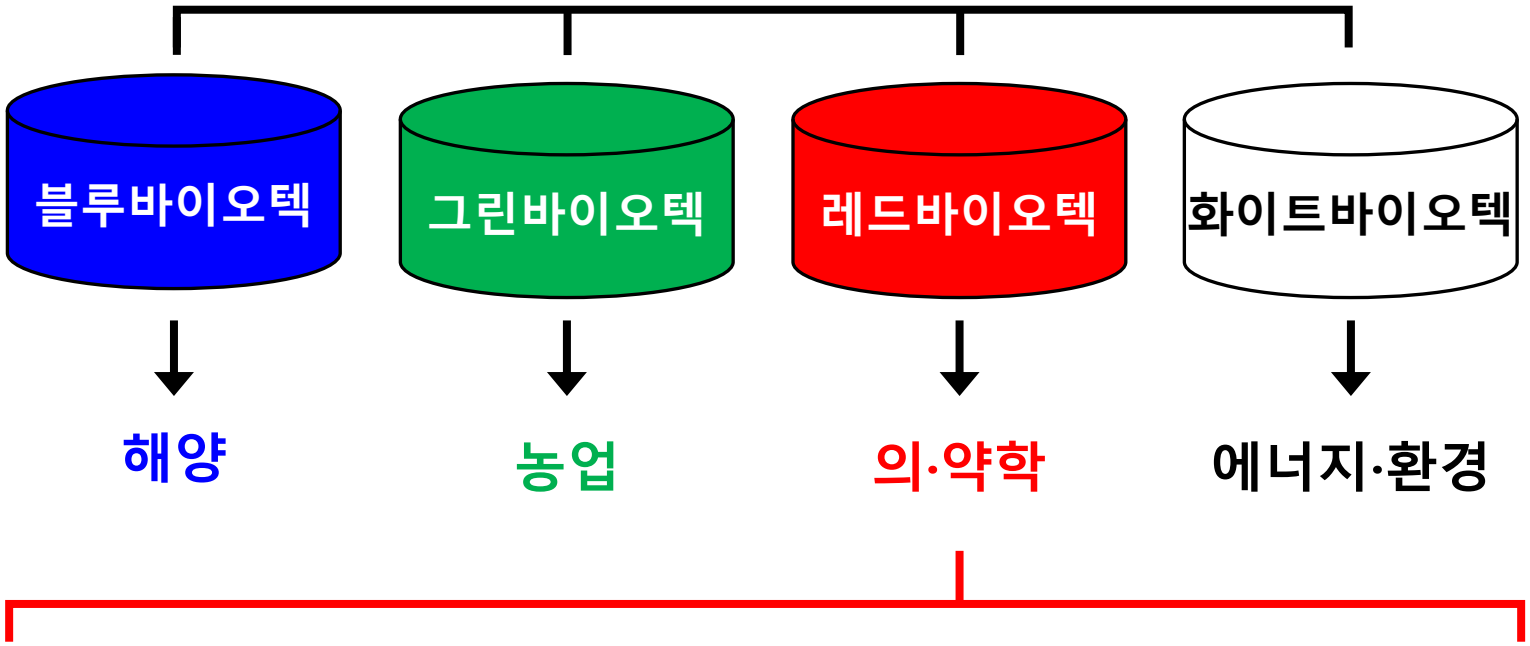
그린바이오 기술 현재와 미래

유전자교정 작물 중심으로

서울대학교 그린바이오과학기술연구원

종자생명과학연구소　김 주 곤

Biotechnology

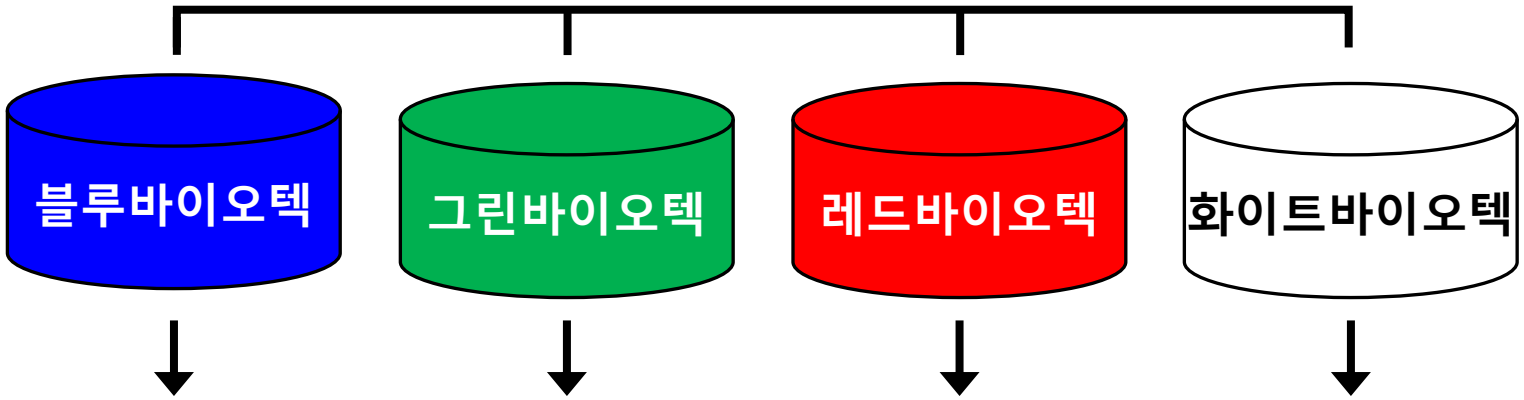


❖ 유전자변형 대장균을 통해 인슐린 생산 제품화 ('82, 미국)

→ 돼지이용 소량 생산에서 대량공급으로 저가 당뇨치료시대 개막

(돼지 70마리의 췌장 → 1사람 분의 인슐린 추출)

Biotechnology



인슐린 생산 GM콩
치매치료용 GM벼

그린바이오텍 ?
레드바이오텍 ?

미세먼지 제거 GM식물
바이오에너지용 GM작물

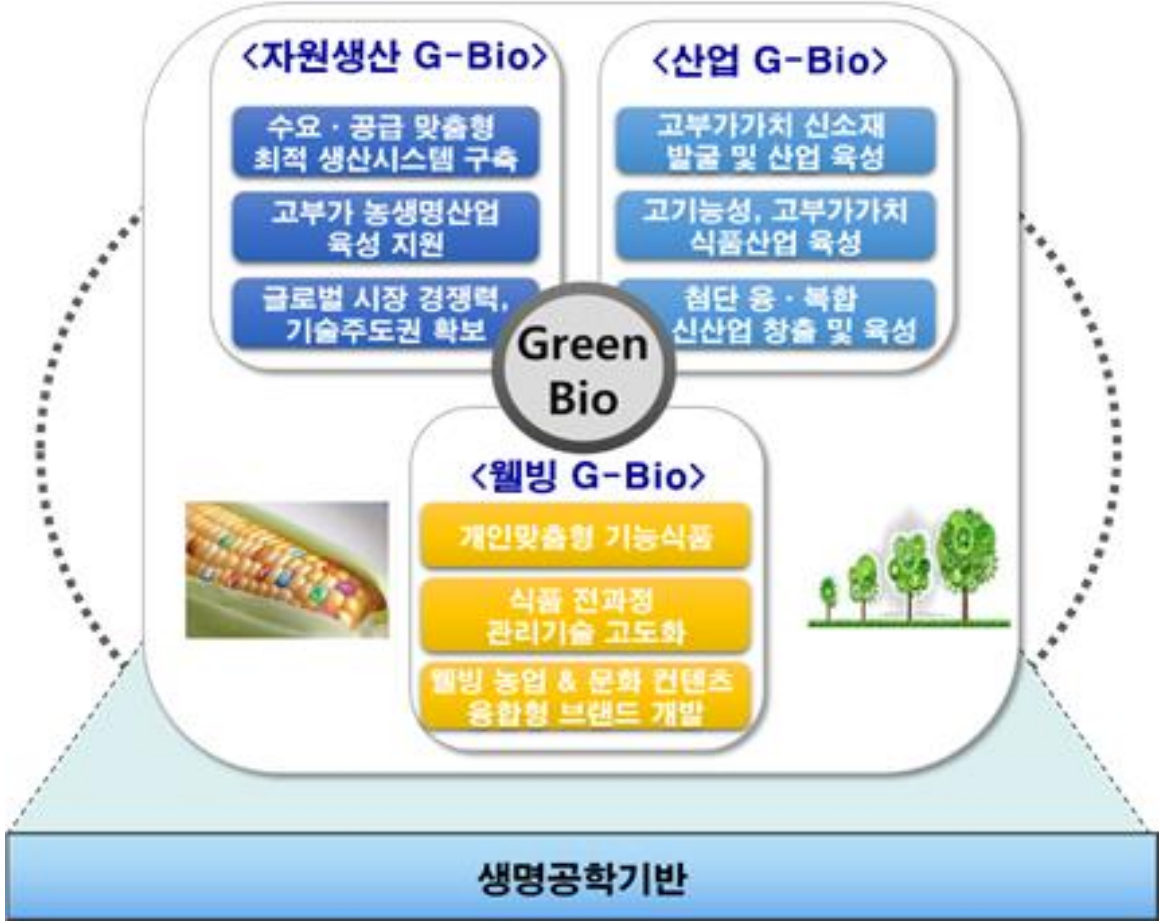
그린바이오텍 ?
화이트바이오텍 ?

농업 생명공학 → 레드바이오와 화이트바이오의 핵심 기술기반

농업의 첨단산업화 → 레드/화이트바이오로 영역 확대 필요

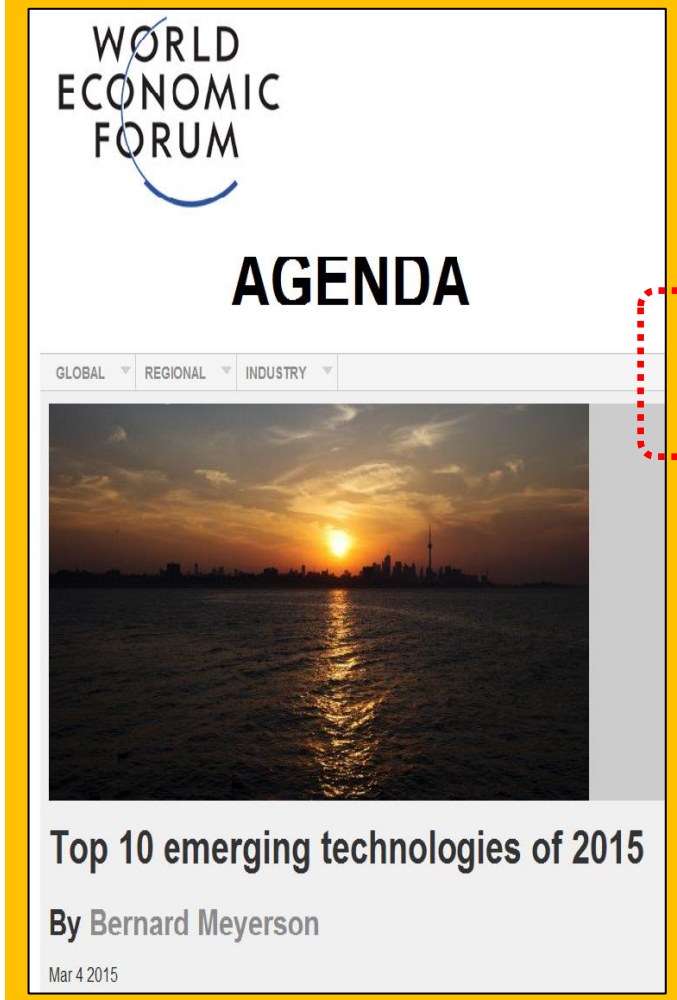
그린바이오 기술

안전한 먹거리와 고부가 농생명 소재산업을 위한
생명공학기반의 과학기술



2015 세계경제포럼 (WEF)이 선정한

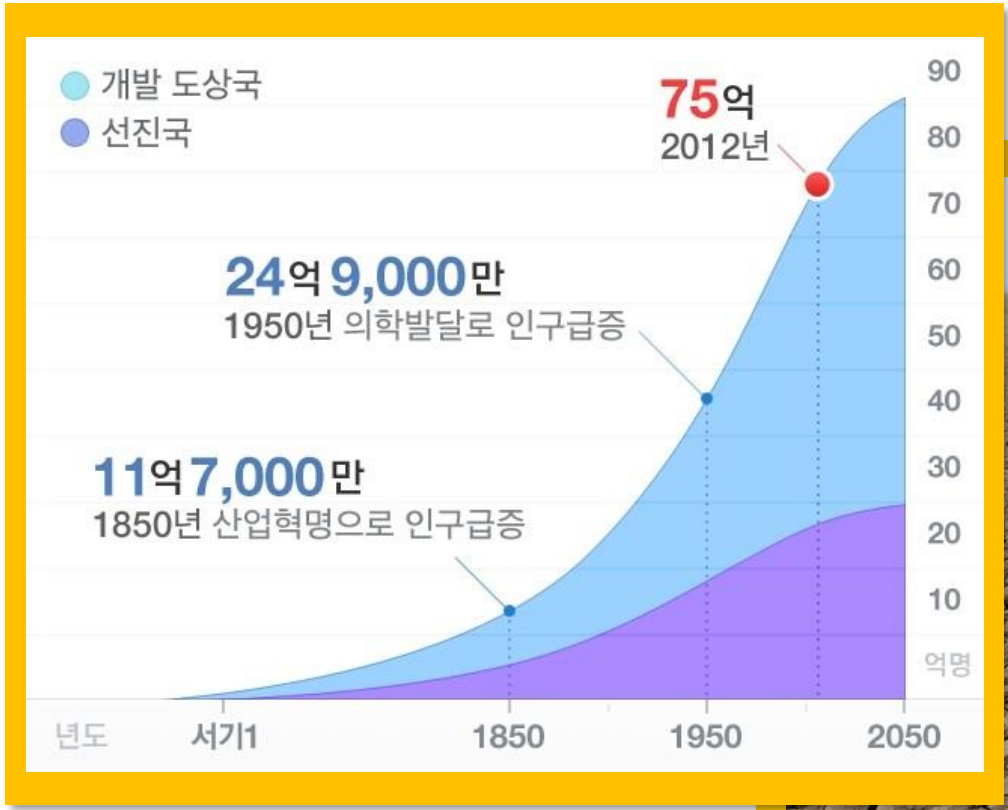
사회, 경제, 환경에 영향을 미칠 세계 10대 첨단기술



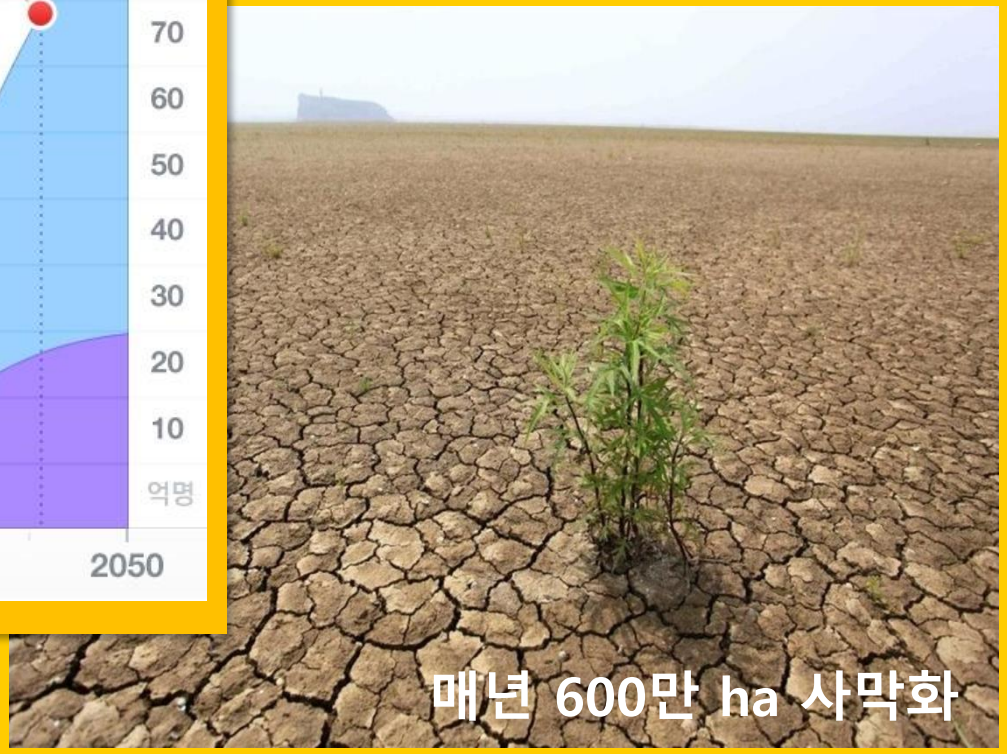
1. Fuel cell vehicles
2. Next-generation robotics
3. Recyclable thermoset plastics
4. Precise genetic engineering techniques
   (정밀 유전공학기술)
5. Additive manufacturing
6. Emergent artificial intelligence
7. Distributed manufacturing
8. 'Sense and avoid' drones
9. Neuromorphic technology
10. Digital genome

■ 글로벌 위기 심화

인구 증가

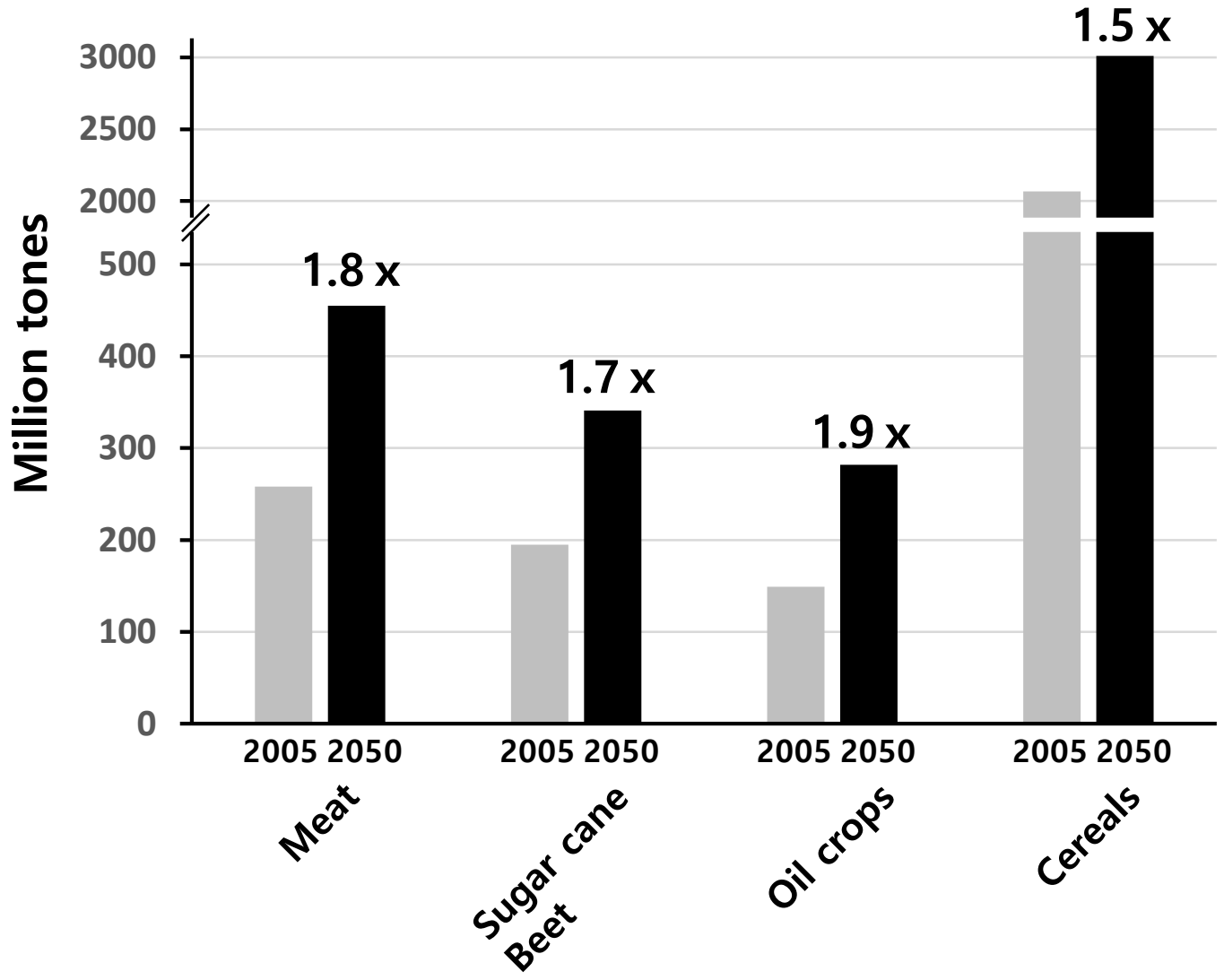


기후 변화



2050년까지 필요한 수확량 증가

http://www.fao.org/economic/eas/



■ 글로벌 식량위기

○ **2007-08년 : 기후변화에 따른 식량위기 본격화**

곡물재고량 감소 → 수출제한 → 곡물가격 폭등

에그플레이션(agflation) 신조어 탄생(2007년)

농업(agriculture)과 인플레이션(inflation)의 합성어,
농산물 가격 급등으로 일반 물가가 상승하는 현상

○ **2010-11년 : 가뭄으로 또 한차례의 식량위기 도래**

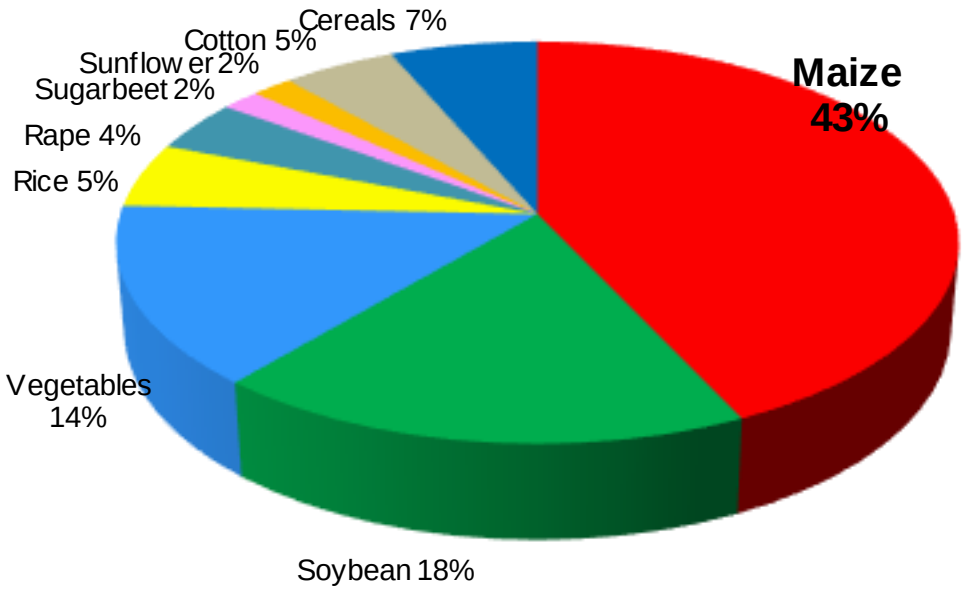
수출제한 → 밀, 옥수수, 대두 등 가격 상승

현재도 매년 지구촌 식량위기 도래

→ 국가별 경제/사회적 위기상황 봉착

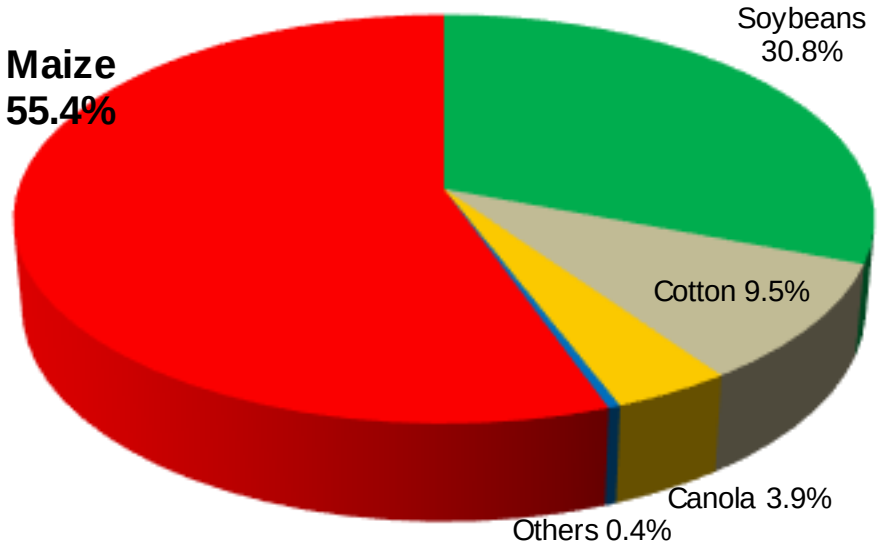
■ 종자시장의 주요 작물 (옥수수)

Seed Market Divided by Crop 2012



Total = $37,560 million

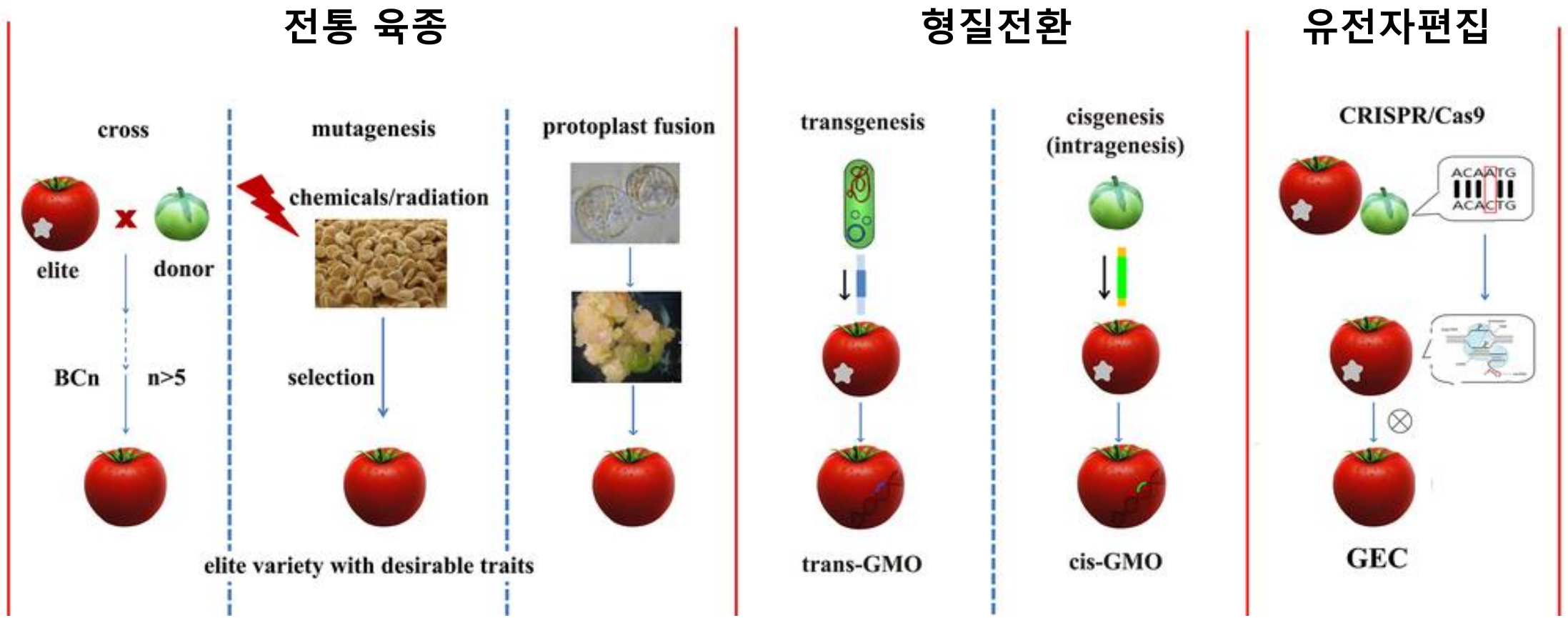
GM Crop Market Value by Crop 2012



Total = $18,495 million

Ref. Phillips McDougall (2013) Seed Industry Overview

■ 육종 방법 비교



https://www.mpg.de/9943316/gene-editing-plants

중국 화공그룹, 스위스 신젠타 52조원에 인수

공감언론 뉴시스 NEWSIS

기사등록 일시 : [2016-02-06 06:30:00]

【서울=뉴시스】 중국 국유기업 화공그룹(CNCC)이 약 430억 달러(약 52조3700억원)에 세계 최대 농약업체이자 3위 종자생명공학 기업인 스위스 신젠타를 인수했다.

바이엘, 몬산토 '660억 달러' 인수 합의

세계 최대 규모 농·화학 기업 탄생

이도현 기자 dhlee@newsfarm.co.kr | 등록 2016.09.20 18:34:19

세계 최대 규모의 농화학 기업이 탄생한다.

독일 화학·제약업체 바이엘이 세계 최대 종자회사 미국의 몬산토를 660억 달러(74조 3800억 원)에 인수하기로 합의했다고 지난 14일 밝혔다.

이번 인수합병은 올해 최대 규모로 인수 금액은 주당 128달러이며 전액 현금으로 지급된다.

바이엘은 '아스피린'으로 잘 알려진 농화학 기업으로 독일에 거점을 두고 152년의 역사를 가지고 있다. 몬산토는 종자 유전자 변형 식물 상업화에 세계 처음 성공한 농업기업으로 미국에 거점을 두고 있다.

이도현 기자 dhlee@newsfarm.co.kr

Trehalose Rice: Technology Licensed to Mahyco 2007 and Bioseed 2012

Trehalose biosynthesis

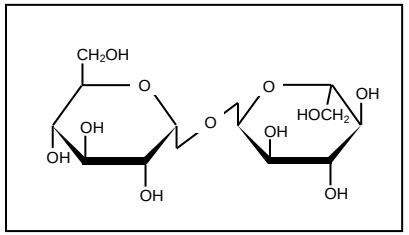
Glucose-6-Phosphate + UDP-Glucose

↓ **Trehalose-6-Phosphate Synthase (TPS)**

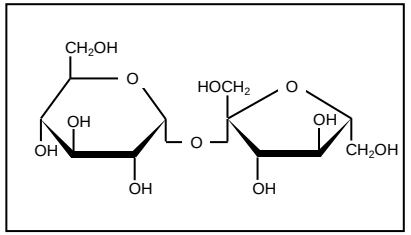
Trehalose-6-Phosphate

↓ **Trehalose-6-Phosphate Phosphatase (TPP)**

Trehalose

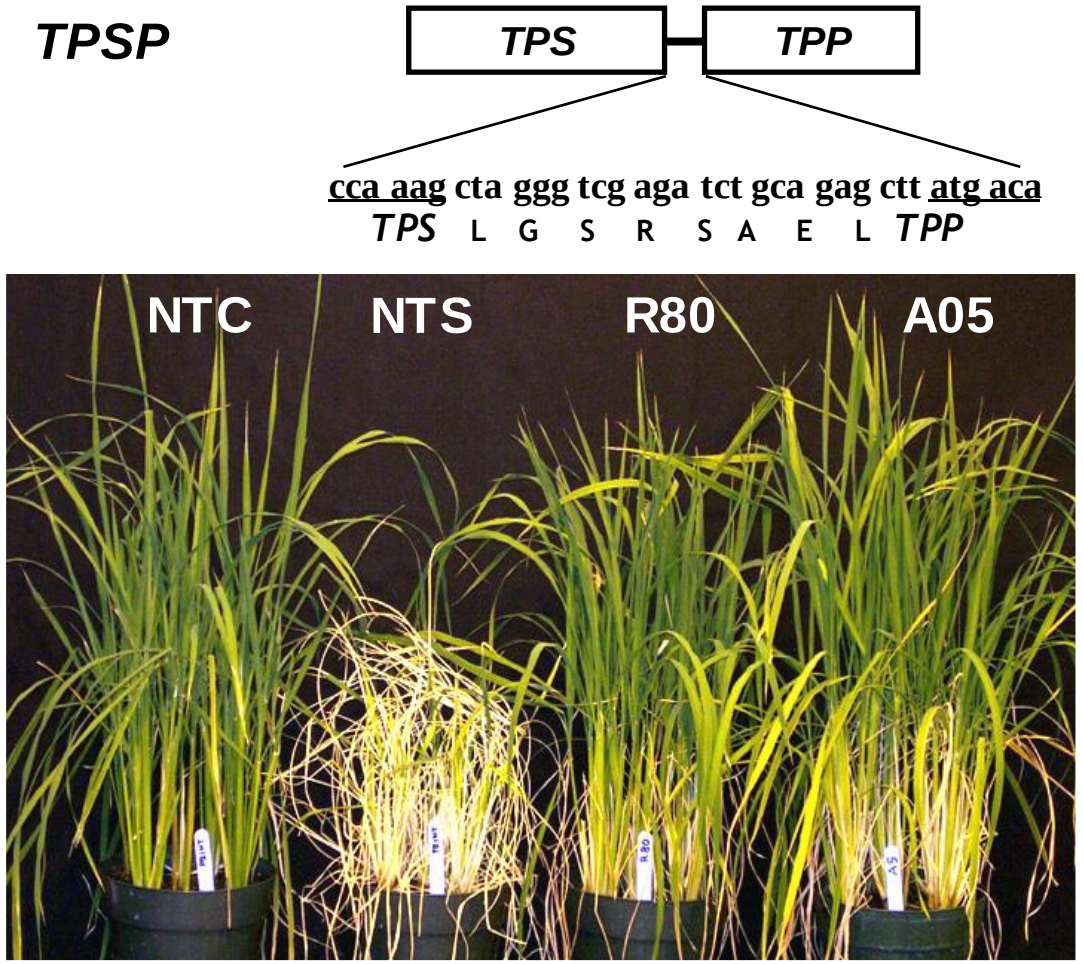


Trehalose



Sucrose

Trehalose Rice –Drough / Salt tolerance



Garg et al *PNAS* 2002

Jang et al *Plant Physiology* 2003

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Tuesday, 26 November, 2002, 03:26 GMT

GM rice can tough it out

The rice plant on the left has been genetically modified

A new genetically engineered variety of rice, which can grow in all types of conditions, has been developed by scientists in the United States and Korea.

The researchers added sugar genes from a bacterium to create their improved plant.

> **We will be able to feed many more people**
>
> **Professor Ray Wu**

The genes allow the rice to maintain yields even if it is stressed, by cold, drought and high salt levels. The sugar leaves the chemical composition of the rice grains unchanged.

It is hoped the new crop will help farmers in developing countries be more productive on poor land, increasing yields by up to 20%.

- Genome revealed
- Future applications
- Data access row
- Why so many genes?
- Rice: A few facts

See also:

- 13 Dec 00 | Science/Nature
  Little weed in science landmark
- 14 Jan 00 | Science/Nature
  Yellow rice gives dietary boost

Internet links:

- PNAS
- Cornell University
- Rice Genome Research Program
- US Rice Genome
- Gene Stories (BBC)

Top Science/Nature stories now:

- Date for first Australians
- Fifth closest star discovered
- Mona Lisa smile secrets

■ 대표특허와 기술이전

특허1: 유전자 발현조절 프로모터 개발 → 미국특허 및 해외 기술이전

등록명	등록자 (주/공)	등록국	등록번호	등록일자	주요내용
PROMOTERS AND METHODS THEREOF	**김주곤(주)** 외 2인	**미국**	US8987557B2	2015.03.24.	작물 유전자 발현용 프로모터 이용기술 (APX/PGD1/R1G1B)

특허2: 가뭄저항성 TPSP 유전자 → 미국특허 및 해외 기술이전

등록명	등록자 (주/공)	등록국	등록번호	등록일자	주요내용
METHOD FOR INCREASING RESISTANCE OF MONOCOT PLANTS AGAINST ABIOTIC STRESSES, TPSP FUSION ENZYME GENE CONSTRUCTS, AND TRANSFORMANTS	**김주곤(주)** 외 9인	**미국**	US8889949B2	2014.11.04.	가뭄저항성 유전자 TPSP 이용기술

○ **2007년 인도 Mahyco 계약기술료 $ 750,000**

○ **2012년 인도 BioSeed 계약기술료 $ 600,000**

※ 기술이전을 통해 다국적기업과 글로벌 시장용 GM종자 공동개발 중 → 상업화 시 로열티 및 공동지분 확보

(국내활용권은 우리가 확보)

■ 해외기술이전 총 20건: 4개국 5개 다국적기업

→계약기술료 430만불 (47억원) / 선급기술료 110만불 (12억원)

기술이전명	기술이전 년도	기술이전기업	대상국가	기술료 수입금액	기술이전 유전자명	선급 기술료
수량증대 유전자 이용기술	2017	Crop Design/ BASF	독일	**EUR 400,000**	Kelch-1/ Kelch-2	**EUR 11,500**
가뭄저항성 TPSP 유전자 이용기술	2012	BioSeed	인도	**USD 600,000**	TPSP	**USD 17,500**
유전자 프로모터 이용기술	2011	Limagrain/ Biogemma	프랑스	**USD 450,000**	APX/PGD1/ R1G1B	**USD 120,000**
작물생산성 OsNAC10 유전자 이용기술	2011	Crop Design/ BASF	독일	**EUR 900,000**	AP2/AP70/ NAC1/ NAC3/NAC4-1/4-2/ NAC6-1/6-2/HB8/ AP2-1/2-2/NAC10	**EUR 442,000**
작물생산성 AP37 유전자 이용기술	2009	Syngenta	스위스	**USD 650,000**	AP37	**USD 150,000**
가뭄저항성 TPSP 유전자 이용기술	2007	Mahyco	인도	**USD 750,000**	TPSP	**USD 157,000**

■ 가뭄저항성 옥수수 (DroughtGard hybrids)

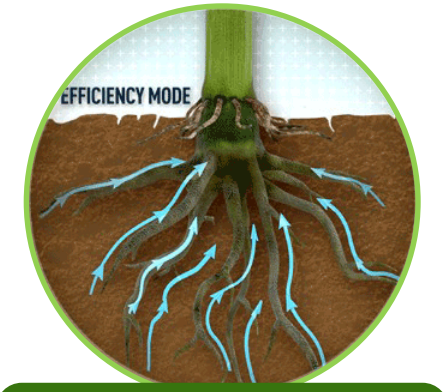
[캐나다(2010), 미국(2011), 일본(2012), 브라질(2016)
재배 승인 획득 및 아프리카 5개국으로 확산]

Genuity ® DroughtGard ® 제품은 세계에서 처음으로 가뭄 저항성 생명공학 형질을 가진 옥수수로, 가뭄 스트레스에 저항하는데 도움을 주고 ***CspB*** **(cold shock proteins, RNA-chaperone)** 발현을 통해 날씨로 인한 위험성을 최소화 하도록 디자인 되었음.

적은 물로 더 많은 것을 할 수 있음

가뭄조건에서 잠재 수확량 최대화

The DroughtGard Hybrids
유전자는 물이 부족한 조건에서 식물이 성장하는데 필수적인 단백질을 생산하도록 하여 수확량 지지를 도움.



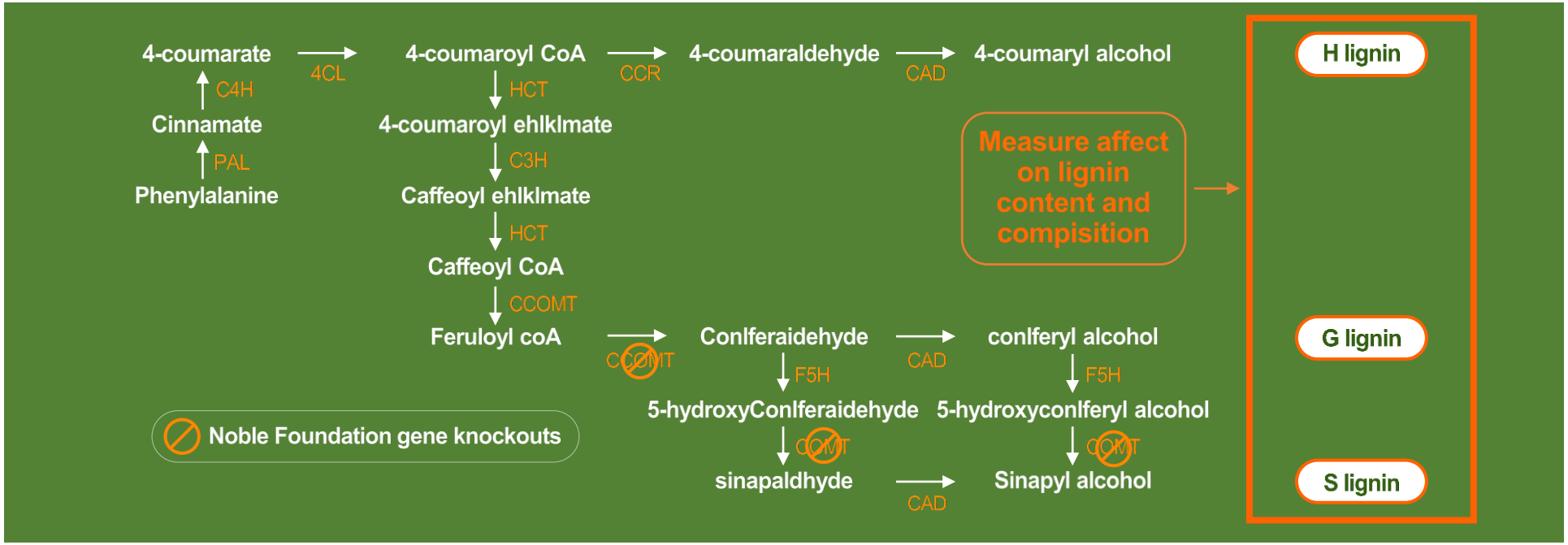
수분 효율성

가뭄이 닥쳤을 때,
수분 효율성은 다음 비가 내릴 때 까지 옥수수 작물로 하여금 물을 아끼고 효율적으로 사용할 수 있도록 함.

■ 리그닌 저감 알팔파 (HarvXtra™ Alfalfa)

- 세포벽 성분인 리그닌 생합성 경로에서 CCOMT 유전자 발현 을 저해시켜 알팔파 사료의 리그닌 함량을 감소시킴
- 기존 알팔파보다 동일 성장단계에서 더 나은 품질 보유
- 재배자에게 수확시기의 유연성을 제공하여 수확량 을 극대화함

HarvXtra™ 알팔파는 고품질과 수확시기의 편의성을 제공함



■ 갈변방지 사과 (Arctic Apple)

(캐나다 기업 Okanagan Specialty Fruits 개발)

폴리페놀 산화효소의 활성 억제

OH OH O

미국 동식물검역국(APHIS)과 식품의약국(FDA)으로부터
상업화에 필요한 환경위해성과 인체위해성에 대한 안전성심사 통과

Monophenol Diphenol Quinone

라이프

[인터넷 광장] 매일 감자튀김 먹으면 암 발생 위험 커져

입력 2015.03.09 (07:29) | 수정 2015.03.09 (08:44)

뉴스광장 2015.03.09

오늘의 HOT클릭!

'취업깡패·화석선배' 올해 뜬 취업 신조어

감자튀김이나 감자 칩을 많이 먹으면 암에 걸릴 확률이 증가한다고 하는데요.

타이완 대학 공중보건학과의 연구결과, 튀김 음식에서 나오는 '아크릴아마이드'라는 유해물질을 매일 60mg을 섭취할 경우 암에 걸릴 위험이 500배 높아지는 것으로 나타났습니다.

'아크릴아마이드'는 감자를 120도 이상의 고온에서 요리할 때 생성된다고 하는데

■ 소비자 지향적 GM감자 개발

(미국 냉동감자회사인 Simplot社개발)

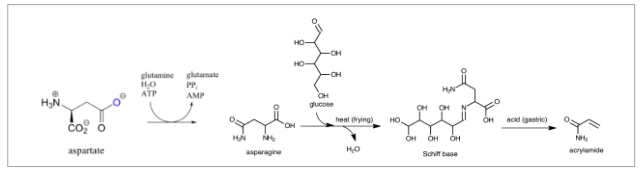
❖ **저장 및 가공 시 상처로 인한 갈변현상 방지**

❖ **고온 요리시 발생하는 잠재적 발암물질(아크릴아마이드) 함량을 감소**

자른 후 10 시간 경과

Innate™ 관행종

아크릴아마이드 생성



- 2014년 11월 미농무에서 상업적 재배 승인
- 2015년 3월 미 식약처에서 식용으로 승인
  (일반 감자와 다른차이 없이 안전하고 건강하다고 인정)

■ 고품질 대두 “Plenish Soybean”

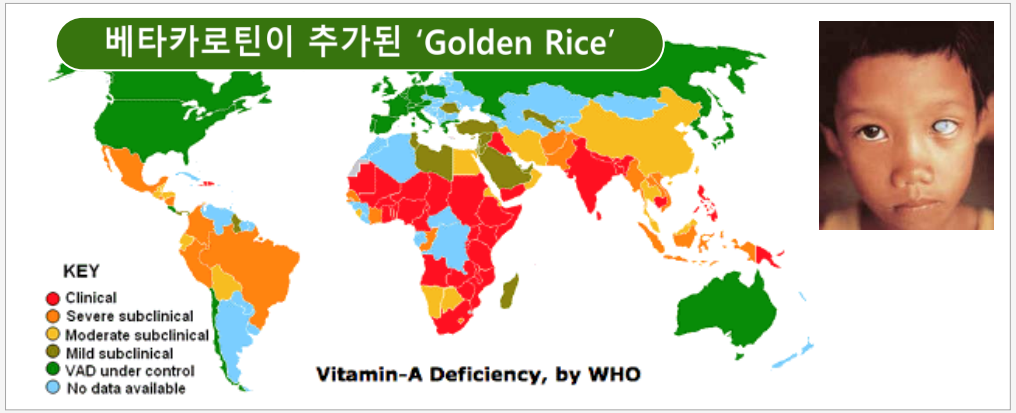
대두유의 안정성과 영양성 향상

- 불안정한 지방산 대폭 감소
- 수소첨가 과정의 필요성과 트랜스 지방 생성 제거
- 심장에 좋은 oleic fatty acid (단일불포화지방산) 대폭 증가
- 지방산 조성이 심장에 좋은 올리브 유와 비슷함

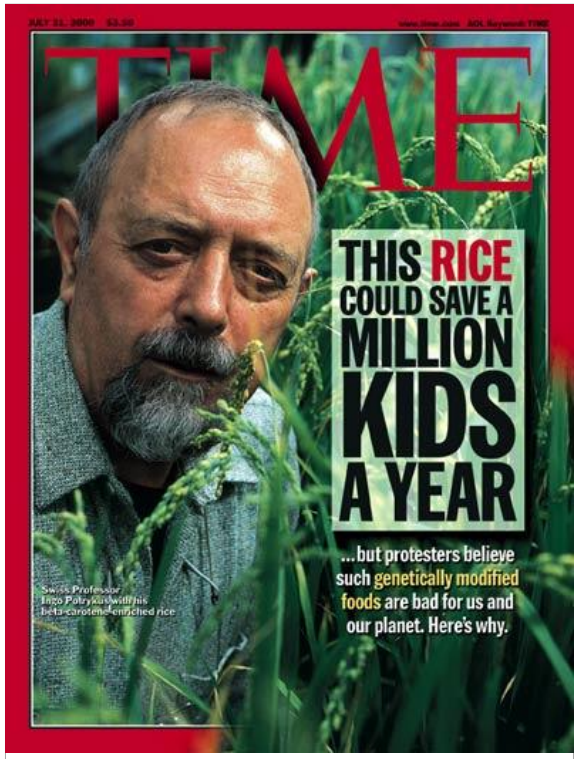
	포화		단일불포화	다중불포화	
시판 대두유	11	4	22	55	8
	Palmitic Acid C16:0 →	Stearic Acid C18:0 →	Oleic Acid C18:1	→ Linoleic Acid C18:2 →	Linolenic Acid C18:3
			oleic 불포화효소 유전자 저해		
Plenish™ High Oleic*	6-7	4-5	>75	5-8	<3

Golden Rice





- 매년 250,000 에서 500,000 명 의 어린이들이 시력을 잃음
- 야맹증이 첫 증상들 중 하나임
- 감염에 대한 저항력이 감소함



Dr. Ingo Potrykus (Swiss)

Crop Biotech Update

GOLDEN RICE GETS APPROVAL FROM HEALTH CANADA

On March 16, 2018, Health Canada has notified the International Rice Research Institute (IRRI) that it has no objection to the food use of Provitamin A Biofortified Rice Event GR2E, more commonly known as Golden Rice. The decision coincides with the approval from Food Standards Australia New Zealand (FSANZ) in December 2017.

Photo source: IRRI

In their announcement, Health Canada said that "the changes made in this rice variety did not pose a greater risk to human health than rice varieties currently available on the Canadian market." In addition, Health Canada also concluded that GR2E would have no impact on allergies, and that there were no differences in the nutritional value of GR2E compared to other traditional rice varieties available for consumption except for increased levels of provitamin A.

Scientists with expertise in molecular biology, microbiology, toxicology, chemistry, and nutrition conducted a thorough analysis of the data and the protocols provided by IRRI to ensure the validity of the results. Health Canada conducted a comprehensive assessment of Golden Rice according to its Guidelines for the Safety Assessment of Novel Foods. Their approach in the safety assessment of GM foods is based upon scientific principles developed through expert international consultation over the last 20 years with agencies such as the World Health Organization (WHO), the Food and Agriculture Organization of the United Nations (FAO), and the Organization for Economic Co-operation and Development (OECD). This approach is also currently applied by regulatory agencies around the world in countries such as the European Union, Australia/New Zealand, Japan, and the United States.

March 16, 2018

■ 농산물의 수요 촉진 (고품질, 고부가 농산물)

Korean 황금쌀: Vitamin A 합성물질인 베타카로테인 생성

“세계 최초 기능성 컬러쌀 개발 성공”

(색소조절 대사공학)

white

유전자 2개

yellow

β- carotene

비타민 A 생성

쌀

유전자 3개

orange

Zeaxanthin

시력증강

쌀

유전자 4개

red

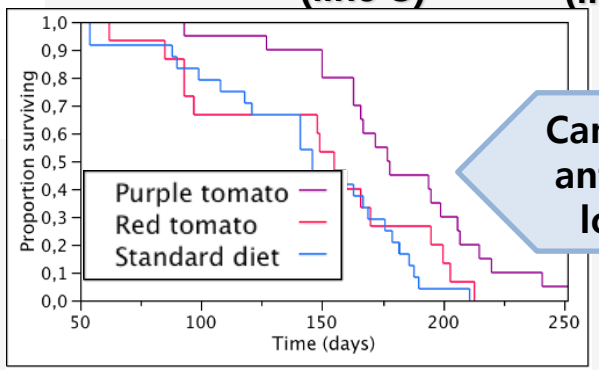
Astaxanthin

노화방지 쌀

■ 고안토시아닌 토마토 (John Innes Center in UK)

del/ros
(line N)

WT | del/ros (line C) | del/ros (line N)



Cancer-prone mice fed high-anthocyanin tomatoes lived longer than control mice

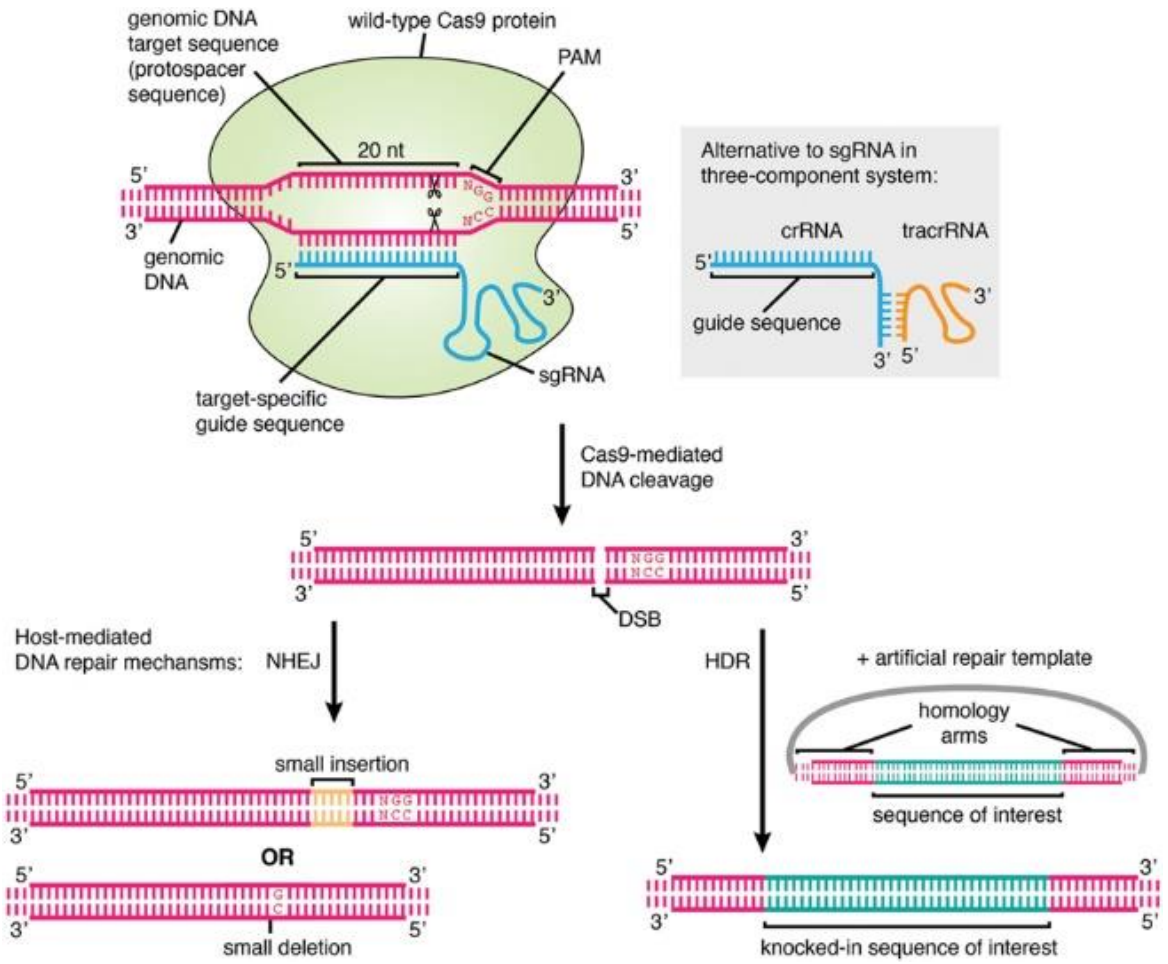
Butelli et al. (2008)

❖ 금어초의 안토시아닌 생합성 전사인자 **2**종을 과실특이적으로 발현시켜 안토시아닌 증가된 토마토

❖ 쥐 실험시 수명 연장 **(1.2~1.3**배**)** 효과 **(Nature Biotechnology, 2008)**

캐나다 기업(New Energy Farms)을 통해 온실 재배 후 주스로 가공된 뒤 건강에 어떤 이로움이 있는지 임상실험 진행 중임

Genome editing using CRISPR/Cas9



Front Genet. (2015) 6:300

Polyphenol oxidase (**PPO**), an enzyme that cause **browning**.

Deleting six PPO genes using **CRISPR-Cas9** in the mushroom's genome, **reducing** the enzymes' activity by **30%**.

nature

BIOTECHNOLOGY

Gene-edited CRISPR mushroom escapes US regulation

A fungus engineered using CRISPR–Cas9 can be cultivated and sold without oversight.

BY EMILY WALTZ

The US Department of Agriculture (USDA) will not regulate a mushroom that has been genetically modified with the gene-editing tool CRISPR–Cas9, the agency has confirmed. The long-awaited decision means that the mushroom can be cultivated and sold without passing through the agency's regulatory process — making it the first CRISPR-edited organism to receive a green light from the US government.

"The research community will be very happy with the news," says Caixia Gao, a plant biologist at the Chinese Academy of Sciences Institute of Genetics and Developmental Biology in Beijing, who was not involved in developing the mushroom. "I am confident we'll see more gene-edited crops falling outside of regulatory authority."

Yinong Yang, a plant pathologist at Pennsylvania State University (Penn State) in University Park, engineered the fungus — the common white button mushroom (*Agaricus bisporus*) — to resist browning. The effect is achieved by targeting the family of genes that encodes polyphenol oxidase (PPO), an enzyme that causes browning. By deleting just a handful of base pairs in the mushroom's genome, Yang knocked out one of six PPO genes — reducing the enzyme's activity by 30%.

STUART MCCALL/GETTY

The common white button mushroom (*Agaricus bisporus*) has been modified to resist browning.

official. "They were very excited," Yang says: "There was certainly interest and a positive

The United States is revamping its rules for regulating GMOs, which collectively are

nature biotechnology

Using the gene-editing tool **CRISPR-Cas9**, the team **Knock-out** the endogenous waxy gene ***Wx1***, which encodes the endosperm's granule-bound starch synthase responsible **for making amylose**.

CRISPR-edited crops free to enter market, skip regulation

The first CRISPR-edited crops presented to the US regulatory system can be cultivated and sold without oversight by the US Department of Agriculture (USDA), the agency said in a pair of letters posted in April. The decisions could reduce by millions the cost of development of the crops: an anti-browning mushroom and a waxy corn genetically modified with the gene editing tool CRISPR-Cas9. Some scientists hailed the decision as a step in the right direction, although media outlets and other interested parties said it illustrates the murky state of US biotech regulations.

© Dnoc4k Photos / Alamy Stock Photo

DuPont Pioneer's high amylopectin corn is the first CRISPR-edited plant likely to bypass USDA oversight.

Johnston, Iowa–based DuPont Pioneer engineered the waxy corn to contain starch composed exclusively of the branched polysaccharide amylopectin—a commodity in processed foods, adhesives and high-gloss paper. Company researchers achieved the effect by shutting down production of cornstarch's other long-chain polysaccharide, amylose. Using the gene-editing tool CRISPR-Cas9, the team knocked out the endogenous waxy gene *Wx1*, which encodes the endosperm's granule-bound starch synthase responsible for making amylose.

DuPont Pioneer, currently undergoing a merger with The Dow Chemical Company, says it expects the CRISPR-edited variety to have higher yields than conventional waxy corn. The company plans to commercialize the plant within five years and follow it with

necessary tool in biotech. Plant pests have served as the trigger for USDA oversight since the 1980s, when the US government wrote the regulatory framework for biotech products.

Newer genetic engineering (GE) techniques that don't involve plant pests are quickly supplanting the old ones, and the USDA appears to be saying it does not have the authority to regulate the products of these techniques. The letters to DuPont and Yang were the agency's first decisions on CRISPR-edited crops. The agency ruled similarly on plants transformed with other gene-editing techniques, such as zinc-finger nuclease and transcription

CRISPR-edited crops free to enter market, skip regulation

ownership of the intellectual property rights to CRISPR-Cas is under review by the US Patent and Trademark Office's Patent Trial and Appeal Board (*Nat. Biotechnol.* **32**, 599–601, *Nat. Biotechnol.* **34**, 121, 2016)

says.

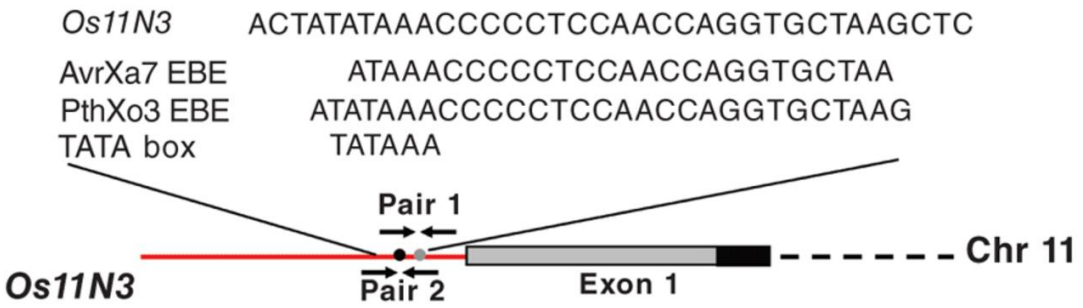
Crops that bypass the USDA may still go through the voluntary review process at the US Food and Drug Administration (FDA). And the US Environmental Protection Agency (EPA) reviews crops with

nature biotechnology

Nat. Biotechnol. (2014) 32, 947-951

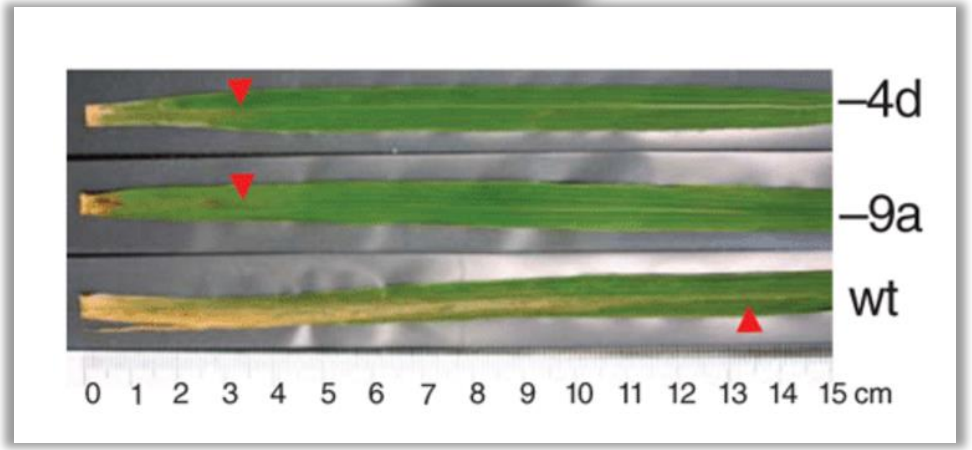
High-efficiency TALEN-based gene editing produces disease-resistant rice

- ✓ ***Xanthomonas oryzae* pv. *oryzae* (Xoo) 벼흰잎마름병**
- ✓ **AvrXa7 or PthXo3, Transcription activator-like (TAL) effectors**
- ✓ ***Os11N3* (*OsSWEET14*), a sucrose-efflux transporter**



Mutations in the *Os11N3* promoter

The loss of induction by TAL effectors



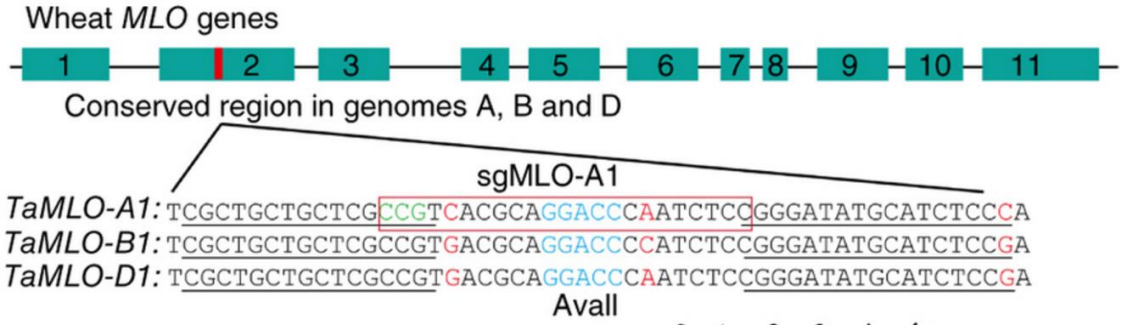
Disease-resistance rice

nature biotechnology

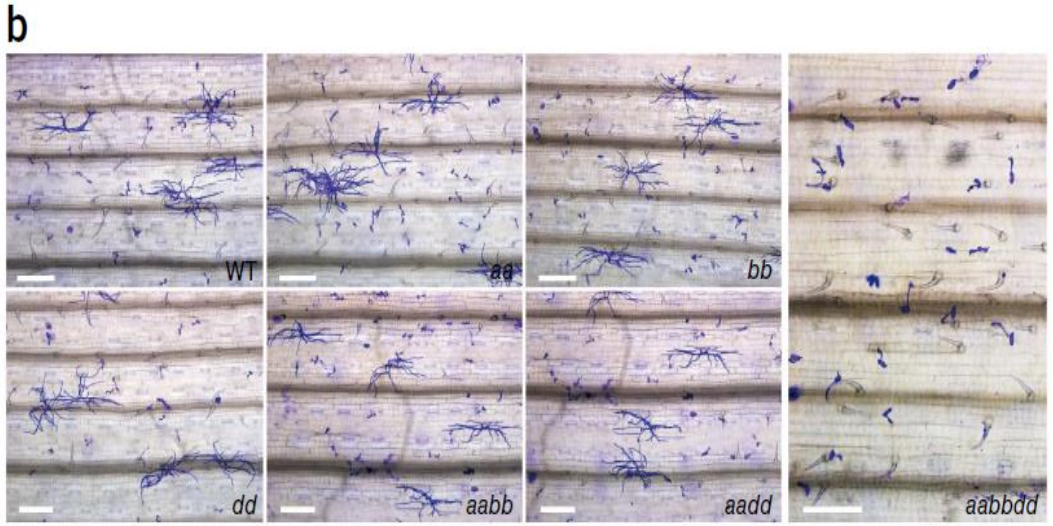
Nat. Biotechnol. (2012) 30, 390-392

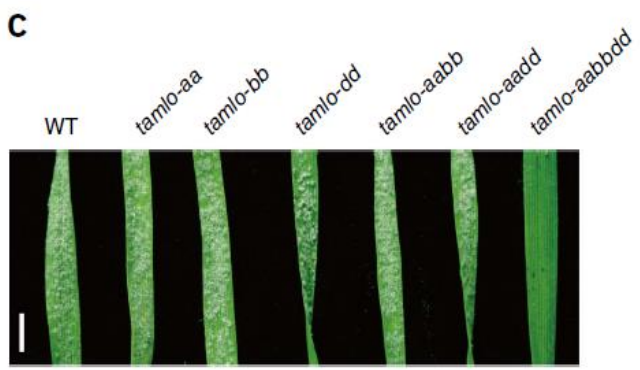
Simultaneous editing of three homoeoalleles in hexaploid bread wheat confers heritable resistance to powdery mildew

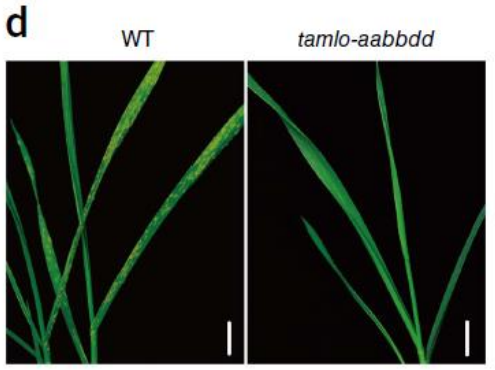
- ✓ **powdery mildew (흰가루병)**
- ✓ **Hexaploid bread wheat (*Triticum aestivum* L., 2n = 42, AABBDD)**
- ✓ ***MLO* loci, encode proteins to repress defenses against powdery mildew diseases in other plants**



TALEN/CRISPR-induced mutations

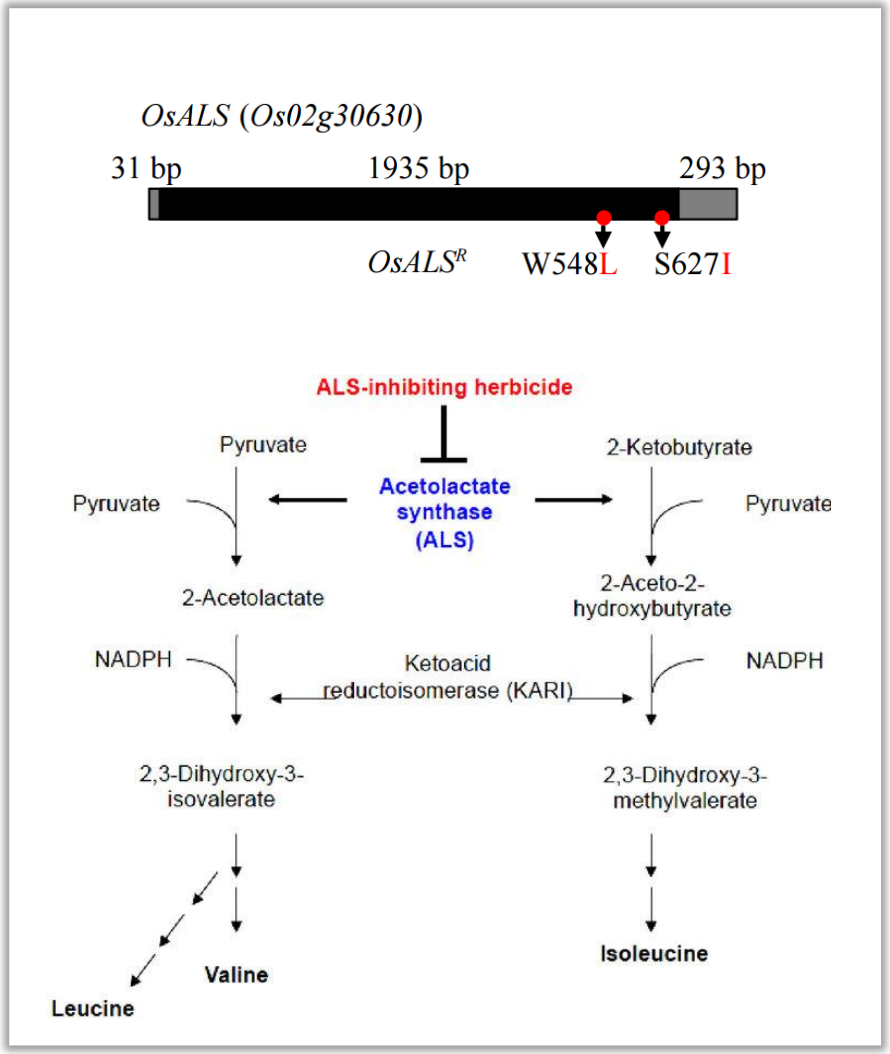


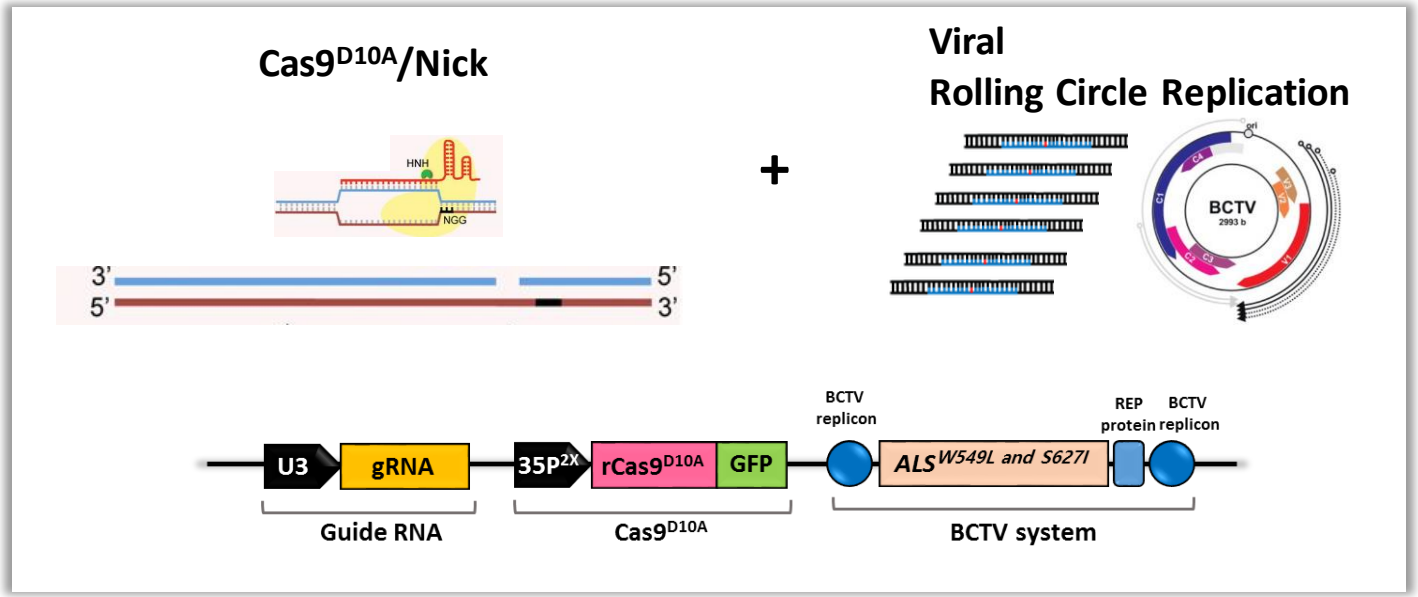




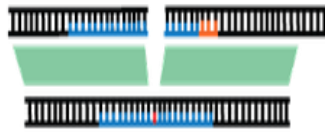
Loss-of-function of wheat *MLO* genes

Herbicide-resistant mutations in Acetolactate synthase (ALS)





HDR

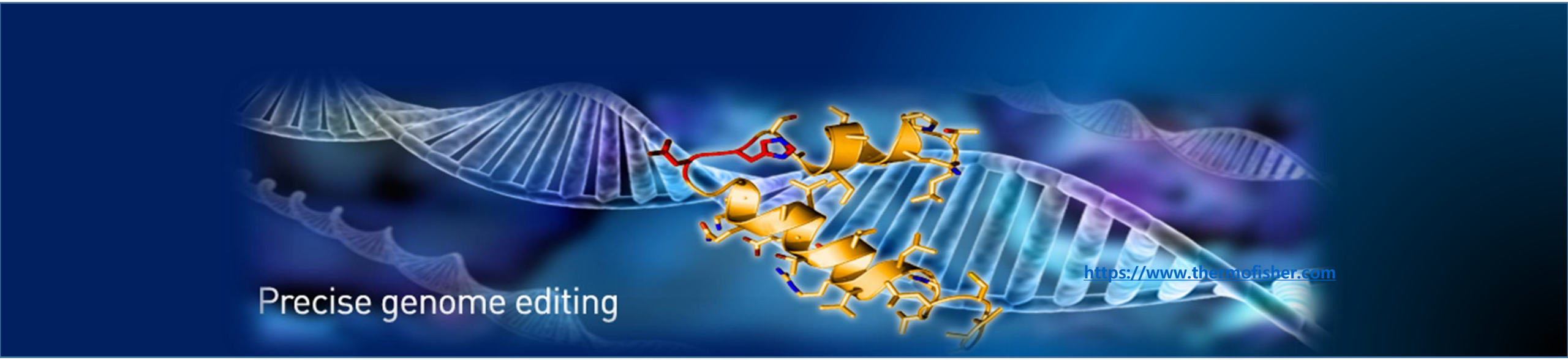


Nick Repair with ds template from BCTV system

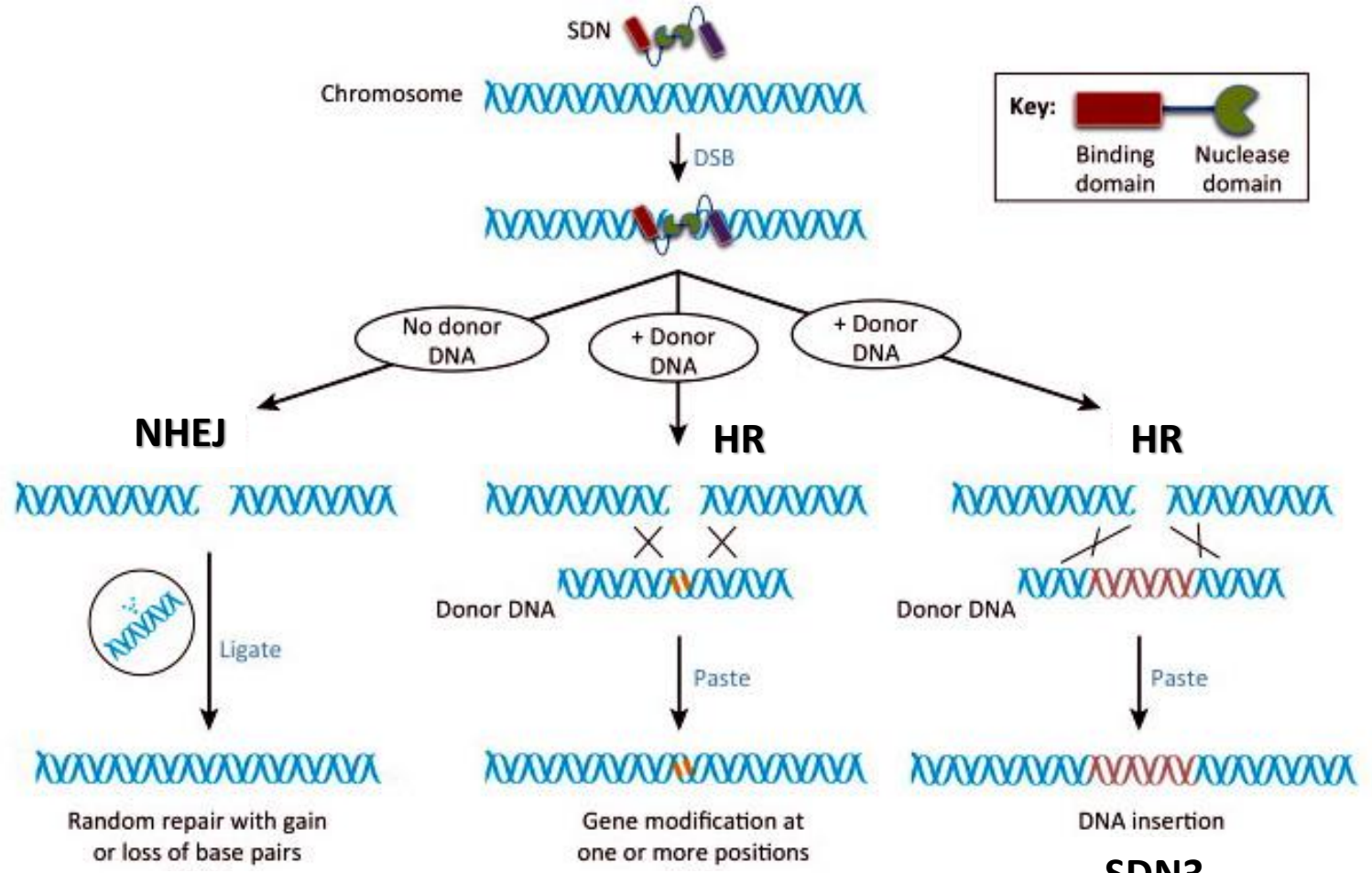
Mutations in Os*ALS (W548L)* and *ALS (S627I)*

Herbicide-Resistant Rice Plants

Gene-Editing Technologies



DSNS (Site-Directed Nucleases)



SDN1
Gene off

SDN2
Gene edit

SDN3
Add gene

New Plant Breeding Techniques

New Plant Breeding Techniques (NPBTs) [1]	산물중 외래 DNA 유무	비고
Site-Directed Nucleases -1 (SDN-1)	무 [2]	Genome Editing
Site-Directed Nucleases -2 (SDN-2)	무 [2]	Genome Editing
Oligonucleotide directed mutagenesis (ODM)	무	Genome Editing [3]
Cisgenesis & Intragenesis	무	
RNA-dependent DNA methylation (RdDM)	무	
Grafting on GM rootstock	무	
Reverse Breeding	무	
Site-Directed Nucleases -3 (SDN-3)	유/무 [4]	Genome Editing
Agro-infiltration (agro-infiltration “sensu stricto”, agro-inoculation, floral dip)	유/무 [5]	

1) European Commission 산하 Joint Research Centre(JRC)의 2011년 보고서에 제시된 기술 중 synthetic genomics를 제외한 기술 중심의 구분.
2) 유전적 분리 (segregation)에 의해 삽입 DNA가 제거된 최종 산물을 생산하는 경우.
3) Sprink T 등 (2016) Plant Cell Rep. doi:10.1007/s00299-016-1990-2
4) 삽입된 DNA의 기원(self 또는 foreign)에 따른 차이
5) 처리 부위 및 DNA의 기원에 따른 차이

NPBT Regulation in USA

USDA **United States Department of Agriculture**
Animal and Plant Health Inspection Service

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Biotechnology (BRS) / Am I Regulated Under 7 CFR Part 340?

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Am I Regulated Under 7 CFR part 340?

Last Modified: Jun 8, 2016 Print

Submission Process for Am I Regulated Letters of Inquiry

The Plant Protection Act (PPA) authorizes the Animal and Plant Health Inspection Service (APHIS) to protect plant health in the United States. Under that authority, APHIS currently regulates certain genetically engineered organisms (GE) that may present a plant health risk. Biotechnology Regulatory Services provides the regulatory oversight of certain GE organisms to protect plant health, by regulating the introduction—meaning the importation, interstate movement, and environmental release—of those GE organisms that may pose a pest risk to plants under the regulations at 7 CFR part 340. The definition of a regulated article is found at 7 CFR § 340.1. In addition, BRS coordinates and works with other programs in APHIS, the Environmental Protection Agency and the Food and Drug Administration consistent with the principles of the Coordinated Framework for the Regulation of Biotechnology to ensure protection of plant health, the environment and food safety.

If your GE organism meets the definition of a regulated article and you plan to import it, move it interstate or release it into the environment, you will need to apply for an authorization (permit or notification) before proceeding with the activity.

If you are unsure whether your GE organism meets the definition of a regulated article as described in 7 CFR part 340, prior to proceeding with an introduction, you may seek a confirmation of regulatory status of the GE organism from BRS by sending a signed letter containing the information described below to:

Address the letter of inquiry to:

Regulated Article Letters of Inquiry

Last Modified: Feb 7, 2017

December 19, 2016
Inquiry from Glowing Plant Inc. Regarding the Regulatory Status of Transgenic Auto-Luminescent Plant

APHIS BRS Response to Glowing Plant Inc.

December 19, 2016
Inquiry from Glowing Plant Inc. Regarding the Regulatory Status of Transgenic Bioluminescent *Nicotiana Tobacum*

APHIS BRS Response to Glowing Plant Inc.

Genome-edited Crops that are deregulated by USDA

년도	회사	작물	기술	유전자	Modification
2010	Dow	Maize	ZFN	IPK1KO/PATKI	토양오염원 저하, 제초제저항성 도입
2011	CPS	Algae	Meganuclease	Undisclosed	Undisclosed
2013	Calyxt (CPS)	Potato	TALEN	Vacuole invertase (Vinv)	저온저장성 향상, 고온 가열조리시 발암물질생성 저해
2014	Iowa State Univ.	Rice	TALEN	OsSWEET14 (Os11N3), OsSWEET11 (Os8N3)	박테리아 브라이트병 저항성
2014	Calyxt (CPS)	Soybean	TALEN	FAD2	Oilcomposition개선
2015	Benson Hill	Maize	Meganuclease	Undisclosed	광합성 효율 증가로 수확량 증가
2015	Agrivida	Maize	Meganuclease	Undisclosed	녹말 축적량 증가
2015	Calyxt (CPS)	Soybean	TALEN	FAD3	Oilcomposition개선
2016	Penn State Univ.	Mushroom	CRISPR-Cas9	Polyphenol oxidase	갈변방지 양송이
2016	Calyxt (CPS)	Wheat	TALEN	Mildew Resistance Locus	흰가루병 저항성 획득
2016	Dupont Pioneer	Maize	CRISPR-Cas9	waxy gene (Wx1)	amylopectin 성분강화
2016	Calyxt (CPS)	Potato	TALEN	Polyphenol oxidase (PPO)	갈변방지 감자
2016	Simplot Plant Science	Potato	TALEN	Polyphenol oxidase (PPO5)	갈변방지 감자

한림원 연구보고서 113 (글로벌 유전자교정 기술동향보고서)

■ 유전자 교정 작물 개발 동향

미농부무 회신일자	작 물	기 술	내 용	개선형질	의뢰인	회신내용*
2016.4.18	옥수수	CRISPR/Cas9	waxy 유전자 knock-out	찰옥수수	DuPont Pioneer	Non GMO
2016.4.13	양송이	CRISPR/Cas9	Polyphenol oxidase 유전자삭제	갈색화	Penn State Univ	Non GMO
2016.2.11	밀	TALEN	MLO 단백질 knockout	흰가루병	Calyxt, Inc.	Non GMO
2015.11.12	옥수수	Meganuclease	내재성유전자 삭제	高 전분	Agrivida, Inc.	Non GMO
2015.5.29	벼	TALEN	2개 유전자의 promoter 삭제	병 저항성	Iowa State Univ	Non GMO
2015.5.21	대두	TALEN	2개 유전자 knock-out	올레산	Cellectis	Non GMO
2015.5.8	대두	TALEN	2개 유전자 knock-out	올레산 oil 증가	Cellectis Plant Sciences	Non GMO

대단히 감사합니다

Thank you for your attention

<군선도> 단원 1776
년 국보 제139호