

“저항성 잡초의 위협과 기회”

Threats & Opportunities of Resistant Weeds

Do-Soon Kim, Jin-Won Kim, Soo-Hyun Lim

College of Agriculture & Life Sciences, SNU
National Institute of Agricultural Sciences of RDA
College of Natural Sciences, KNOU

Beginning of Weed Science

By Early 80s

- ✓ Still low concerns on effective weed management
- ✓ Dominant annual weeds in both upland and paddy fields
- ✓ High reliance on labor-intensive weed control (Manual weeding)
- ✓ Low reliance on herbicide for weed control
- ✓ Occasional herbicide use for annual weed control in paddy fields
- ✓ **Weed Science emerging as an independent agricultural science**

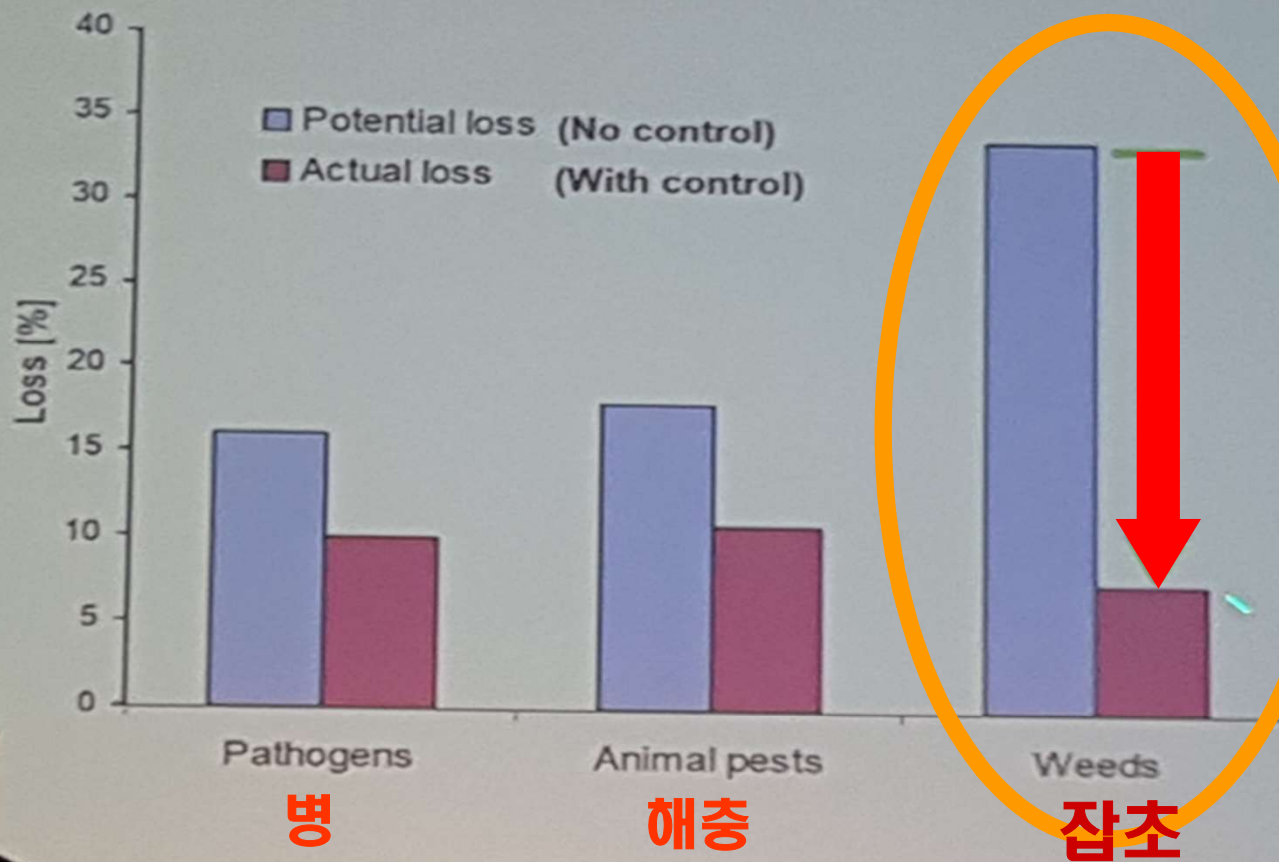
Dominant annual weeds & low concerns on weed management



Cheap labor cost, so heavy reliance on manual weeding



Weeds are a major threat of securing crop yield



Prof. Martin Kropff
(Former EWRS president)

Prof. Husrev Mennan
(EWRS SPC Chair)

Weed science emerging as an independent science

- ✓ Universities started teaching weed science & producing bona fide MSc & PhD in weed science
- ✓ Weed research activated in various institutions



THE KOREAN SOCIETY of WEED SCIENCE

한국잡초학회

Governmental Research Institutes

농약연구소
작물시험장
각도농업진흥원

Universities

경북대 고려대
단국대 동국대
서울대 순천대
원광대 전남대
전북대 충남대

Industry - Companies

경농 동방 동양
미성 삼공 성보
영일 제철 한농
외국계

Renaissance in Weed Science

Mid 80s ~ Mid 90s

- ✓ Introduction of sulfonylurea (SU) herbicides
- ✓ Introduction of one-shot application (2 way mixture with SU)
- ✓ Herbicide industry booming period
- ✓ Booming of weed science education & research
- ✓ New discovery program started & the first new herbicide developed

Mega-hit herbicide boosted herbicide R&D



Weed science played key roles in crop science & protection

- ✓ >18 universities teaching weed science
- ✓ KRICT started herbicide discovery
- ✓ LG Chemicals developed the first new herbicide



THE KOREAN SOCIETY of WEED SCIENCE

한국잡초학회

Governmental Research Institutes

농약연구소
작물시험장
도농업기술원
한국화학연구소

Universities

강원대 경북대 경상대
경희대 고려대 공주대
농수산대 단국대 동국대
서울대 순천대 시립대
우석대 원광대 전남대
전북대 충남대 충북대

Industry - Companies

경농 동방 동양
미성 삼공 성보
영일 제철 한농
LG화학, 외국계

Dark Ages in Weed Science

Late 90s ~ Now ?

- ✓ Introduction of herbicide tolerant GM crops
- ✓ Merger of many agrochemical companies
- ✓ Less investment on herbicide & More investment on biotech seed
- ✓ Less & less governmental weed research investment
- ✓ Less & less weed science education & research

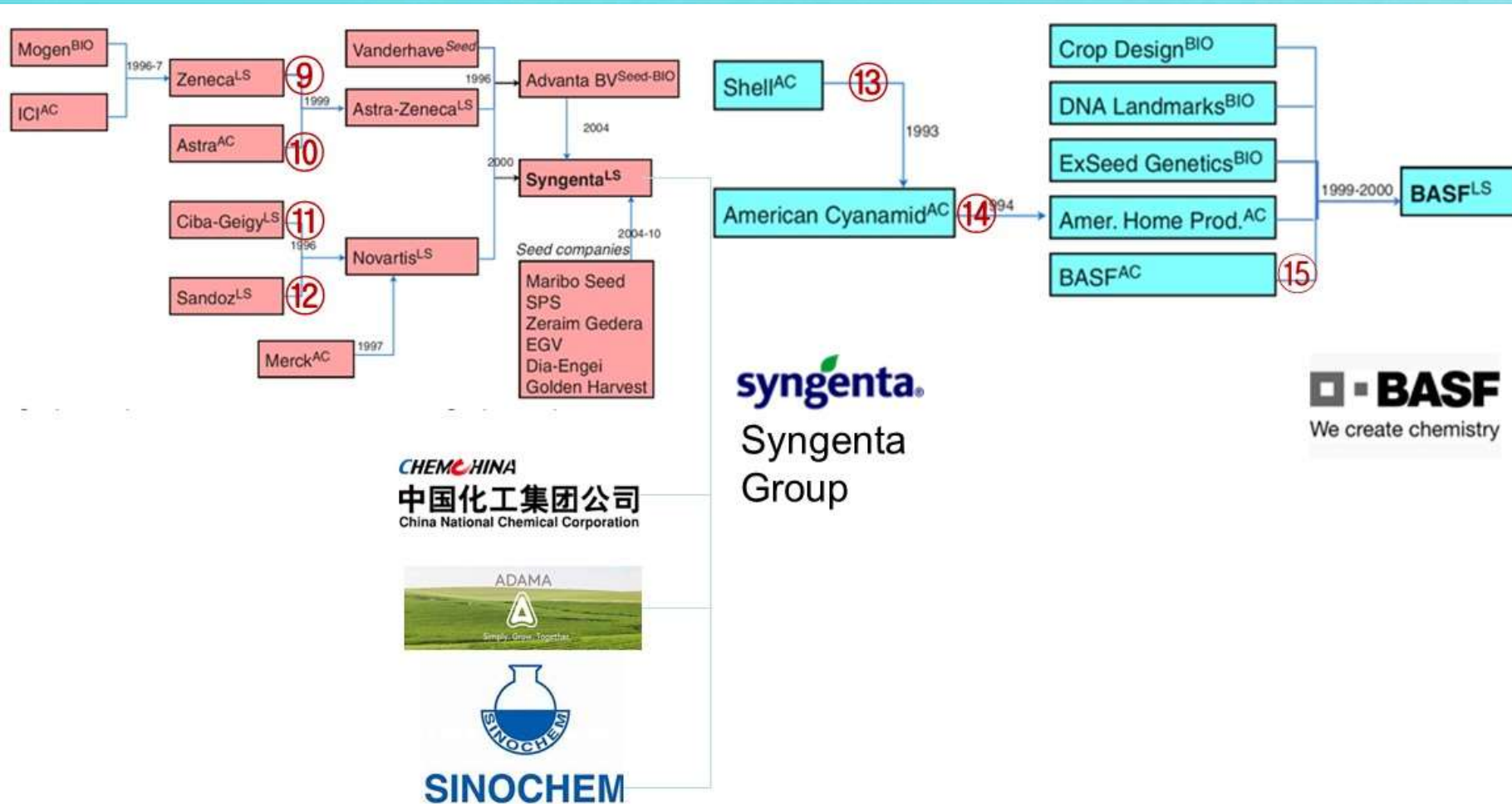
Introduction of GM crops since 1996

- ✓ Roundup Ready Soybeans (1996)
- ✓ Roundup Ready Cotton (1997)
- ✓ Roundup Ready Canola (1997)
- ✓ Roundup Ready Corn (1998)
- ✓ Roundup Ready Alfalfa (2005)
- ✓ Roundup Ready Sugarbeet (2005)



Merger of many agrochemical companies

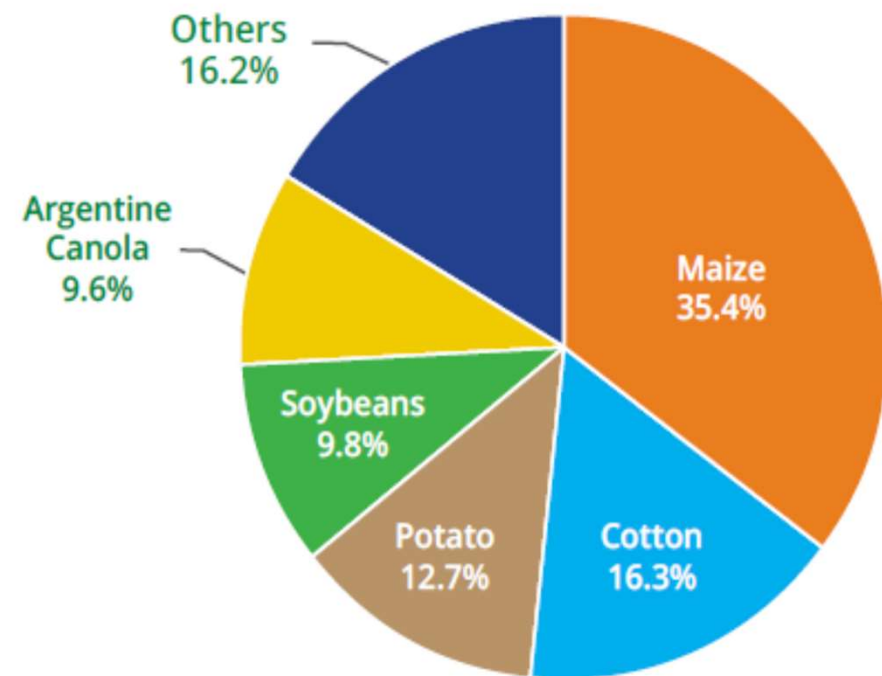
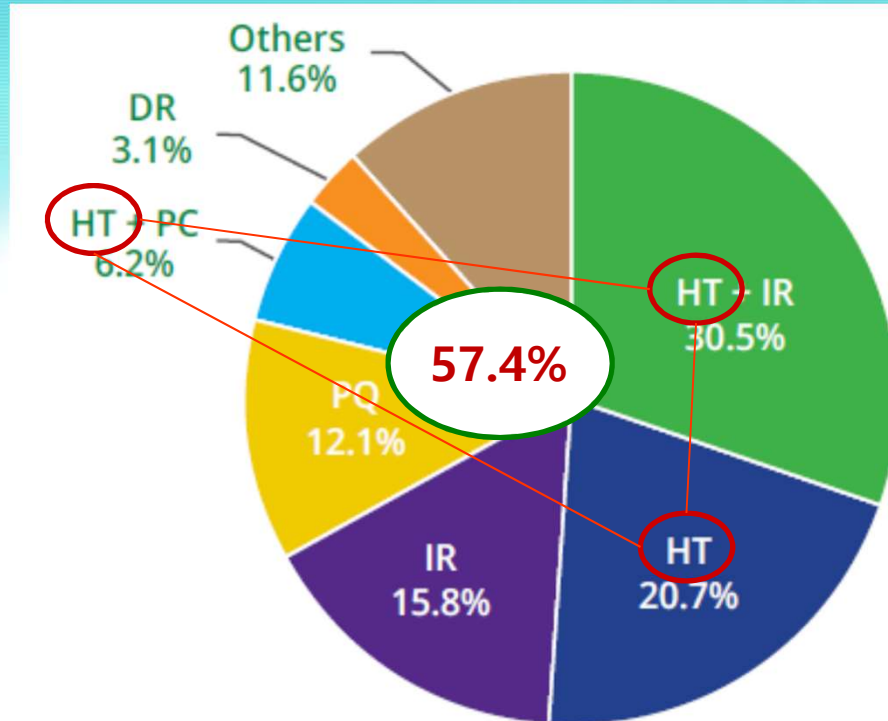
15 MN companies → 5 MN companies



Dominance of biotech investment over agrochemicals

Approved GM Events

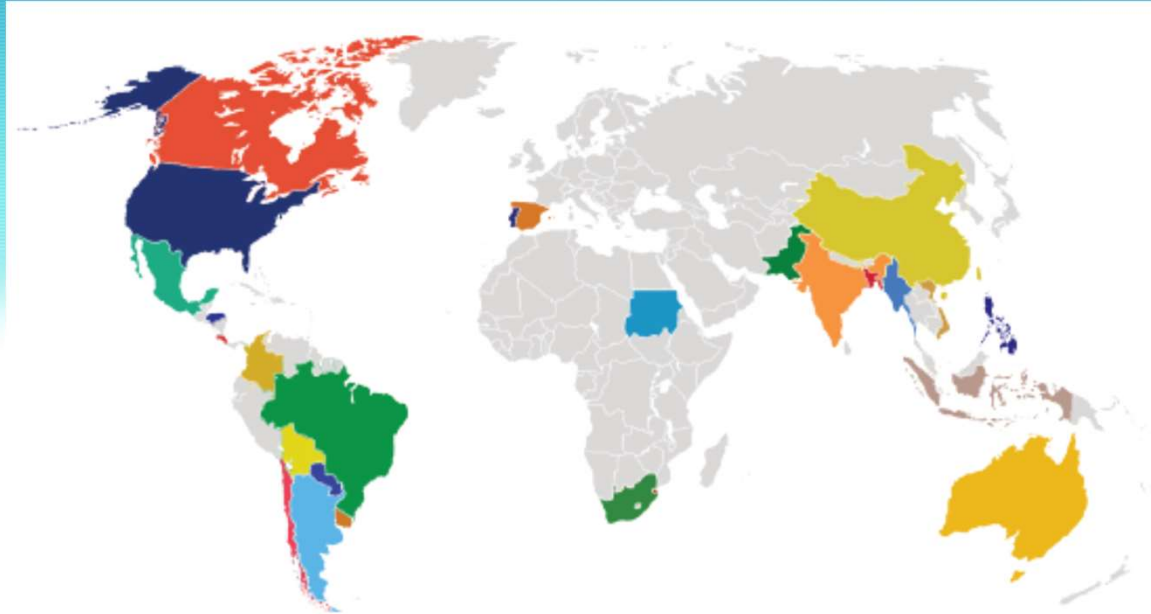
Approved GM Crops (1992-2018)



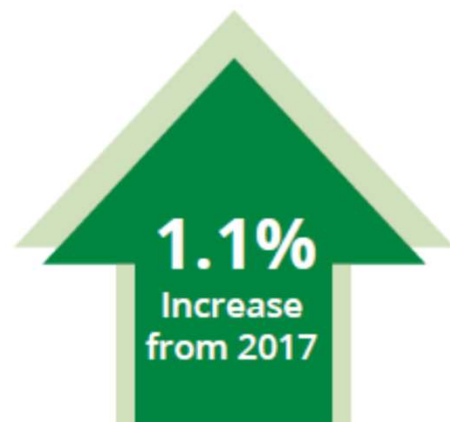
HT - Herbicide Tolerance; IR - Insect Resistance; DR - Disease Resistance; PC - Pollination Control; PQ - Modified Product Quality: Anti-allergy; Delayed Fruit Softening; Delayed Ripening; Enhance Vitamin A Content; Modified Alpha-Amylase; Modified Amino acid; Modified oil/fatty acid; Modified starch/carbohydrate; Nicotine Reduction; Non-Browning Phenotype; Phytase production; Reduced Acrylamide Potential; Reduced Black Spot Bruising | Others: DR + IR; HT + PQ; ST; DR + HT + IR; AGY; PC; HT + IR + PQ; HT + IR + ST; DR + PQ; HT + ST; IR + PQ; IR + ST

Others: Tomato, Rice, Alfalfa, Sugarcane, Papaya, Polish Canola, Apples, Chicory, Sugar beets, Melon, Poplar, Safflower, Squash, Tobacco, Bean, Creeping bentgrass, Eggplant, Eucalyptus, Flax, Plum, Sweet pepper, Wheat

Global area (Million Ha) of Biotech crops



26 countries which have adopted biotech crops



In 2018, global area of biotech crops was 191.7 million hectares, representing an increase of 1.1% from 2017, equivalent to 1.9 million hectares.

Source: ISAAA, 2018

50,000 hectares, or more

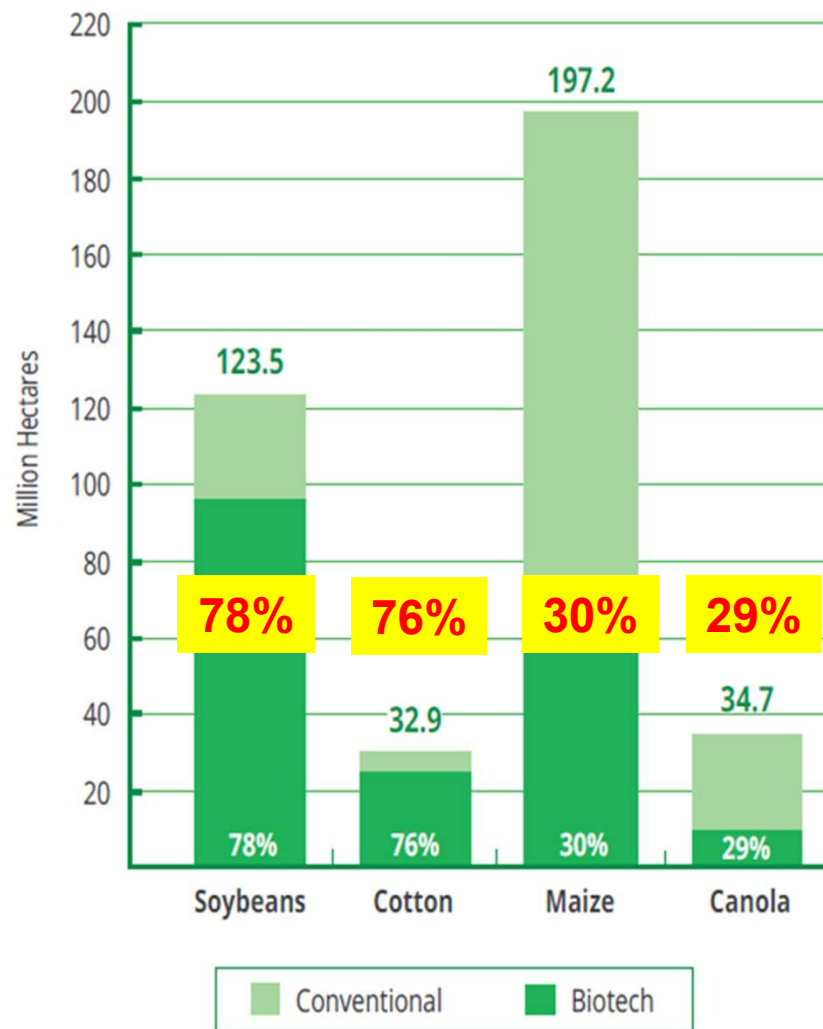
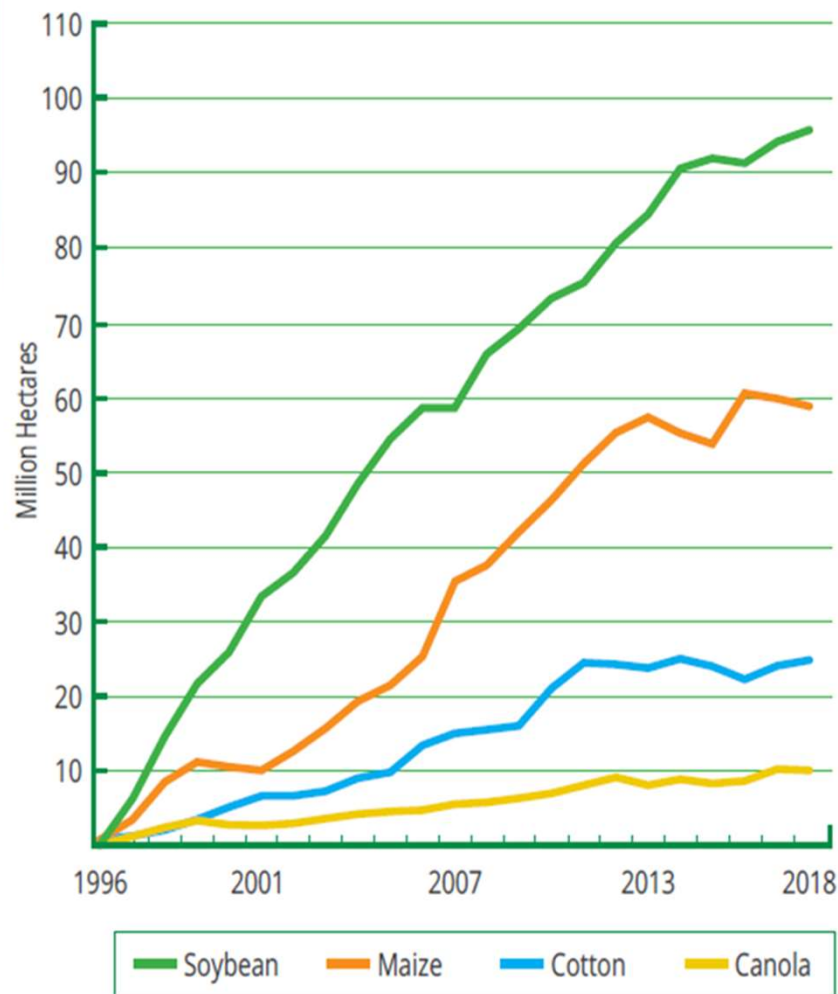
1. USA	75.0 million
2. Brazil*	51.3 million
3. Argentina*	23.9 million
4. Canada	12.7 million
5. India*	11.6 million
6. Paraguay*	3.8 million
7. China*	2.9 million
8. Pakistan*	2.8 million
9. South Africa*	2.7 million
10. Uruguay*	1.3 million
11. Bolivia*	1.3 million
12. Australia	0.8 million
13. Philippines*	0.6 million
14. Myanmar*	0.3 million
15. Sudan*	0.2 million
16. Mexico*	0.2 million
17. Spain	0.1 million
18. Colombia*	0.1 million

Less than 50,000 hectares

Vietnam*	Bangladesh*
Honduras*	Costa Rica*
Chile*	Indonesia*
Portugal	eSwatini*

* Developing countries

Global area (Million Ha) of Biotech crops

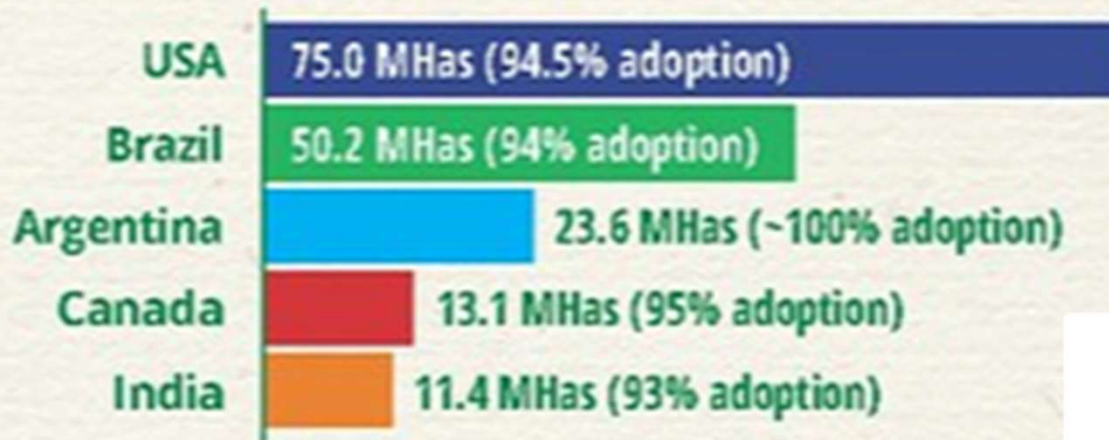


Global adoption of Biotech crops

67 COUNTRIES ADOPTED BIOTECH CROPS SINCE 1996

24 COUNTRIES PLANTING & IMPORTING + 43 IMPORTING BIOTECH CROPS
IN AFRICA, ASIA & THE PACIFIC, EUROPE, LATIN AMERICA, & NORTH AMERICA

ADOPTION RATES OF TOP 5 BIOTECH
CROP-GROWING COUNTRIES
REACHED CLOSE TO SATURATION IN 2017



91.3%

OF TOTAL BIOTECH CROP
AREA IN 2017 PRODUCED
BY TOP 5 BIOTECH MEGA
COUNTRIES

USA	75.0 MHas
BRAZIL	50.2 MHas
ARGENTINA	23.6 MHas
CANADA	13.1 MHas
INDIA	11.4 MHas



www.isaaa.org

f [isaaa.org](https://www.facebook.com/isaaa.org)

🐦 [isaaa_org](https://twitter.com/isaaa_org)

📷 [isaaa_org](https://www.instagram.com/isaaa_org)

📺 [isaaaorg](https://www.youtube.com/channel/UCisaaaorg)

#GMCrops2017
#ISAAAResult2017

Shrinking weed science due to lack of interest/investment

- ✓ Decreasing universities teaching weed science
- ✓ Only 2 weed scientists actively working at RDA
- ✓ One new discovery-oriented agrochemical company



Governmental Research Institutes

농과원 안전성부
식량원 남부작물부
한국화학연구소

Universities

강원대 경북대
경상대 농수산대
방통대 서울대
순천대 충남대
한경대

Industry - Companies

경농 농협 동방
목우 삼공 선문
성보 인바이오
팜한농 한얼
Bayer Syngenta
기타 외국계

Herbicide Resistant Weeds

Since 1997

- ✓ 1st herbicide resistance in *Monochoria korsakowii* in 1997 (ALS)
- ✓ 1st herbicide resistance in *Echinochloa* species in 2008 (ACCase/ALS)
- ✓ Glyphosate resistant weeds in many countries since 1997,
→ **Roundup ready crops cannot sustain solely**
- ✓ Multiple resistant weeds expanding globally (ALS, ACCase, PSII, HPPD, EPSPS, etc.)

HR seed bombing to re-boost weed science



The 1st case of herbicide resistant weed in 1997

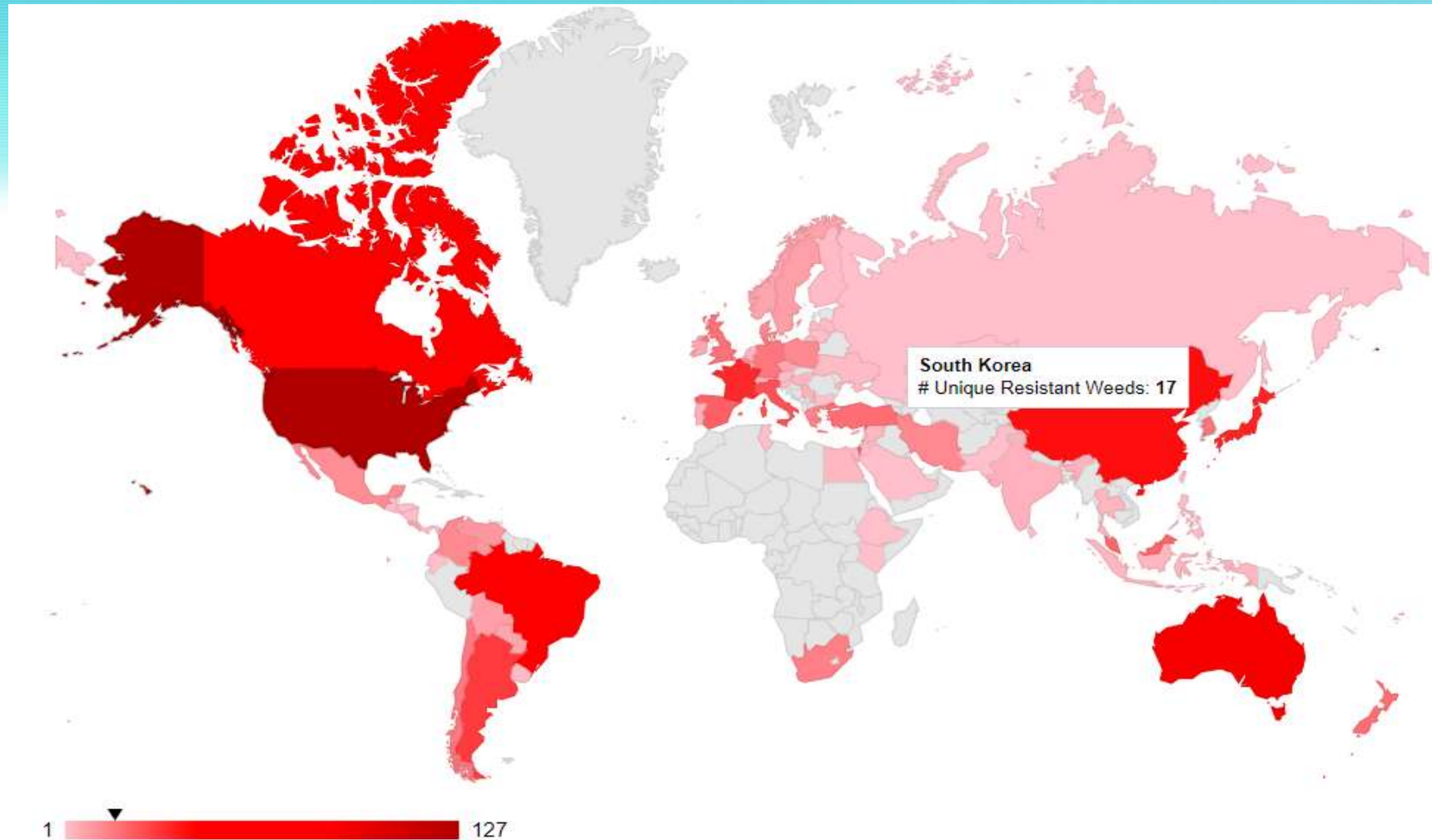
→ *Monochoria korsakowii*



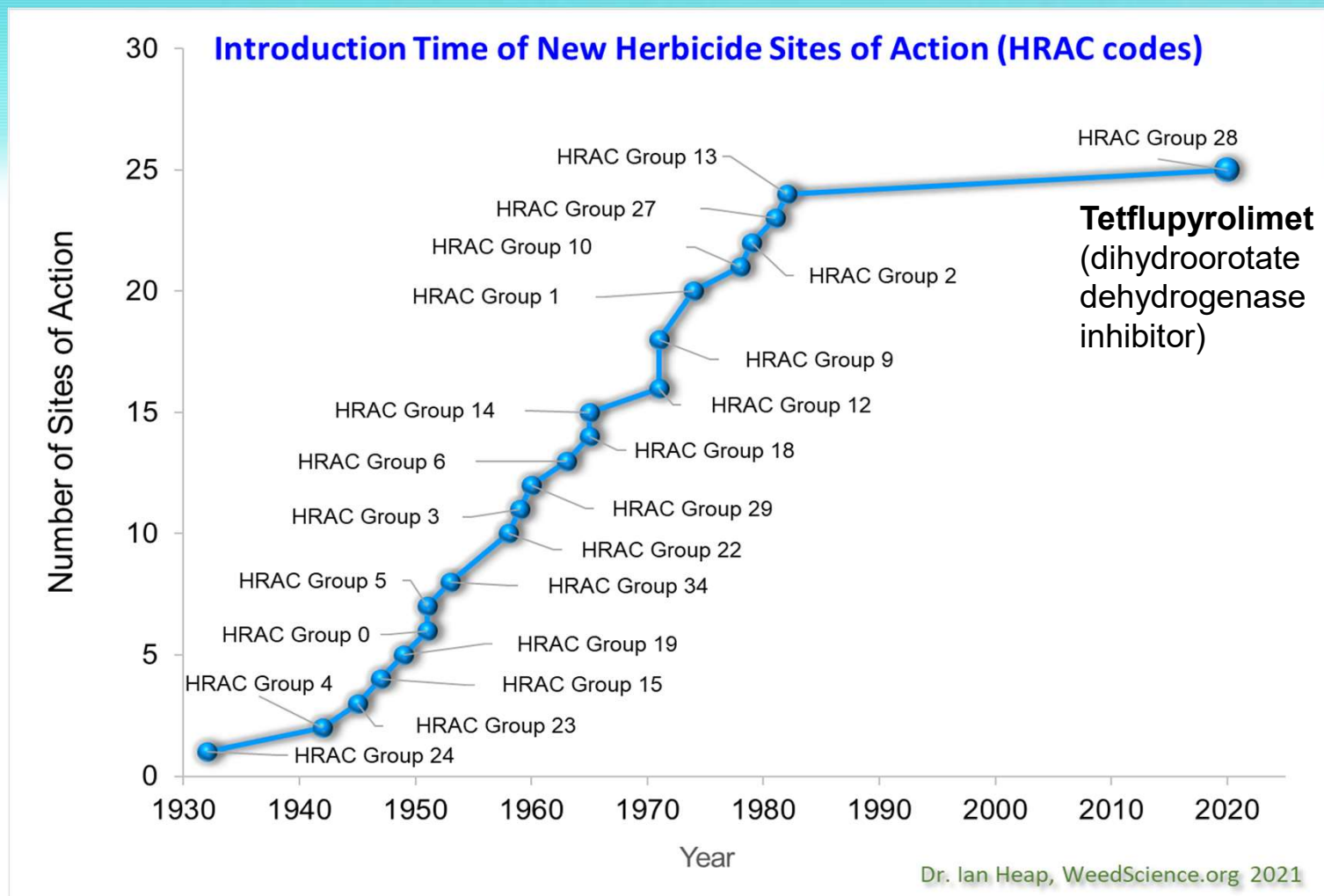
The 1st case of herbicide resistant *Echinochloa* in 2008 → *E. oryzicola* & *E. crus-galli*



Global distribution of HR weeds



Introduction of new herbicide sites of action



Threats

- ✓ Increasing risk of weed control failure
- ✓ Weed shift
- ✓ Losing market of existing herbicides
- ✓ Limiting herbicide use
- ✓ Lacking available herbicide
- ✓ Weed shift and new problem

Opportunities

Increasing needs of

- ✓ Sustainable herbicide use
- ✓ Diagnosis & monitoring of herbicide resistance
- ✓ Prediction of herbicide resistance evolution
- ✓ New MoA herbicides
- ✓ Alternative control measure

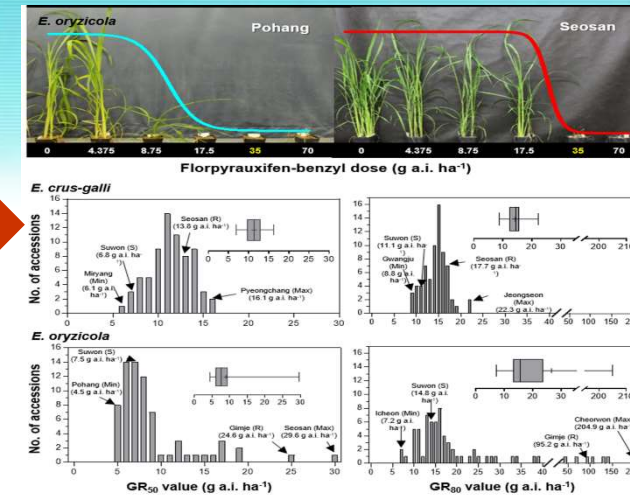
New opportunities for weed research

2011~CF assessment

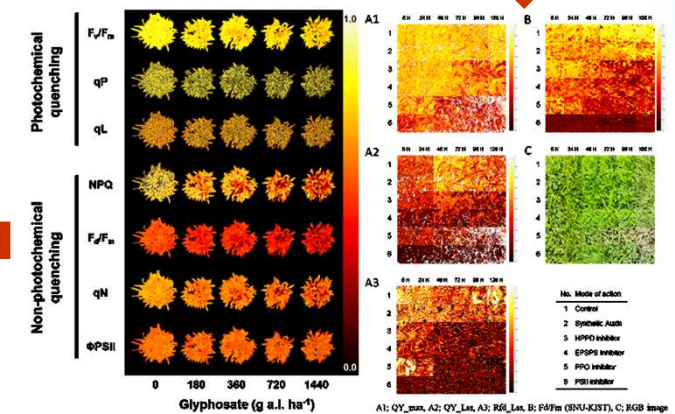


Herbicide (Modes of action)	Biotypes	Chlorophyll fluorescence assay	Whole plant assay
		I_{so} R/S	GR_{50} R/S
Propanil (PSII inhibitor)	93.010-R	3100.0 (40.10) ^a	1520.9 (129.0)
	92.007-S	1100.0 (66.7)	627.5 (34.9)
Fenoxaprop-P-ethyl (ACCase inhibitor)	93.010-R	278.1 (105.0)	58.6 (9.7)
	92.007-S	76.6 (5.8)	17.6 (1.1)
Cyhalofop-butyl (ACCase inhibitor)	Seosan-R	1274.1 (1164.0)	932 (9.0)
	Seosan-S	512.9 (64.4)	254 (1.8)
Pendimethalin (ALS inhibitor)	Gimje-R	240.6 (62.3)	62.7 (8.1)
	Seosan-S	68.7 (3.2)	115 (1.1)

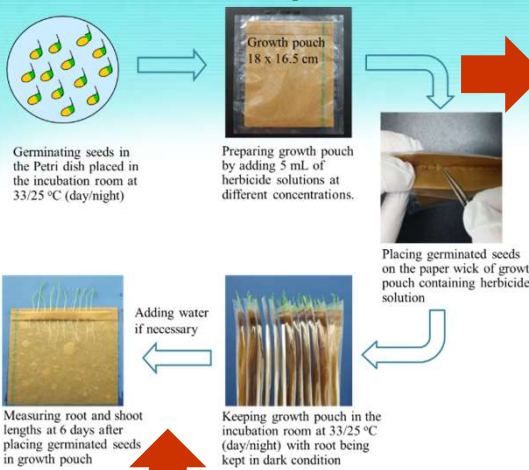
2013~Baseline sensitivity of new a.i.



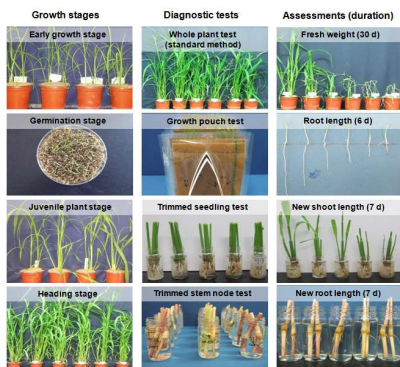
2015~CF image analysis



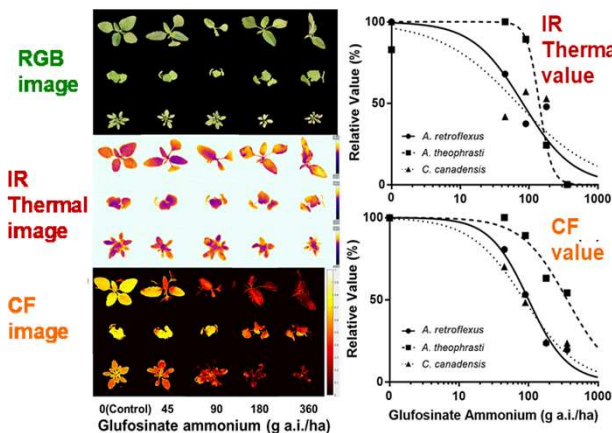
2006~Growth pouch test



1998~Stem node test



2016~Plant image analysis



Environment Resistant Weeds

Since 1999

- ✓ 1st invasive exotic weed listed in 1999 by Ministry of Environment
- ✓ The destroy of existing vegetation by non-selective herbicides and engineering works has facilitated introduction of invasive exotic weeds
- ✓ Climate change has provided invasive exotic weeds with more favorable climatic condition

Listed invasive exotic weeds by Ministry of Environment

1. Ragweed 돼지풀, *Ambrosia artemisiifolia* (1999)
2. Giant ragweed 단풍잎돼지풀, *Ambrosia trifida* (1999)
3. White snakeroot 서양등골나물, *Eupatorium rugosum* (2002)
4. Horsenettle 도깨비가지, *Solanum carolinense* (2002)
5. Knotgrass 물참새피, *Paspalum distichum* var. *distichum* (2002)
6. Hairy knotgrass 털물참새피, *Paspalum distichum* var. *indutum* (2002)
7. Sheep's sorrel 애기수영, *Rumex acetosella* (2009)
8. Bur cucumber 가시박, *Sicyos angulatus* (2009)
9. False dandelion 서양금혼초, *Hypochoeris radicata* (2009)
10. Frost aster 미국쑥부쟁이, *Aster pilosus* (2009)
11. Late goldenrod 양미역취, *Solidago altissima* (2009)
12. Prickly lettuce 가시상추, *Lactuca scariolia* (2012)
13. Smooth cordgrass, 갯줄풀, *Spartina alterniflora* (2016)
14. Common cordgrass, 영국갯끈풀, *Spartina anglica* (2016)
15. Japanese Hop, 환삼덩굴, *Humulus japonicas* (2019)

Invasive exotic weeds causing troubles in non-cropping area

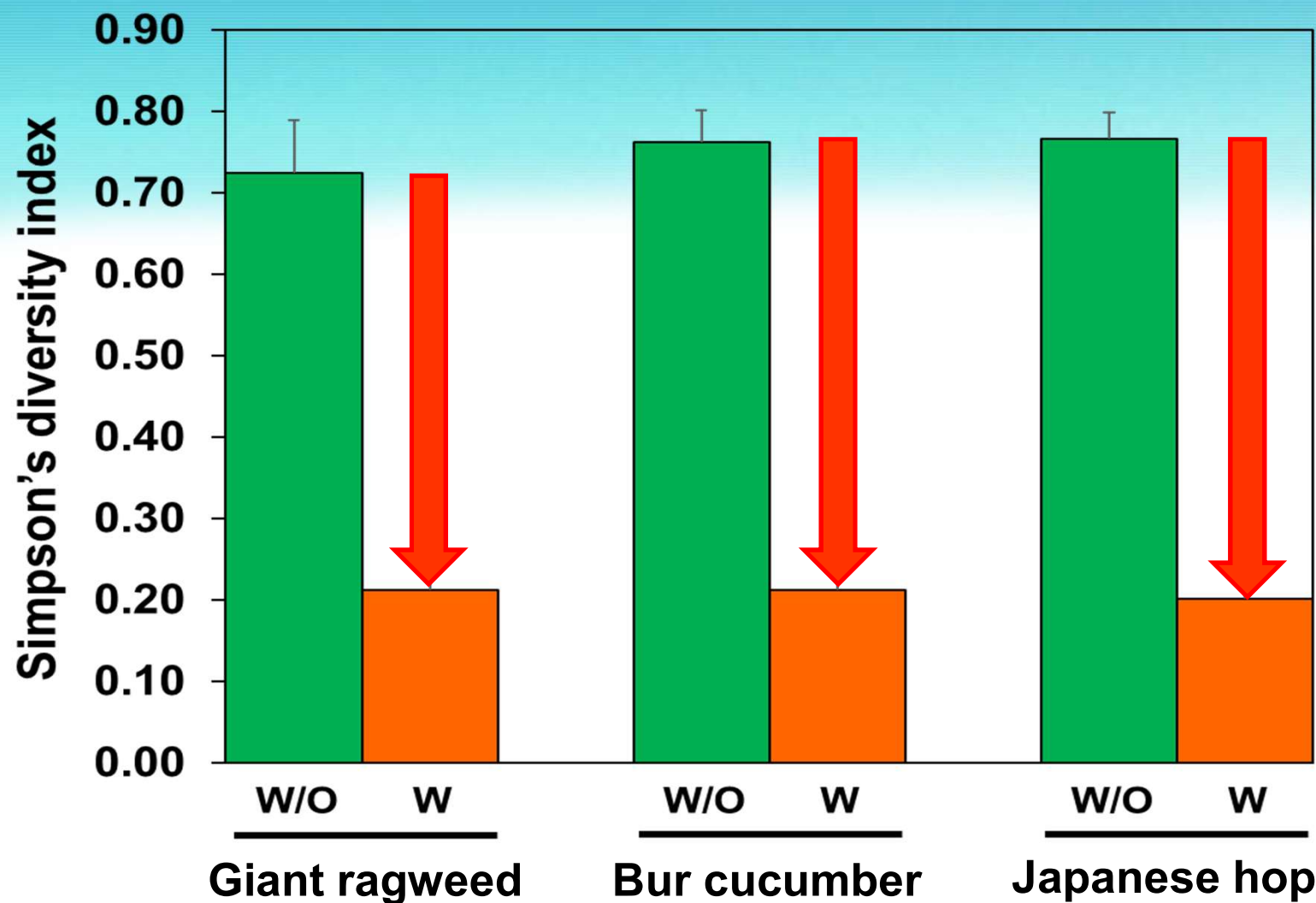
Giant ragweed interfering irrigation channel and roadside



Inappropriate herbicide uses made situation even worse



Invasive exotic weeds devastated field margin vegetation



Threats

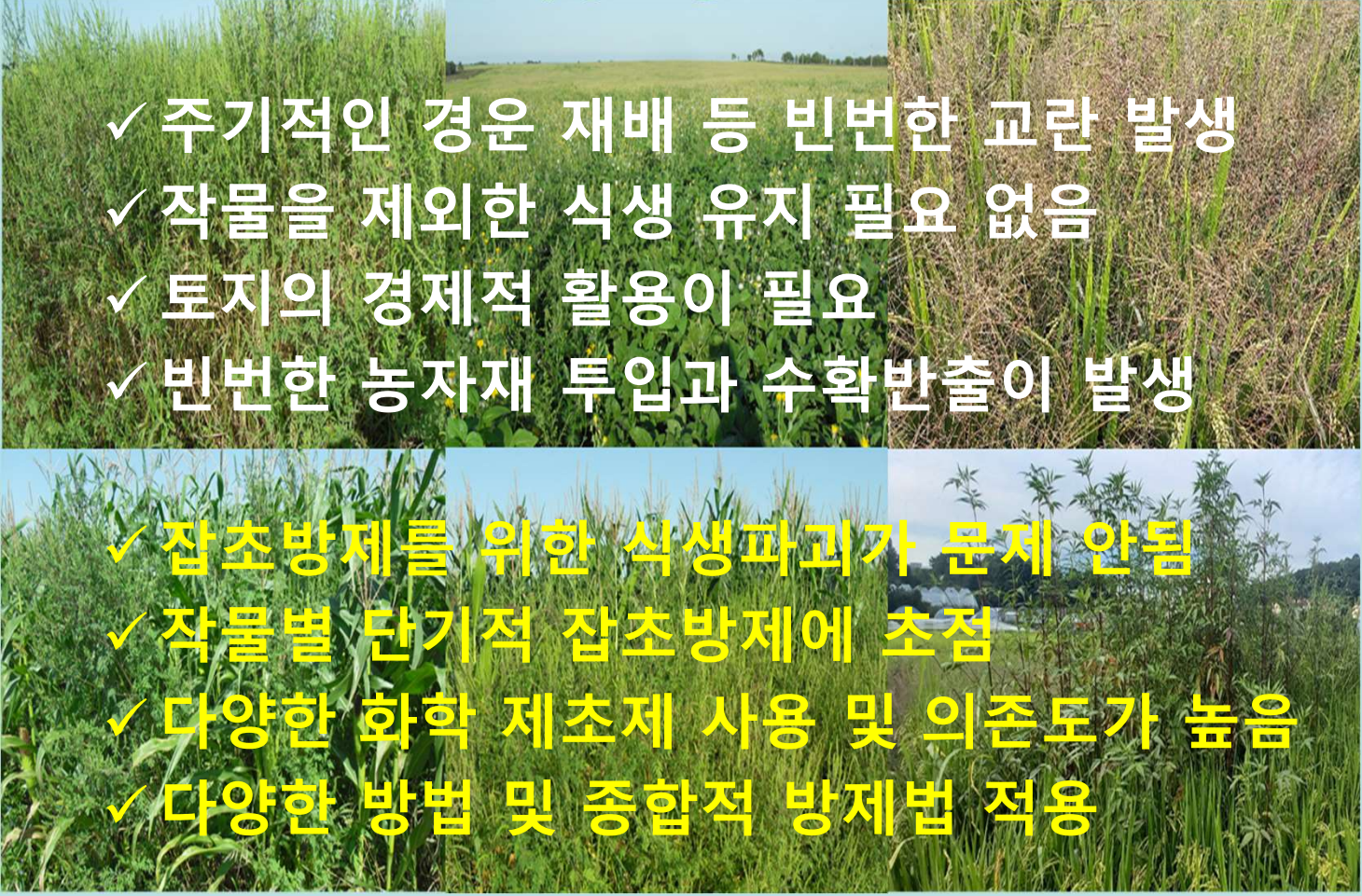
- ✓ Decreasing biodiversity in field margins, resulting in poor landscape beauty
- ✓ Limited option for managing weeds in field margin areas including bank, roadside, irrigation channel, etc.
- ✓ Lack of experts in landscape & weed management
- ✓ Invasion of new weeds into crop fields

Opportunities

Increasing needs of

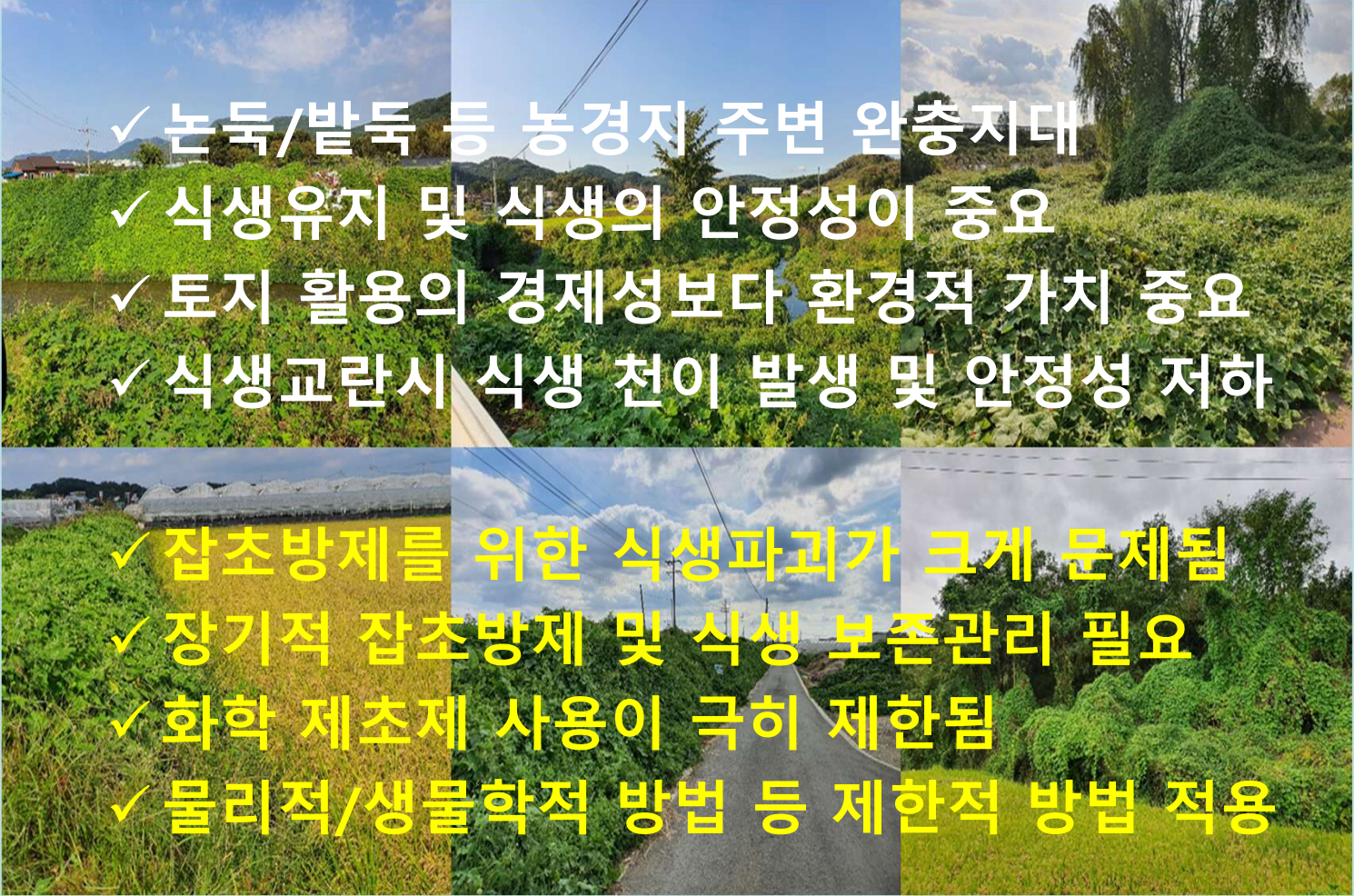
- ✓ Landscape management
- ✓ Option to manage weeds in non-cropping margin areas
- ✓ New herbicides for selective invasive exotic weeds
- ✓ Experts in landscape & weed management
- ✓ Collaboration with ME and MOLIT

Cropping Area

- 
- ✓ 주기적인 경운 재배 등 빈번한 교란 발생
 - ✓ 작물을 제외한 식생 유지 필요 없음
 - ✓ 토지의 경제적 활용이 필요
 - ✓ 빈번한 농자재 투입과 수확반출이 발생

- ✓ 잡초방제를 위한 식생파괴가 문제 안됨
- ✓ 작물별 단기적 잡초방제에 초점
- ✓ 다양한 화학 제초제 사용 및 의존도가 높음
- ✓ 다양한 방법 및 종합적 방제법 적용

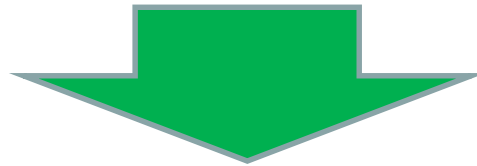
Non-cropping Area

- 
- ✓ 논둑/밭둑 등 농경지 주변 완충지대
 - ✓ 식생유지 및 식생의 안정성이 중요
 - ✓ 토지 활용의 경제성보다 환경적 가치 중요
 - ✓ 식생교란시 식생 천이 발생 및 안정성 저하

- ✓ 잡초방제를 위한 식생파괴가 크게 문제됨
- ✓ 장기적 잡초방제 및 식생 보존관리 필요
- ✓ 화학 제초제 사용이 극히 제한됨
- ✓ 물리적/생물학적 방법 등 제한적 방법 적용

BIG opportunity to expand weed science into non-agricultural area

- ✓ Limited option for weed management in non-cropping area



- ✓ Survey & mapping of weeds in non-cropping area
- ✓ Assessment of impact of invasive weeds on ecosystem/crop

Management of invasive weeds in non-cropping area

- ✓ Selective herbicide for weed control in non-cropping area

Invasive weed management emerging

INVASIVE PLANT SCIENCE AND MANAGEMENT



VOLUME 15, NUMBER 2
APRIL - JUNE 2022

WSSA

Weed management in non-cropping area

→ Weed management by selective herbicides

“하늘아래”

침에 대한 효과



산딸기에 대한 효과



아카시에 대한 효과



필레에 대한 효과



Threats vs Opportunities

- ✓ **Necessity is the mother of invention**
- ✓ **A new crisis is a new opportunity**

이제 논과 밭 밖의 더 넓은 세상으로 나갑시다.