Finally, Hon - Ming Lam, Guihua Shao, and Tsui - Hung Phang wrapped up with the outlook on future directions of soybean stress tolerance research. All the English extended summaries appended to each chapter and the English translation of figures and tables were prepared by Hon - Ming Lam and Tsui - Hung Phang.

The editing of this comprehensive compendium of reviews requires much collaborative effort of the soybean research community. Hon - Ming Lam of the Chinese University of Hong Kong has visited Beijing on several occasions to discuss the overall plan and contents. He has reviewed all the manuscripts and provided his editorial comments. Guihua Shao of the Institute of Crop Sciences, The Chinese Academy of Agricultural Sciences (CAAS) is instrumental in the logistical organization that allows the idea of the compendium to be brought to fruition. Zhongtang Liu of Heilongjiang Academy of Agricultural Sciences and Xinan Zhou of the Institute of Oil Crops, CAAS edited parts of the manuscript. Ruzhen Chang of the Institute of Crop Sciences, CAAS is in charge of the overall editing, integrating different comments and suggestions from the three comprehensive reviews. Editors at the China Agriculture Press have been most helpful in various editing tasks. We are particularly honored to have Academician Junyi Gai, a renowned biostatistician and soybean geneticists, writing the preface for this compendium. This book is the cumulative efforts of many and they all have our heartfelt gratitude. To the readers, we look forward to your comments and suggestions.

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