中国转基因作物的环境安全评介与风险管理

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基因工程技术是 21 世纪最伟大的科学技术之一,基因工程技术的应用开启了一次全新的农业"绿色革命"。自 1996 年美国第一例商业化转基因作物诞生以来,全球转基因作物的种植快速平稳增长。转基因作物的种植具有巨大的潜在效益,但是其可能带来的环境风险已成为了人们关心和争论的焦点。转基因作物的安全性已然成为许多国家和政府不得不面对的主要议题之一。

在过去的 20 年里,中国在全国范围内开展了针对农业生物技术产品的环境安全性监管工作,目前已经形成了一套全面的转基因作物及相关附属产品环境安全性的监管制度。以转 Bt 基因抗虫作物为例,其监管框架主要包括:同时注重环境影响和农业利益、靶标昆虫对抗虫基因抗性演化的可能性、转基因作物对非靶标生物体的影响以及其他潜在的环境影响。

对于转基因作物新品种来说,为了在商业化前有效评价和确保其环境安全性,转基因作物的生物安全研究涉及从实验室研发到种植的各过程中,可以分为 5 个阶段:1)室内试验;2)中间试验,指在封闭或可控条件下进行的小规模生物安全性试验;3)环境释放田间试验,指在具备适当的安全控制措施的自然条件下进行的中等规模的田间试验;4)生产性试验,指在申请转基因食品安全证书之前进行的大规模生物安全性检验;5)申请生物安全证书。

在生物安全评价的室内试验阶段,试验过程中必须要采取妥当的安全措施,并且在隶属于相应机构或大学的农业转基因安全领导小组的监管之下进行。当室内试验阶段完成并准备进入环境风险评估阶段时,研究人员必须向农业部提交申请,经审批允许后才能进入下一试验阶段。当申请风险评估试验从某阶段推进到下一阶段的许可时,申请者都需要向农业部递交必需的数据。当生产性试验及其之前的所有试验都完成后,研发者可以向农业部申请转基因生物安全证书。然而,截至目前只有转 Bt 基因抗虫棉和抗病毒木瓜在中国获准广泛种植。

自 1997 年中国批准转 Bt 基因抗虫棉商业化种植以来,Bt 棉的种植面积显著增长。到 2012 年,Bt 棉的种植面积达到 359 万 hm^2,占棉花种植总面积的 80%。种植 Bt 棉 17 年以来,农民和环境都获益良多。许多害虫特别是棉铃虫会对棉花生产造成严重的经济损失,在 Bt 棉推广之前,中国棉农只能用大量的农药控制棉铃虫,这造成了害虫抗药性、害虫再猖獗以及环境污染等严重的生态问题。长期的田间监测发现,随着抗虫棉种植面积的推广,不仅有效地控制了棉花上的棉铃虫种群,而且同一片种植区域其他非转基因作物(包括玉米、大豆和花生)上的棉铃虫种群数量也大大降低。转基因棉产生的 Bt 蛋白只会特异性地识别靶标昆虫,对非靶标生物无直接毒性。此外,由于农药使用量的大大降低,棉田广谱性天敌(如瓢虫、草蛉和蜘蛛)的种群数量逐渐上升,害虫天敌对非靶标害虫(如蚜虫)的自然控制能力增强。此外,广谱性捕食天敌种群有着很强的扩散能力,因此,在棉花种植区域的益虫数量的增多实际上对整个农业生态系统都大有裨益。然而,种植转 Bt 基因作物区域农药使用的大幅度减少,也会带来非靶标的次级害虫种群数量上升。例如,在 20 世纪末中国推广抗虫棉之初,盲蝽仅为棉田次要害虫,随着抗虫棉的推广,棉田盲蝽种群数量渐渐增多,已成为棉花的主要害虫。这个结果说明单靠种植转基因抗虫作物不可能解决所有虫害的控制问题,但是转基因抗虫作物可以是害虫综合治理策略中的重要一部分。从经济学角度看,转 Bt 基因抗虫棉平均可以为农民增产 10%,并降低 60%的农药使

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用量，对环境保护和农民健康都有着积极作用。

木瓜是一种重要的果树作物，在中国一般为鲜品出售。然而，木瓜环斑病毒对其危害极大。为了控制这种病毒和保护木瓜产业，美国于 20 世纪 90 年代研制出了抗木瓜环斑病毒的转基因木瓜，并于 1998 年首先在夏威夷得以商业化种植。在中国，抗木瓜环斑病毒的转基因木瓜由华南农业大学研发成功，并于 2006 年首先在广东省获准商业化种植。转基因木瓜在广东省的种植比例由 2007 年刚开始商业化种植时的 70％上升到 2012 年的 95％。此外，海南省也批准了种植转基因木瓜，其木瓜总种植面积为 5 000 hm^2，其中 40％的种植区域种植转基因品种，因此，转基因木瓜在全国的种植总面积达到了 6 275 hm^2。种植抗病毒的转基因木瓜有效地控制了木瓜病毒病，从而大幅度地降低了化学农药的使用，不仅增加了农民收入，而且大大改善了生态环境。

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Environmental safety evaluation and risk management of GM crops in China

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Genetic engineering is one of the most powerful 21st-century technologies, and its use is driving the new "green revolution" in agriculture. In global terms, the use of genetically modified (GM) crops has increased rapidly and steadily since the first commercialization in the United States in 1996. Although there are great potential benefits from the use of GM crops, the potential risks to the environment have been the subject of concern and debate. GM crop safety has become one of the major issues faced by governments in many countries.

With over 20 years of nationwide oversight of agricultural biotechnology, China has developed a comprehensive regulatory framework for regulating environmental safety of GMOs and related products. Taking insect-resistant Bt crops as an example, the regulatory framework typically includes considerations of environmental and agronomic benefits, potential for evolution of resistance to insecticidal genes in target pests, effects on non-target organisms and other potential environmental impacts.

To facilitate regulatory decision-making and guarantee the safety of GM events before commercialization, biosafety regulation from laboratory research to approval for use of a novel GM plant event is divided into five stages, namely: 1) laboratory research, 2) pilot testing, during which small-scale biosafety tests are conducted within a contained system or under controlled condition, 3) environmental release field testing, during which medium-scale biosafety tests are conducted under natural conditions with appropriate safety control measures, 4) pre-production testing, during which large-scale biosafety tests are conducted prior to application for a GMO biosafety certificate, and 5) application for biosafety certificates.

During the stage of laboratory research on GMOs, appropriate measures have to be adopted for guaranteeing safety under the supervision of an agricultural GMO safety leading group affiliated to the institute or university. When the laboratory research has been completed and a GM plant event is ready to enter the risk assessment period, the developers have to apply for a permit from the Ministry of Agriculture (MOA) for moving to the next stage. When applying for a permit to move risk assessments from one developmental stage to the next, the applicants have to submit required data to the MOA. When all the required safety tests after pre-production testing are finished, the developers can apply for a biosafety certificate to the GM event from the MOA. However, only insect-resistant Bt cotton and virus-resistant papaya have been widely grown in China to date.

Since 1997 when transgenic Bt cotton was approved for commercial production in China, the area planted with Bt cotton has dramatically increased. In 2012, the total area planted with Bt cotton reached 3.59 million hectares, representing 80% of the total cotton area. The growing of Bt cotton in China for 17 years has brought great benefits to farmers and the environment. Many insect pests, especially cotton bollworms, can cause serious economic damage to cotton. Before the introduction of Bt cotton, Chinese cotton farmers applied large quantities of chemical insecticides for cotton bollworm control, causing serious ecological problems of insecticide resistance, pest resurgence, and environmental pollution. Long-term field surveys showed that with the increasing adoption of Bt cotton, cotton bollworm populations have not only been effectively suppressed in cotton, but also greatly reduced in other non-Bt host crops such as maize, soybean and peanut in the same planting area. The Bt proteins expressed by GM cotton are very specific to the target pest, and has no direct toxicity to non-target organisms, such as the natural enemies of insect pests. Thus, due to the dramatic decrease of insecticide applications on cotton, the population abundances of generalist predators such as ladybirds, lacewings and spiders in cotton fields have gradually increased, providing better natural control for non-target pests such as aphids. In addition, generalist predators usually have great dispersal ability, and increased predator abundance in Bt cotton ultimately promoted biological control services in the whole agroecosystem. However, with the reduction of insecticide application on Bt crops, populations of secondary pests that are not sensitive to Bt proteins may increase. For example, following the start of production of Bt cotton in China, mirid bugs that had been regarded as secondary pests on cotton during last century have progressively increased their population levels and acquired pest status in cotton. This outcome demonstrates that it is not possible to solve all insect pest control problems by using insect-resistant GM crops, but such crops can be involved in an integrated pest management strategy for insect pest management. From an economic perspective, it is estimated that on average at the farm level, Bt cotton increases yield by 10%, reduces insecticide use by 60%, with positive implications for both the environment and the farmer's health.

Papaya is an important fruit crop that is widely consumed as fresh fruit in China. However, it is severely affected by the disease caused by papaya ringspot virus (PRSV). To control this disease and protect papaya industry, PRSV-resistant GM papaya was produced in 1990s in the USA, and it was first commercialized in Hawaii in 1998. In China, a PRSV-resistant GM papaya that was developed by South China Agricultural University was first approved for commercial planting in Guangdong Province in 2006. The percentage adoption of GM papaya in Guangdong increased from 70% in 2007 when it was first commercially planted to 95% in 2012. In addition, GM papaya was grown for the first time on Hainan Island, where 40% of 5 000 hectares of papaya grown was GM. Thus, the total area of GM papaya grown in China reached 6 275 hectares in the whole country. The planting of disease-resistant papaya has provided efficient protection against papaya ringspot virus. As a consequence, chemical application to this crop has been significantly reduced, with the results that the farmer's income has been enhanced and the environment has been improved.

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