Forces Driving the Development of Herbicide-Resistant Weeds

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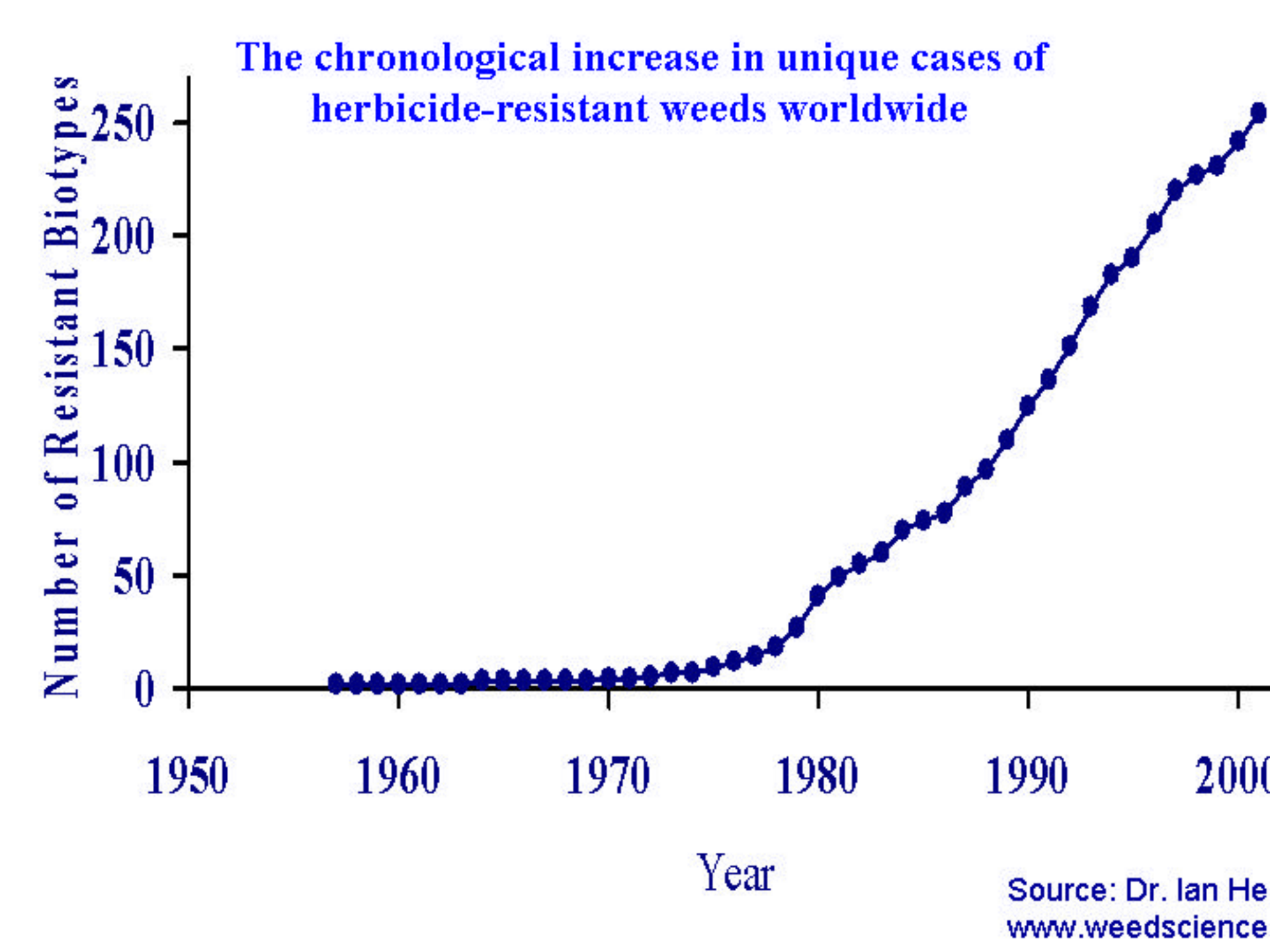
Overview

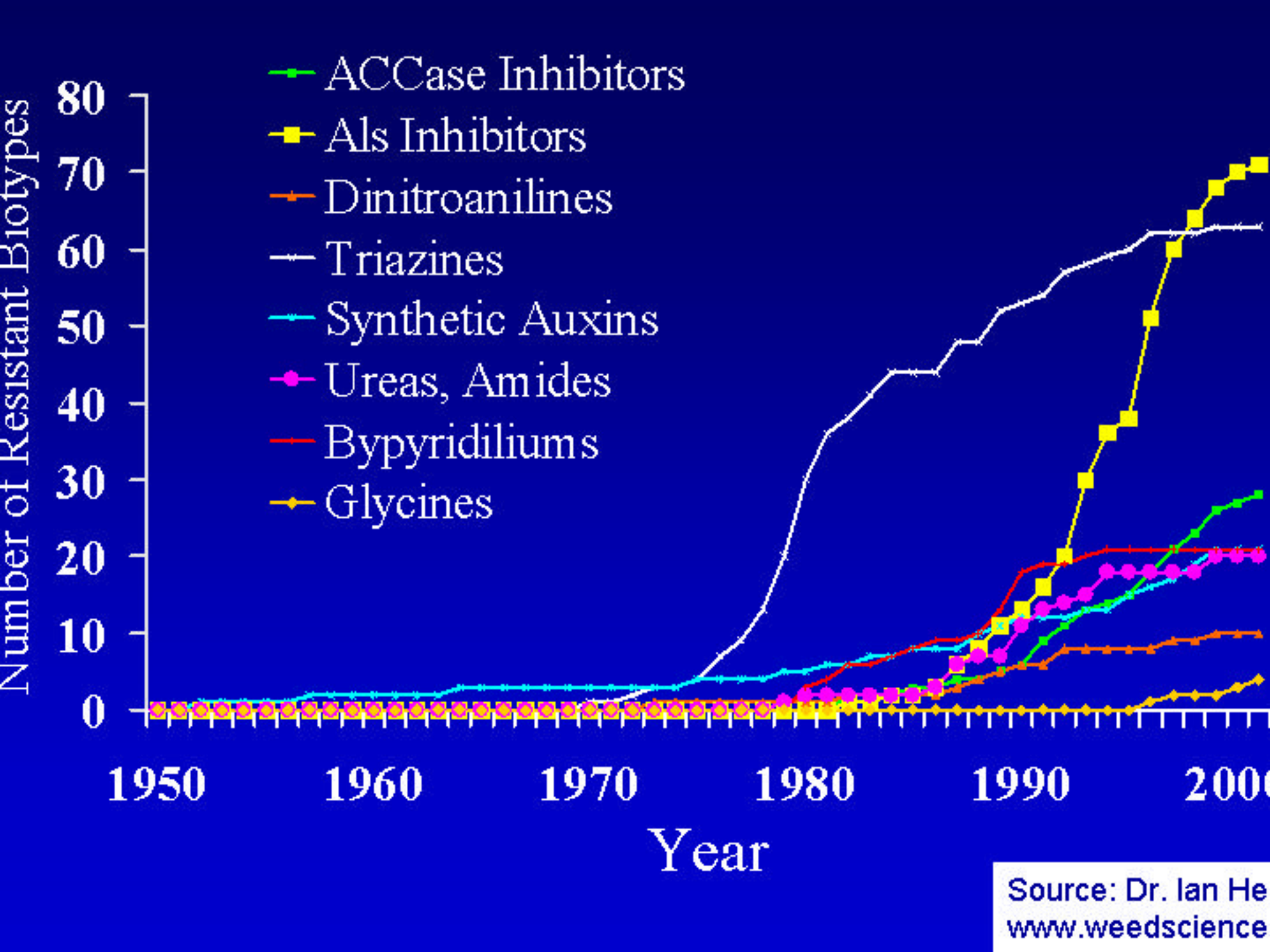
- What is resistance?
- What are the critical factors that affect the occurrence of herbicide-resistant weeds?
- What are the critical factors that affect their spread?

What is resistance?

Herbicide resistance is the inherited ability of a plant to survive and reproduce following exposure to a herbicide dose normally lethal to the wild type.

(Weed Science Society of America 199


The chronological increase in unique cases of herbicide-resistant weeds worldwide
Number of Resistant Biotypes
250
200
150
100
50
0
1950
1960
1970
1980
1990
2000
Year
Source: Dr. Ian He
www.weedscience


ACCase Inhibitors
Als Inhibitors
Dinitroanilines
Triazines
Synthetic Auxins
Ureas, Amides
Bypyridiliums
Glycines
Number of Resistant Biotypes
0
10
20
30
40
50
60
70
80
1950
1960
1970
1980
1990
2000
Year
Source: Dr. Ian He
www.weedscience

Herbicide-Resistant Weeds in Wisconsin

ALS Inhibitors



ACCase Inhibitors

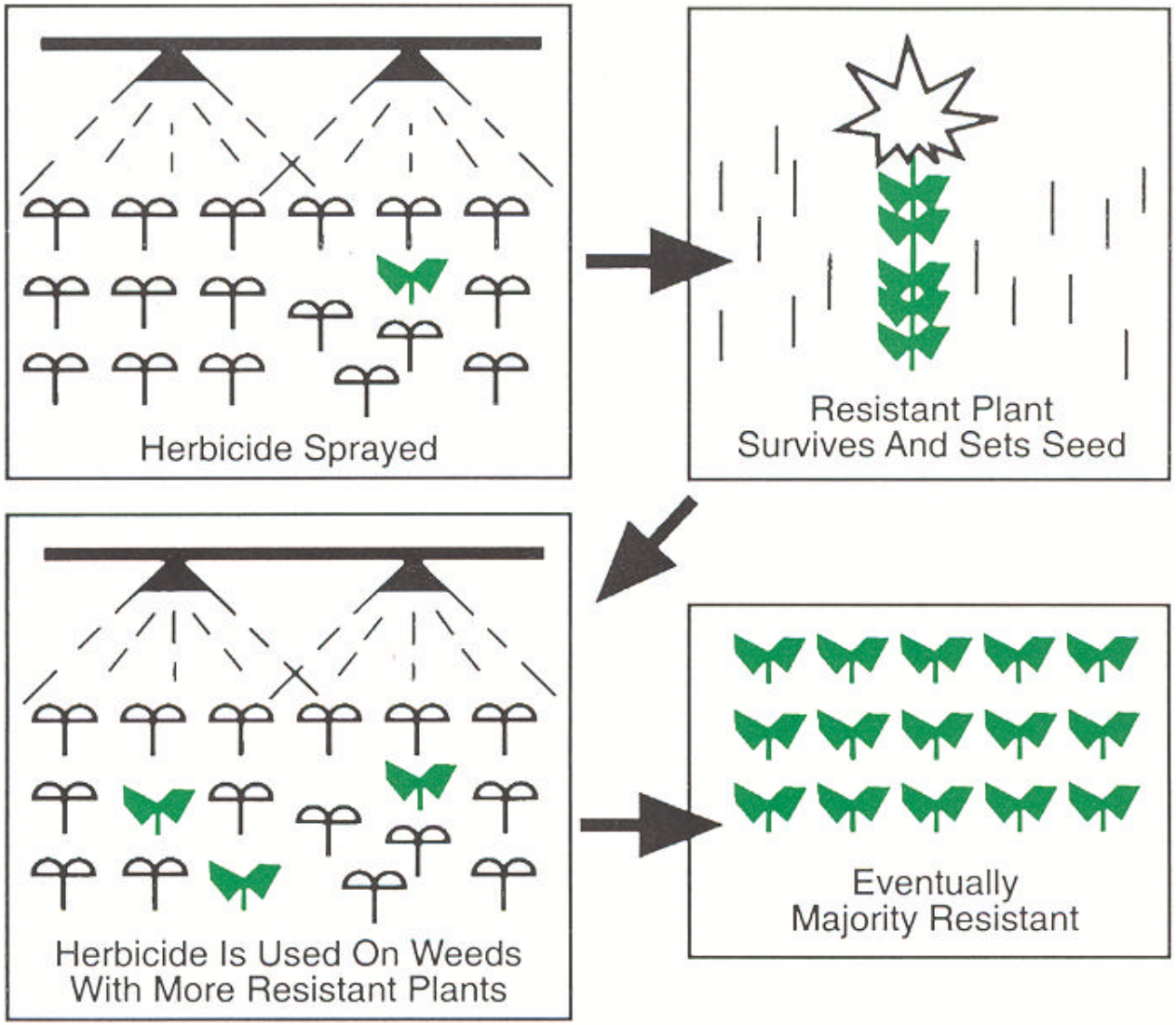

Triazine Herbicides




How Does Selection For Herbicide Resistance Occur?

Susceptible Weed

Resistant Weed



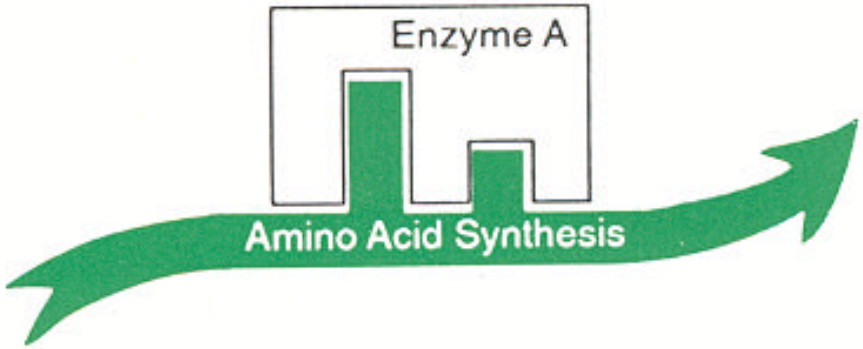
(Adapted from Gunsolus 19

What are the critical factors?

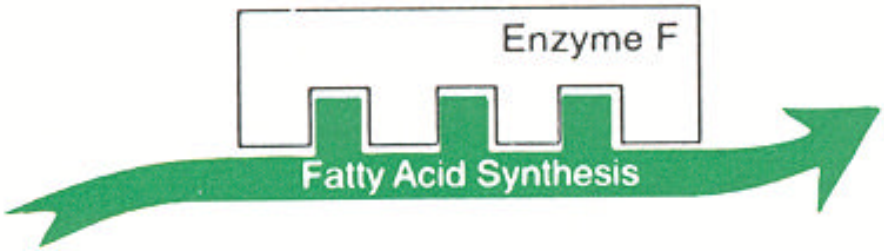
- Mutation rate for resistance traits
- Initial frequency of resistant weeds
  - Fitness of resistant weeds
- Herbicide selection intensity
  - Herbicide effectiveness and frequency of use
  - Fitness of resistant weeds
- Inheritance of resistance traits
- Gene flow
  - Outcrossing vs. selfing weeds
  - Seed and pollen dispersal

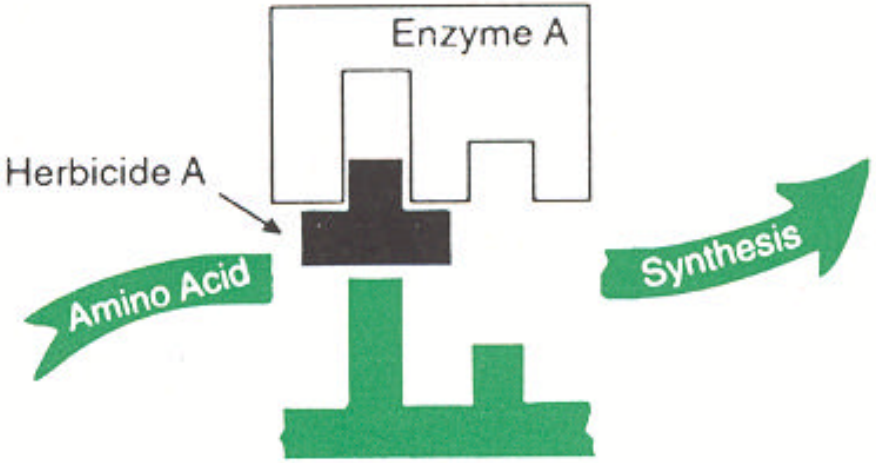
Mutation for Resistance

- **Where does resistance come from?**
  - Genetic variation in weed populations caused by mutation
- **What is mutation?**
  - A change in the genetic code of an organism
  - A spontaneous, natural process
  - Not associated with herbicide action
- **What are typical mutation rates?**
  - Estimates range from 10^{-4} to 10^{-12}

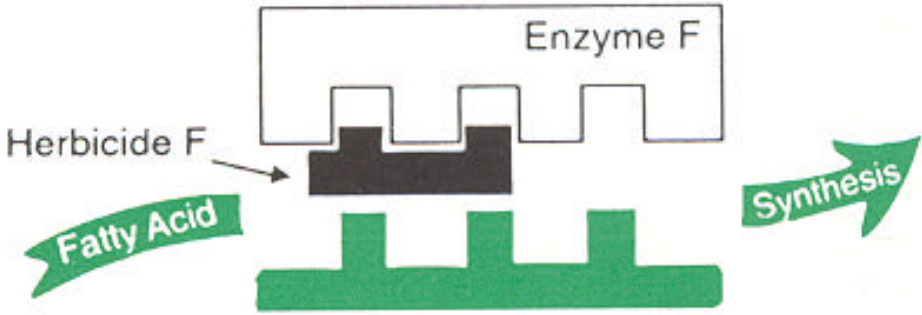


PLANTS ARE HEALTHY





PLANTS ARE KILLED



(Gunsolus 199

Effect of mutation rate and weed density on the probability of at least one resistant weed occurring in a 75-acre field

Mutation rate	Weed density		Probability
	Weeds/10 ft^2	Weeds/75 acres	
10^{-6}	1	325,000	0.45
	5	~1.6 million	0.95
	50	~16 million	1.00
	500	~160 million	1.00
10^{-8}	1	325,000	0.006
	5	~1.6 million	0.03
	50	~16 million	0.26
	500	~160 million	0.95
10^{-10}	1	325,000	0.00006
	5	~1.6 million	0.0003
	50	~16 million	0.003
	500	~160 million	0.03

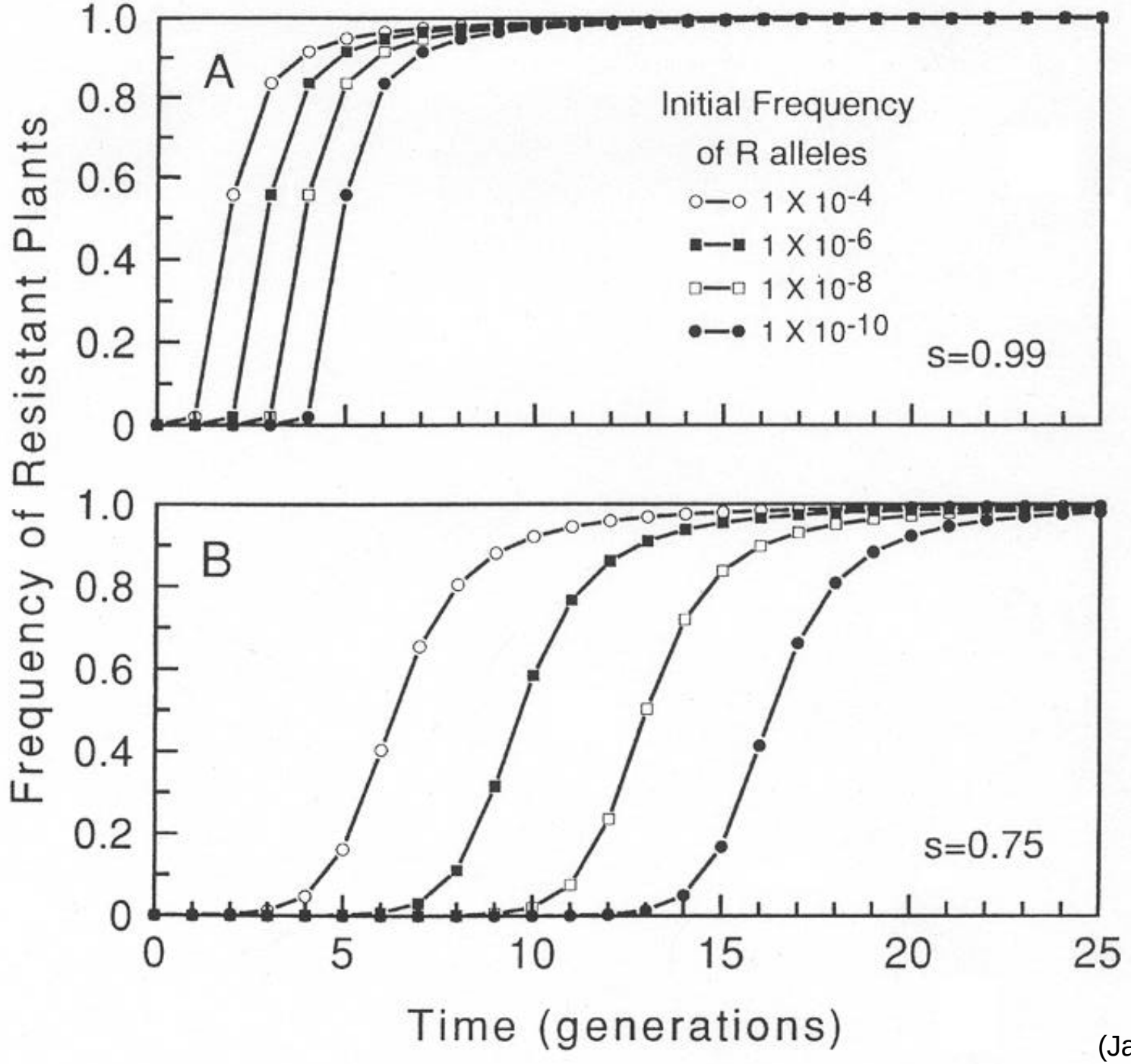
(Adapted from Jasieniuk et al. 1996)

Frequency of Resistant Weeds

- **Initial frequency of resistant weeds**
  - Determined by mutation rate and fitness
    - *Fitness refers to reproductive success over time*
  - Initial frequency ≤ mutation rate
  - Affects the rate of resistance development
- **Frequency of resistant weeds over time**
  - Initial frequency interacts with herbicide selection intensity to greatly affect rate of development

Herbicide Selection Intensity

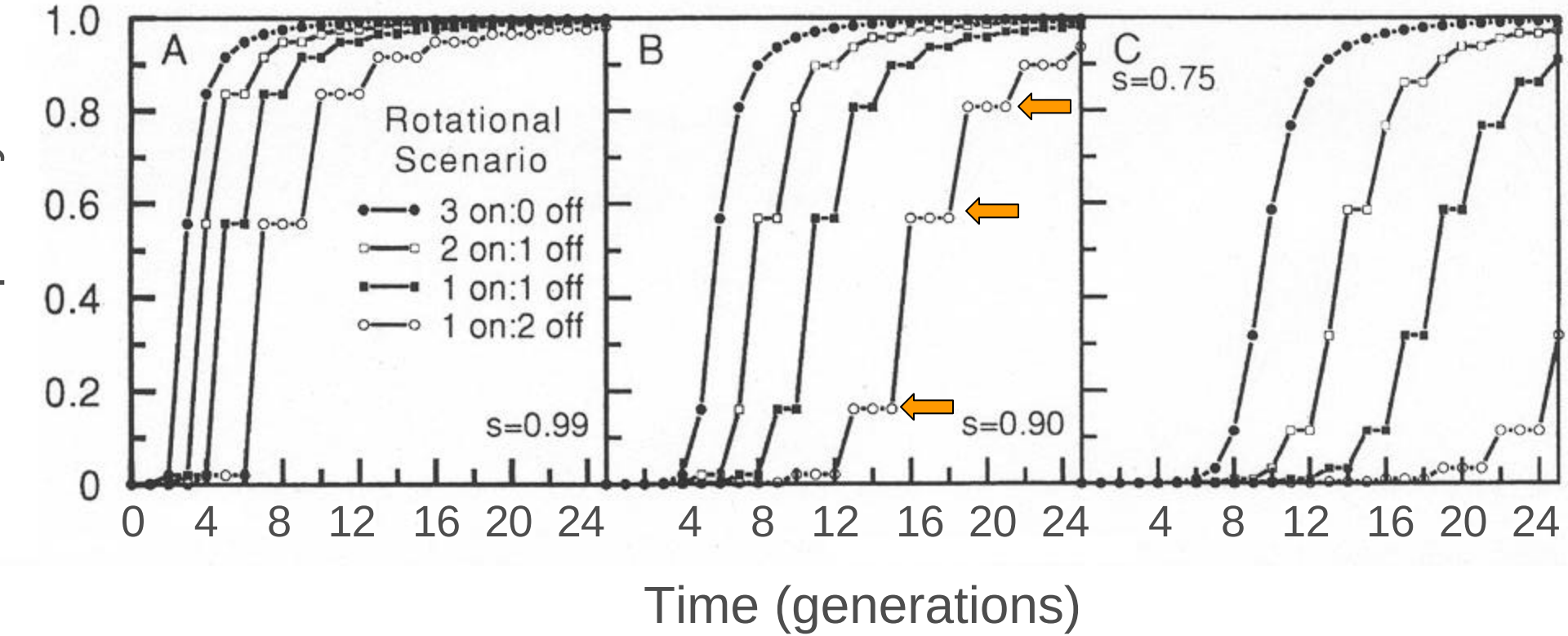
- **What is it?**
  - An indicator of the effective kill of weeds by a herbicide
- **How is it measured?**
  - Reduction in weed seed yield
    - ***Very strong* selection intensity:** **s = 99%**
    - ***Strong* selection intensity:** **s = 90%**
    - ***Moderate* selection intensity:** **s = 75%**
- **How important is it?**
  - Prediction models show that it is one of the most important factors that determines the rate of resistance development



(Jasieniuk et al. 1

Effect of Herbicide Rotation and Selection Intensity on Frequency of Resistant Weeds

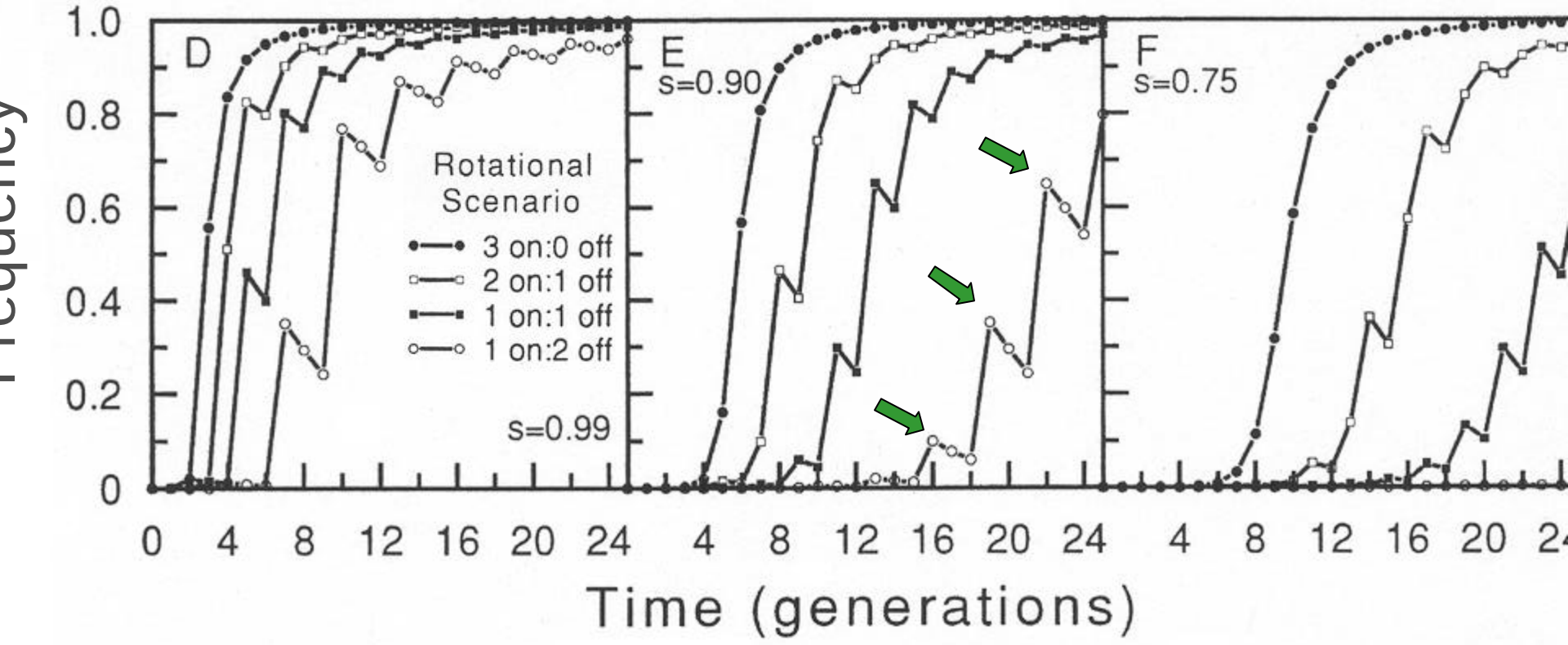
R and S weeds are equally fit



(Jasieniuk et al. 1

Effect of Herbicide Rotation and Selection Intensity on Frequency of Resistant Weeds

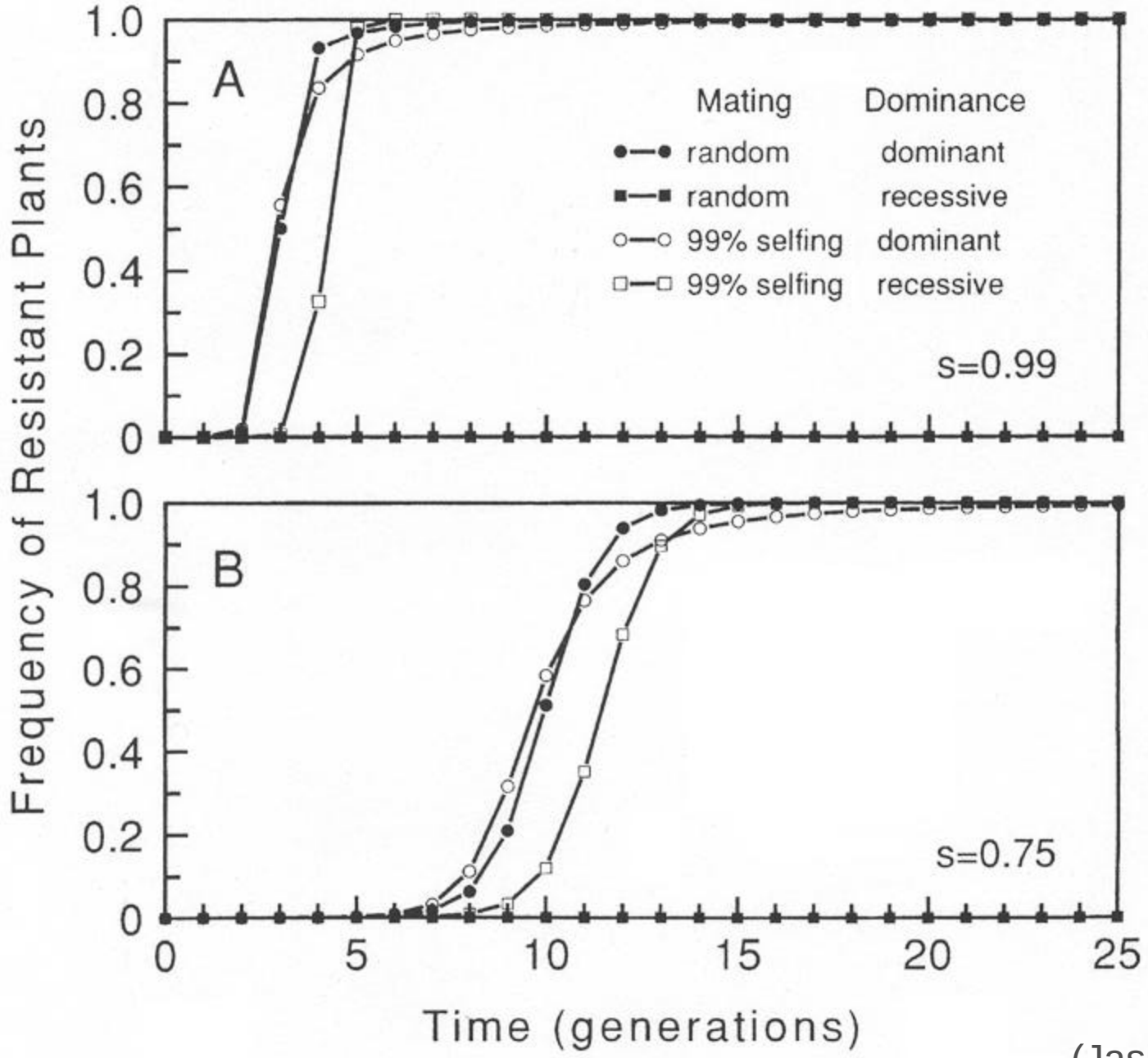
R weeds are 75% as fit as S weeds



(Jasieniuk et al. 1

Inheritance of Resistance Traits and Gene Flow

- **Types of Inheritance**
  - Dominant, nuclear alleles are most common
  - Recessive alleles are rare
  - Cytoplasmic alleles are typical for resistance to triazine herbicides
- **Why is this important?**
  - Nuclear alleles occur in seed and pollen
- **Gene flow**
  - The movement of resistance alleles
  - Outcrossing vs. selfing species
  - Pollen vs. seed dispersal



(Jasieniuk et al. 1

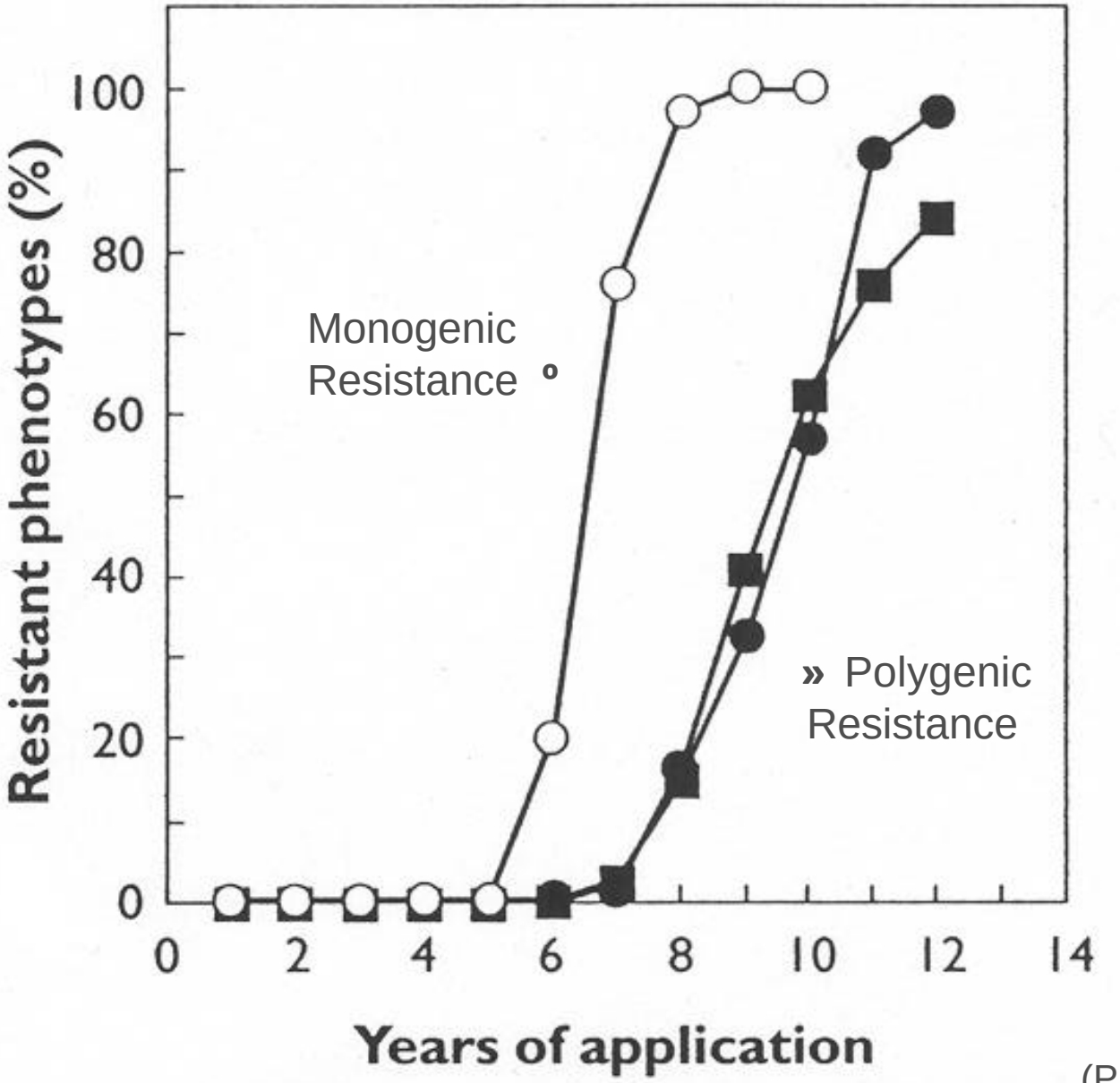
Glyphosate-Resistant Horseweed

Why such a rapid increase in occurrence since 2000?

- **Herbicide selection intensity**
  - **Widespread adoption on no-tillage, glyphosate-resistant soybeans**
- **Reproductive biology**
  - **Outcrossing can occur**
    - **transfer of resistance trait in pollen**
  - **Prolific seed production**
  - **Wind dispersal of seeds**

(Heck et al. 2002; VanGessel 200

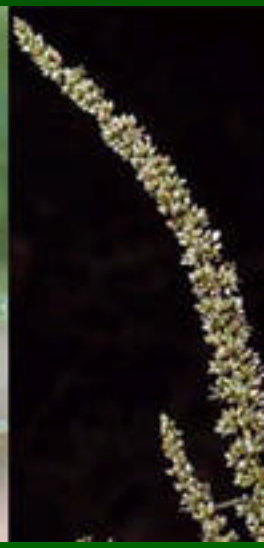
Monogenic vs. Polygenic Resistance



(Preston and Roush 1

Common Waterhemp: Resistant to Glyphosate?

- Iowa, Illinois, Missouri
  - Inconsistent control in several fields
  - Individual plants within populations survive exposure to glyphosate
    - varies among experiments
    - varies with methodology
  - Resistance appears to be heritable, but complex, likely polygenic
  - Inheritance poorly understood
  - Mechanism of resistance unknown



rtzler et al. 2002; Owen 2002; Smeda and Schuster 2002)

Summary

- Several critical factors affect resistance
  - Mutation rate for resistance alleles
  - Initial frequency of resistance plants
  - Herbicide selection intensity
  - Inheritance of resistance alleles
  - Gene flow
  - Fitness of resistant weeds
- Accurate prediction of resistance is difficult
- Practices can be adopted to reduce the selection intensity for weed resistance to herbicides
  - Effective management, using a diversity of practices