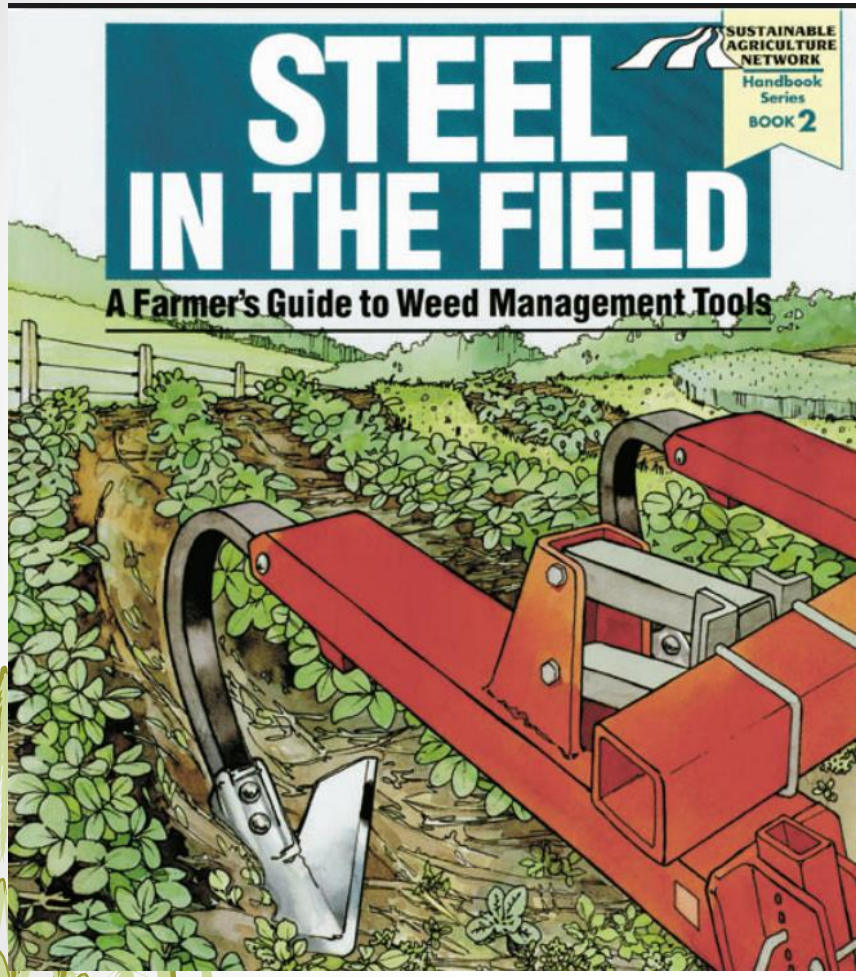
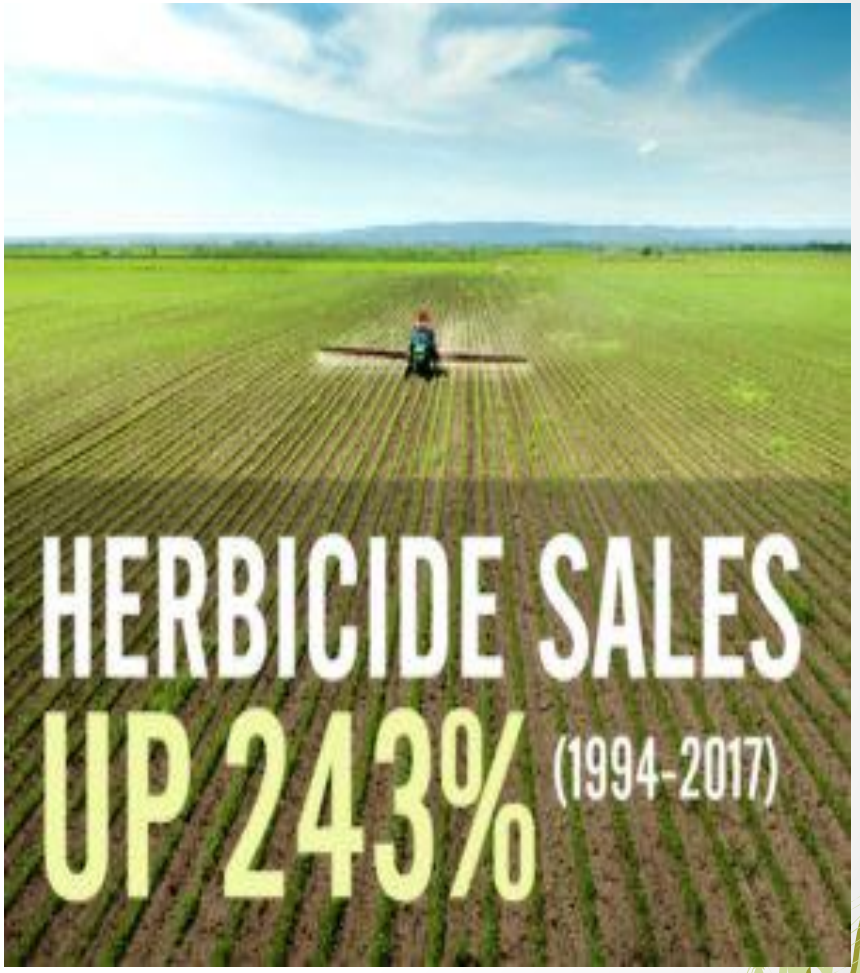
Principles of Integrated Weed Management: Are they applicable for invasive plants?

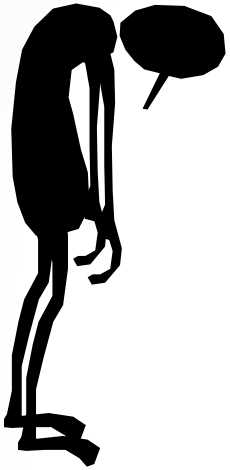
Anil Shrestha
Dept. of Viticulture & Enology

FRESNO STATE
Discovery. Diversity. Distinction.


STEEL
IN THE FIELD
A Farmer's Guide to Weed Management Tools
SUSTAINABLE AGRICULTURE NETWORK
Handbook Series
BOOK 2

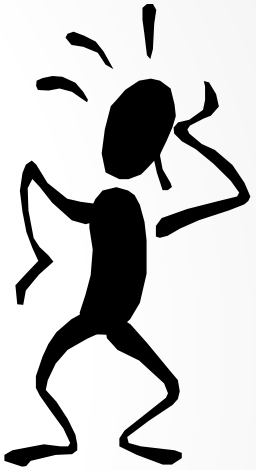

HERBICIDE SALES
UP 243% (1994-2017)

Despite all our efforts,
we still have weeds



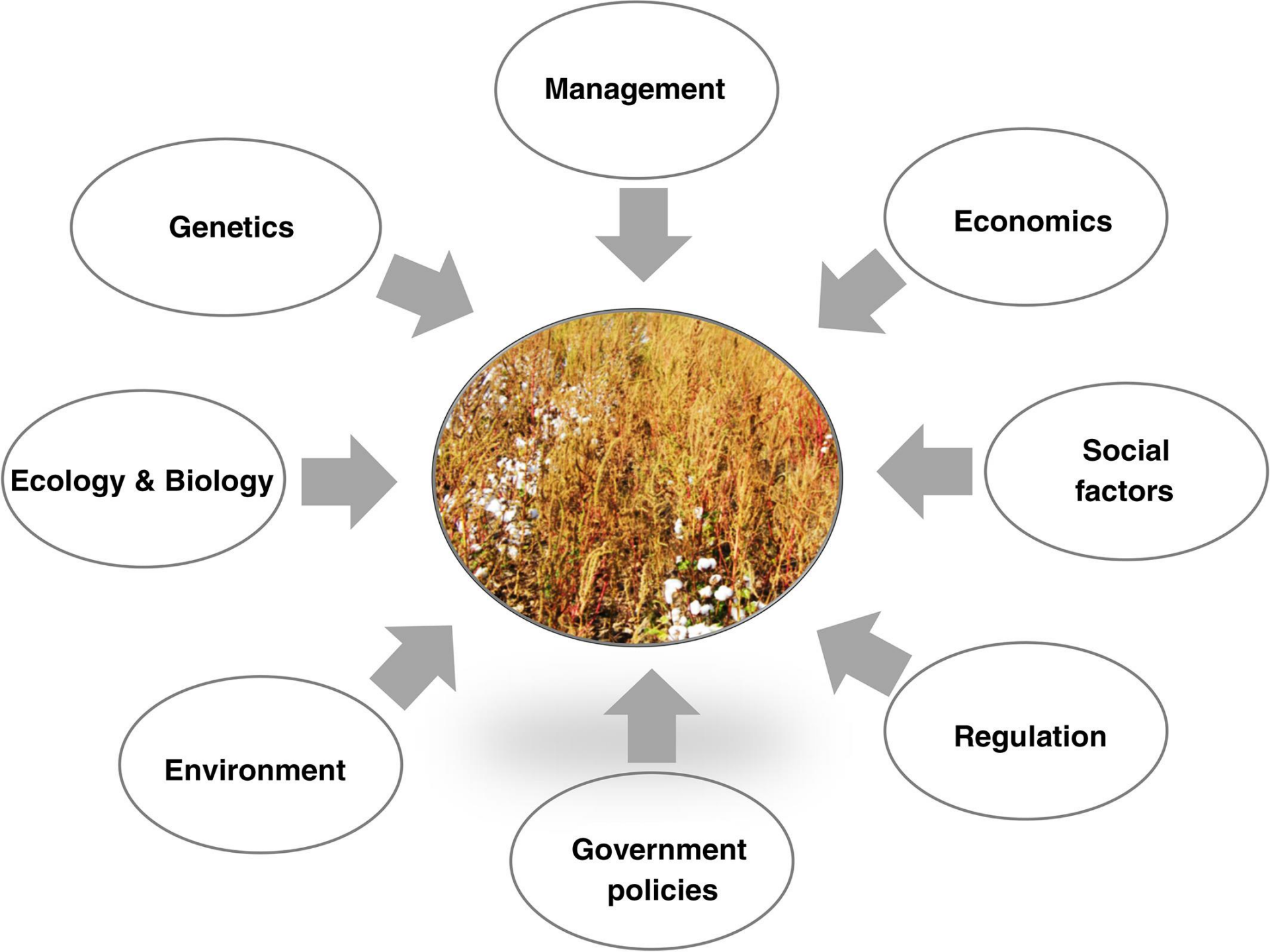
Why ???

That's life !!!



But to be more specific:

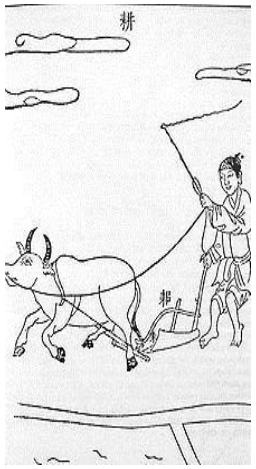
A weed's life !

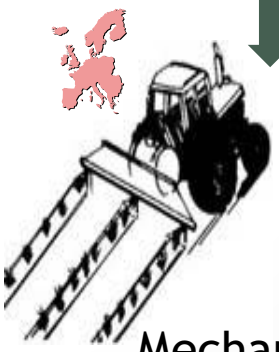

Management
Genetics
Economics
Ecology & Biology
Social factors
Environment
Regulation
Government policies

A Learning Cycle in Weed Science

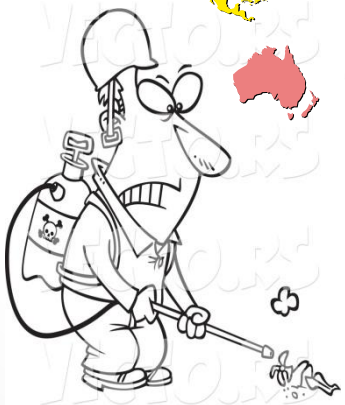
Hand weeding

Animal weed control

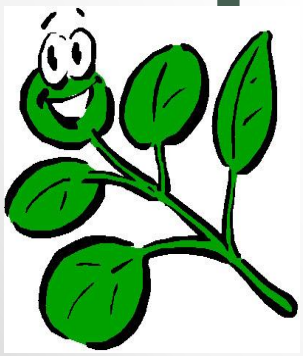




Mechanical weed control



Chemical weed control



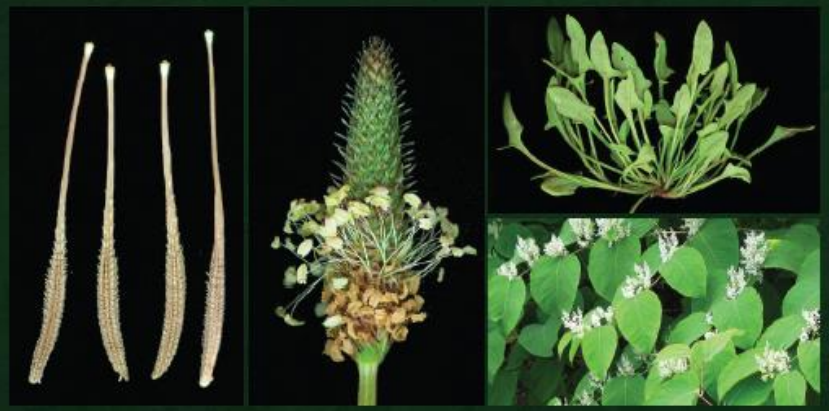
GM Herbicide-tolerant crops

Example of a ‘learning cycle’ in human medicine

- 2000 B.C. – Here, eat this root.
- 1000 A.D. – That root is pagan. Here, say this prayer.
- 1750 A.D. – That prayer is superstition. Here, drink this potion.
- 1900 A.D. – That potion is snake oil. Here, swallow this pill.
- 1985 A.D. – That pill is ineffective. Here, take this antibiotic.
- 2000 A.D. – That antibiotic is unnatural. Here, eat this root.

Picture:
Dr. Matthew Fidelibus

PERSISTENCE STRATEGIES OF WEEDS



EDITED BY **MAHESH K. UPADHYAYA,**
DAVID R. CLEMENTS ▪ **ANIL SHRESTHA**

WILEY Blackwell

Questions we ask

What makes a weed so persistent?

Why are the natural and human-developed selection pressures failing to eliminate them?

What lessons can we learn from the strategies that have developed to persist in the various ecosystems?

How can we use this knowledge of weed persistence to minimize the damage they cause to ecosystems?

What is the reason for weediness?

Are weeds present in the field because of a deficiency of herbicide or cultivation?

Species diversity - High

Natural ecosystems

Species diversity - Low

Agroecosystems

Weeds are the natural result of defying nature's design for high species diversity and covered ground

In crop production systems

- Large acreage of single plants
- High percentage of bare soil

Such systems leave room for invasion

What causes weeds?

Fallow

Annuals

Biennials/Perennials

Shrubs/bushes

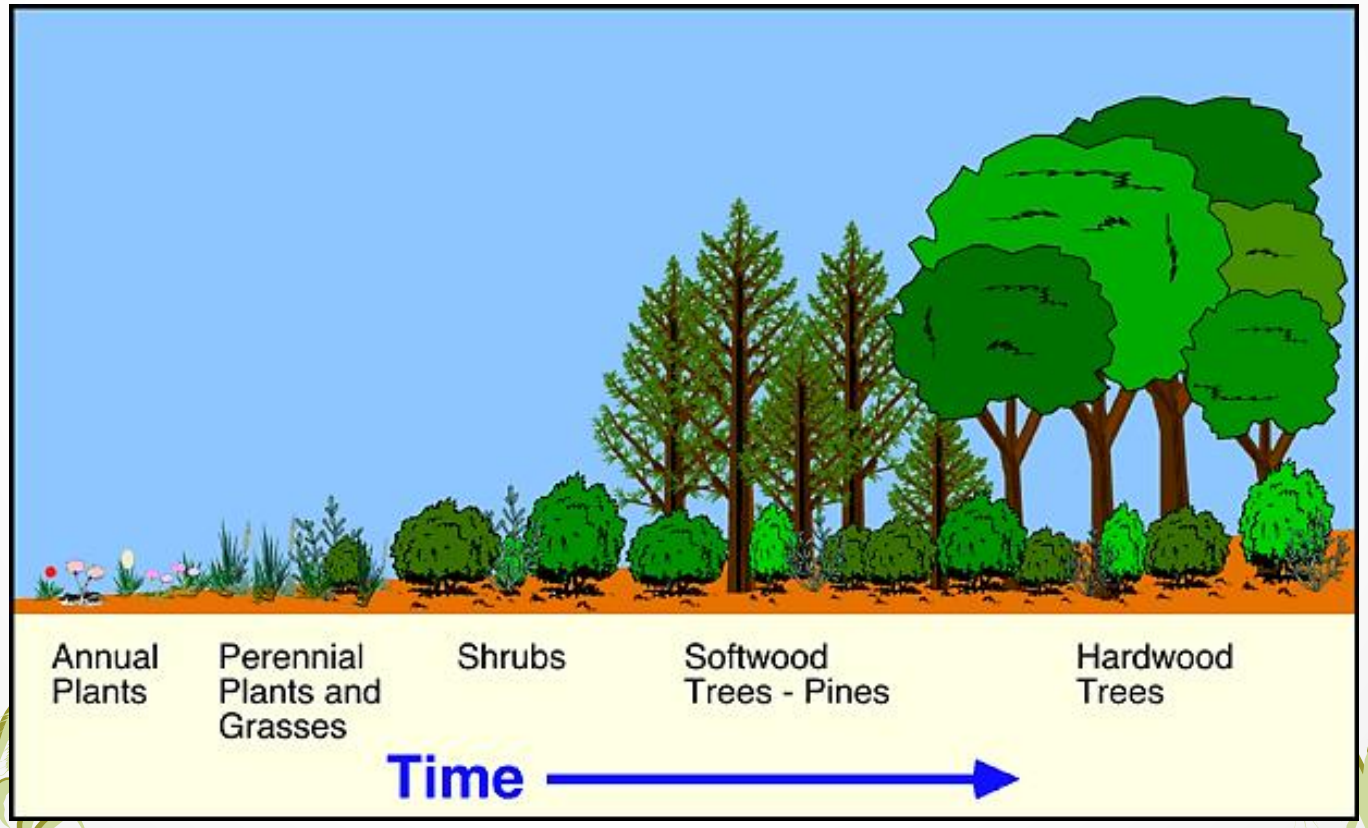
Climax

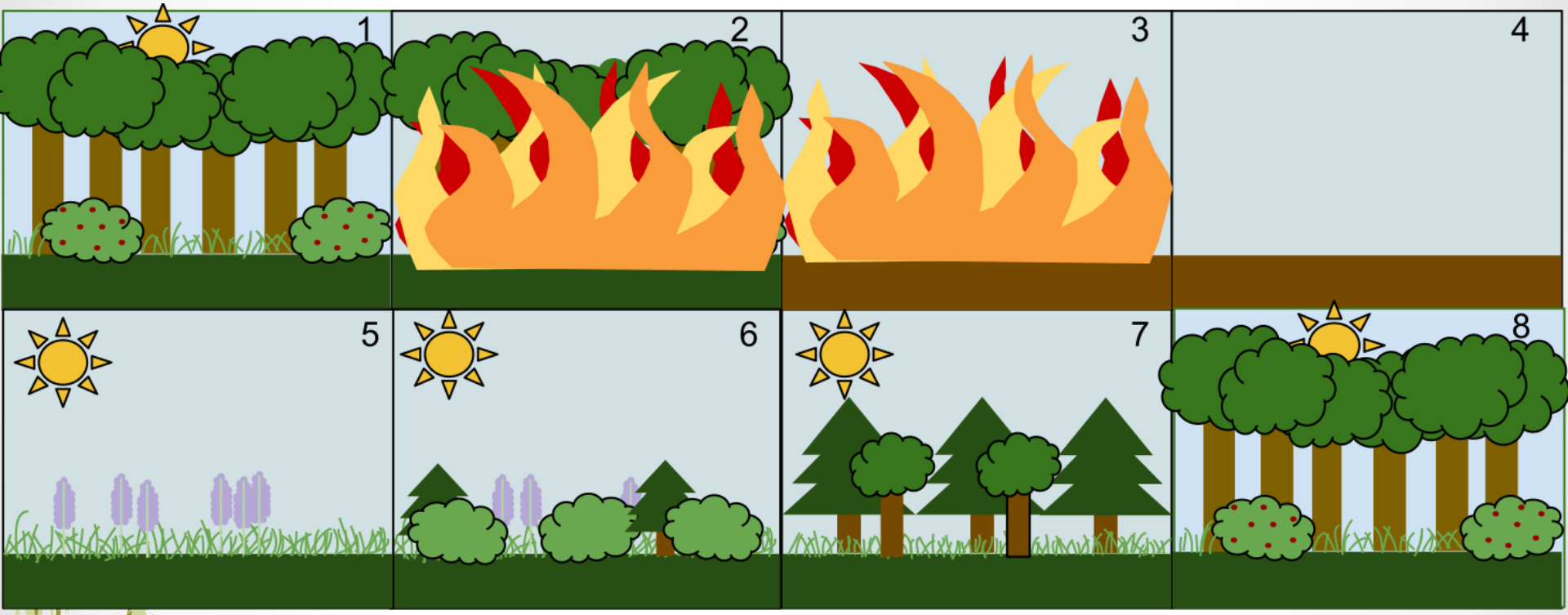
Disturbances
(often facilitates invasion)

Succesion

Ecological Succession

Is a natural, continuous process of change in the species structure of an ecological community over time.



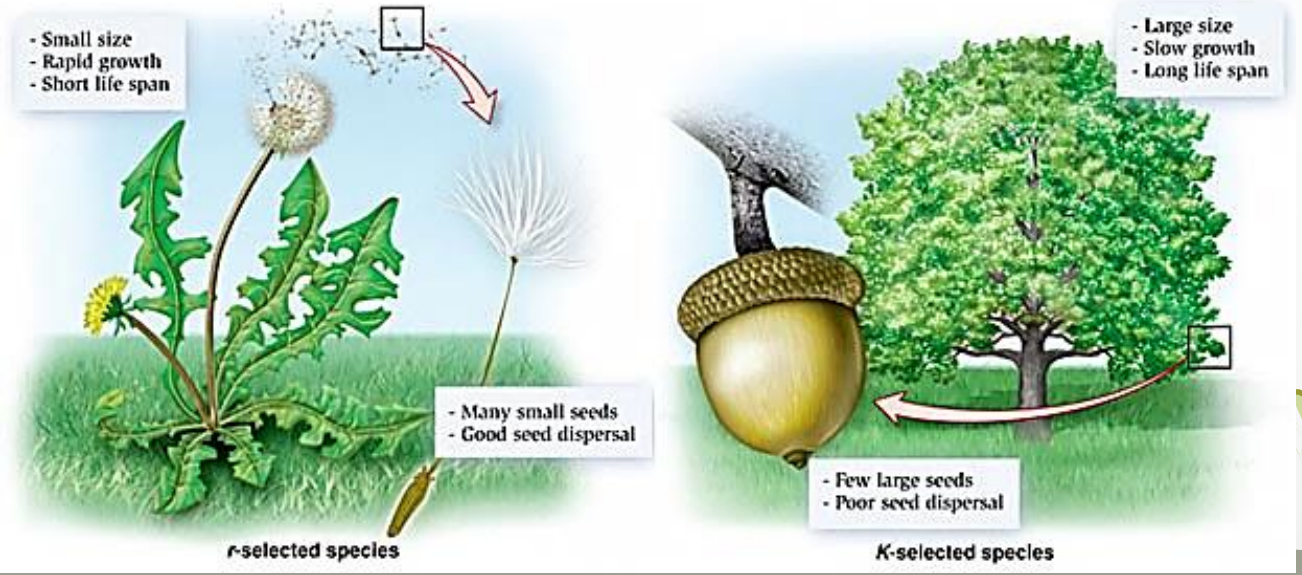

1
2
3
4
5
6
7
8

r- and K-selection

- **r-strategy**
  - Following disturbances, the species that will recolonize most rapidly are generally small annuals that have a rapid growth rate, reproduce early and produce many small seeds. These traits allow the species to arrive, germinate, establish, and reproduce quickly. If further disturbance occurs there will be seed available to re-establish. This set of traits is called an ‘r-strategy’; ‘r’ means high intrinsic rate of population growth
  - Most agricultural weeds are ‘r-strategists’. These weeds are adapted to frequent distribution through tillage, herbicides or other agronomic practices.

r- and K-selection

- **K-strategy**
  - In situations where disturbance is infrequent, and environmental conditions are relatively stable, traits such as large size, longevity, delayed reproduction are favored. Plants with this set of traits are called ‘K-strategists’. e.g., johnsongrass



How are we fighting the process of ecological succession?

- Physical
- Cultural
- Mechanical
- Biological
- Chemical

Each of these are selective forces

What makes a weed successful?

- No special environmental requirements for germination
- Discontinuous germination
- Longevity of seeds
- Rapid seedling growth with short vegetative periods
- Ability to maintain seed production as long as growing conditions permit
- Self- and cross-pollinated
- Ability to produce numerous seeds even under unfavorable environments
- Good mechanisms for short- and long-distance dispersal
- Vigorous and multiple methods of vegetative reproduction

We are dealing with plants that have very successful persistence mechanisms despite of above- and below-ground natural and human-induced selection pressures and management methods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Getting to the ‘seed’ cause of the problem

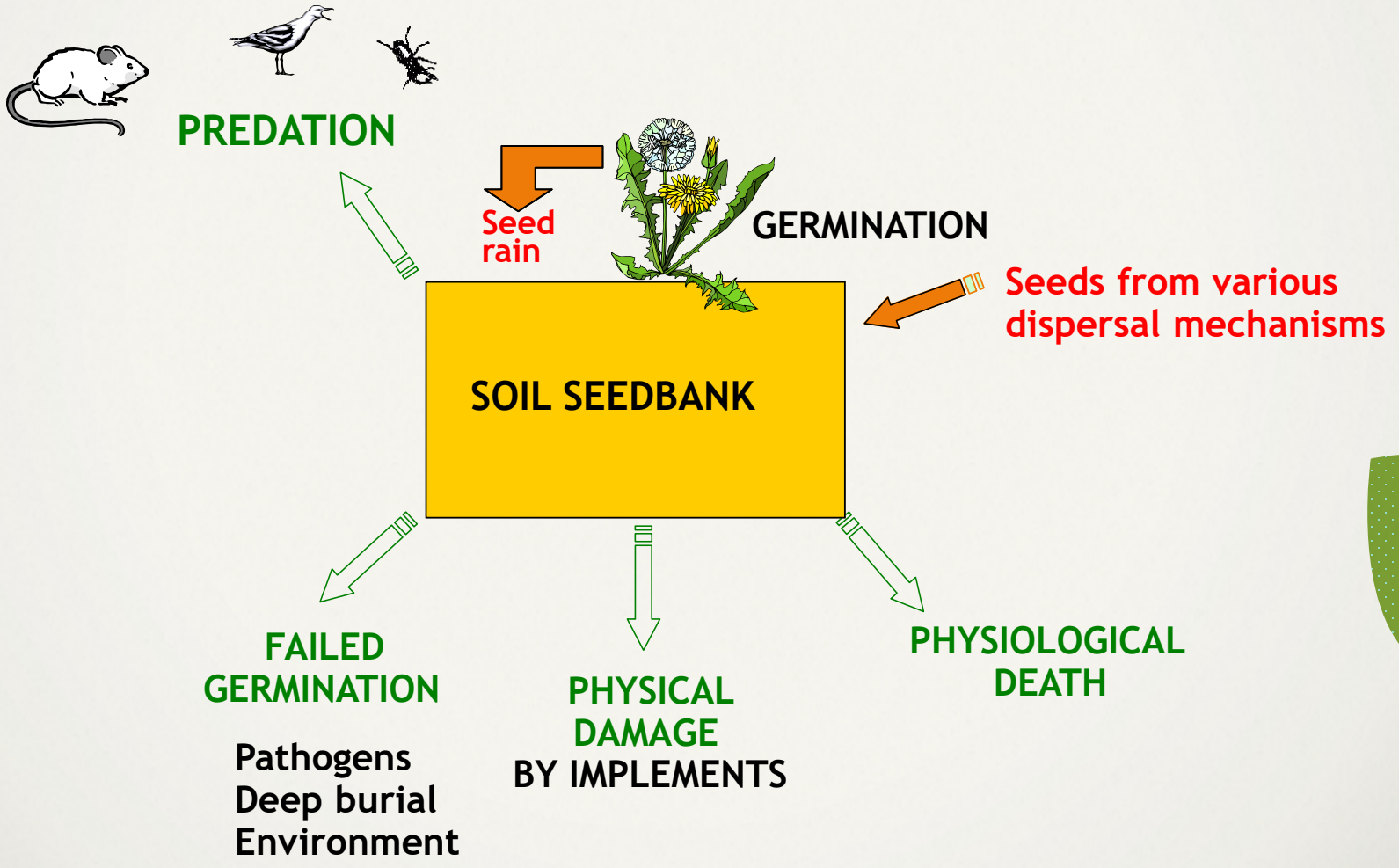
"One year's seeding-seven years' weeding" - an old adage

All it takes is~ one seed

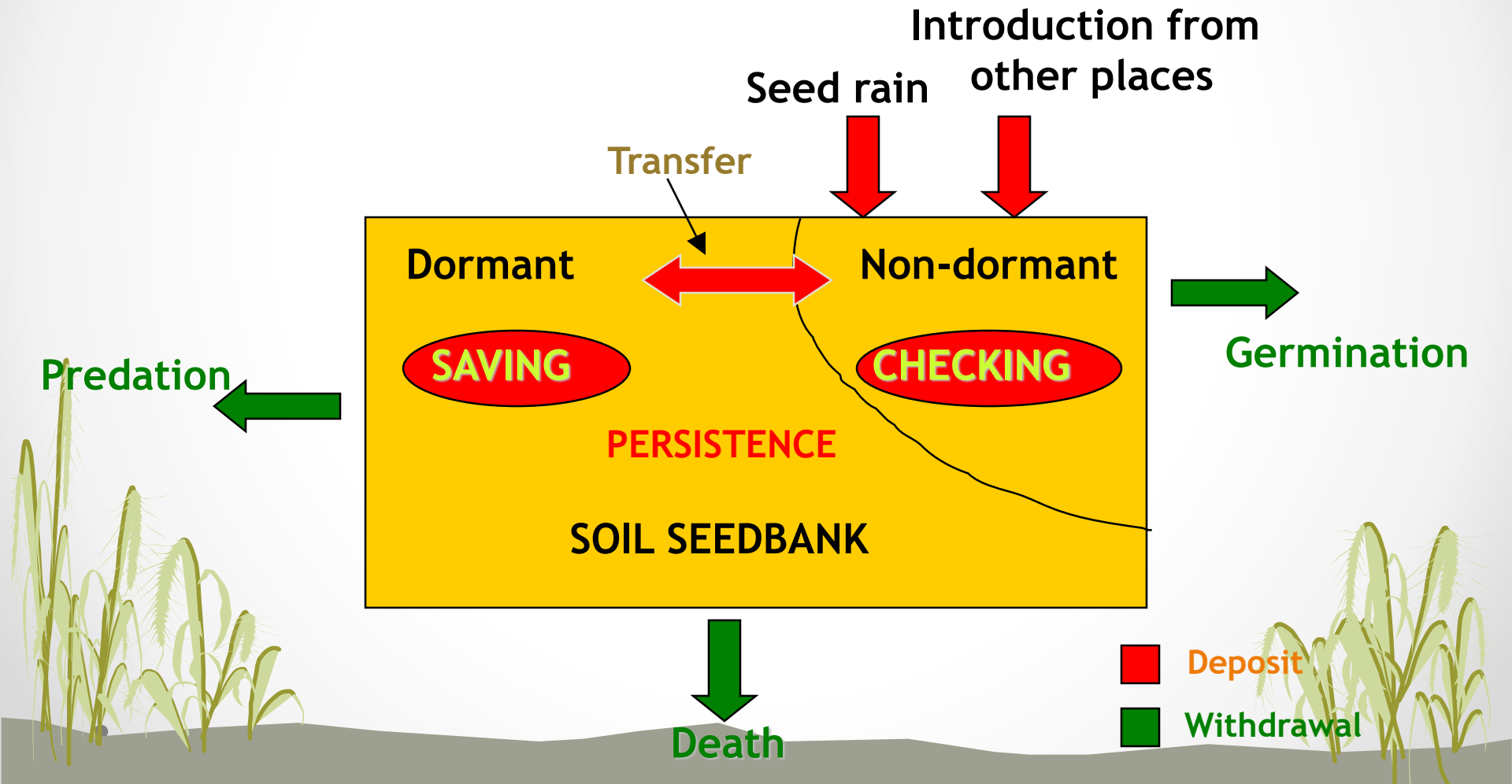
INTRODUCTION TO THE WEED SEEDBANK

- The weed seed bank is the main source of weeds
- Most weeds start their life cycle from a single seed
- If weeds are allowed to escape, they can produce thousands of seeds
- These seeds are returned to the soil and become the source of future weed infestations

What happens to the seeds in the seed bank?



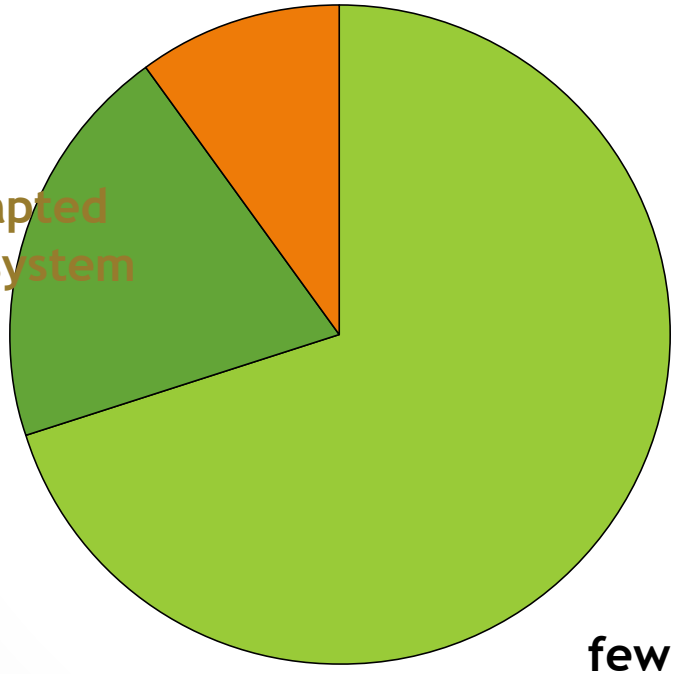
Input and Output of Weed Seeds in the Soil Seed bank & Persistence



Composition of the seed bank

Newly introduced species
1-5%

10-20%
species not adapted
to the current system



70-90%
few dominant species
adapted to the current system

Do not let weeds set seeds !!!

Weed Seed Production

Examples of seed production by various weed species

Weed species	No. of seeds produced/plant
Barnyardgrass	700,000
Horseweed	200,000
Eastern blacknightshade	825,000
Common lambsquarters	72,450
Common purslane	1,800,000
Shepherdspurse	150,000
Redroot pigweed	229,175
Puncturevine	100,000
Velvetleaf	48,000
Wild radish	1,875

Weed seed longevity

Species	Years
Barnyardgrass	5
Common purslane	20-25
Velvetleaf	15-40
Puncturevine	15-20
Shepherd’spurse	15-35
East. black nightshade	40+
Cheeseweed	200
Burclover	200

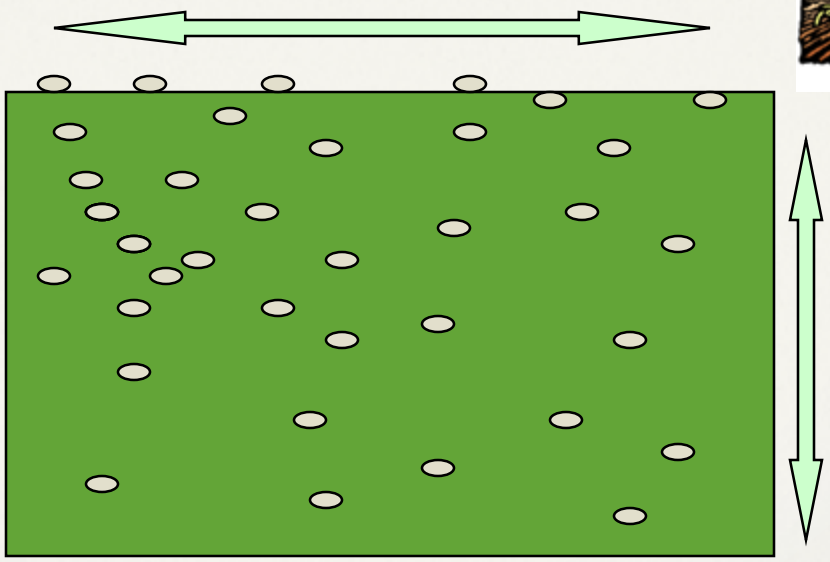
Addition to the seed bank

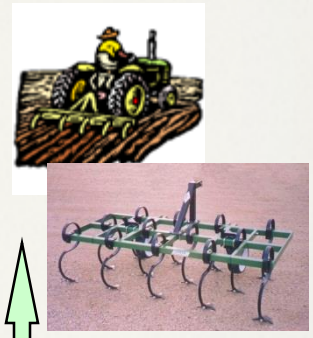
- 95% of the seeds in the seed bank come from annual weeds growing on the land
- Dispersal from other places ~ by equipment, crop seed contamination, animals, wind, water, manure
- e.g., irrigation water has the potential to add 4,210 to 38,280 seeds/acre
- manure could add 4,174 to 21,755 seeds/ton

Seed distribution in the seed bank

Seeds are distributed both horizontally and vertically in the soil seed bank

Horizontal distribution generally follows the direction of crop rows

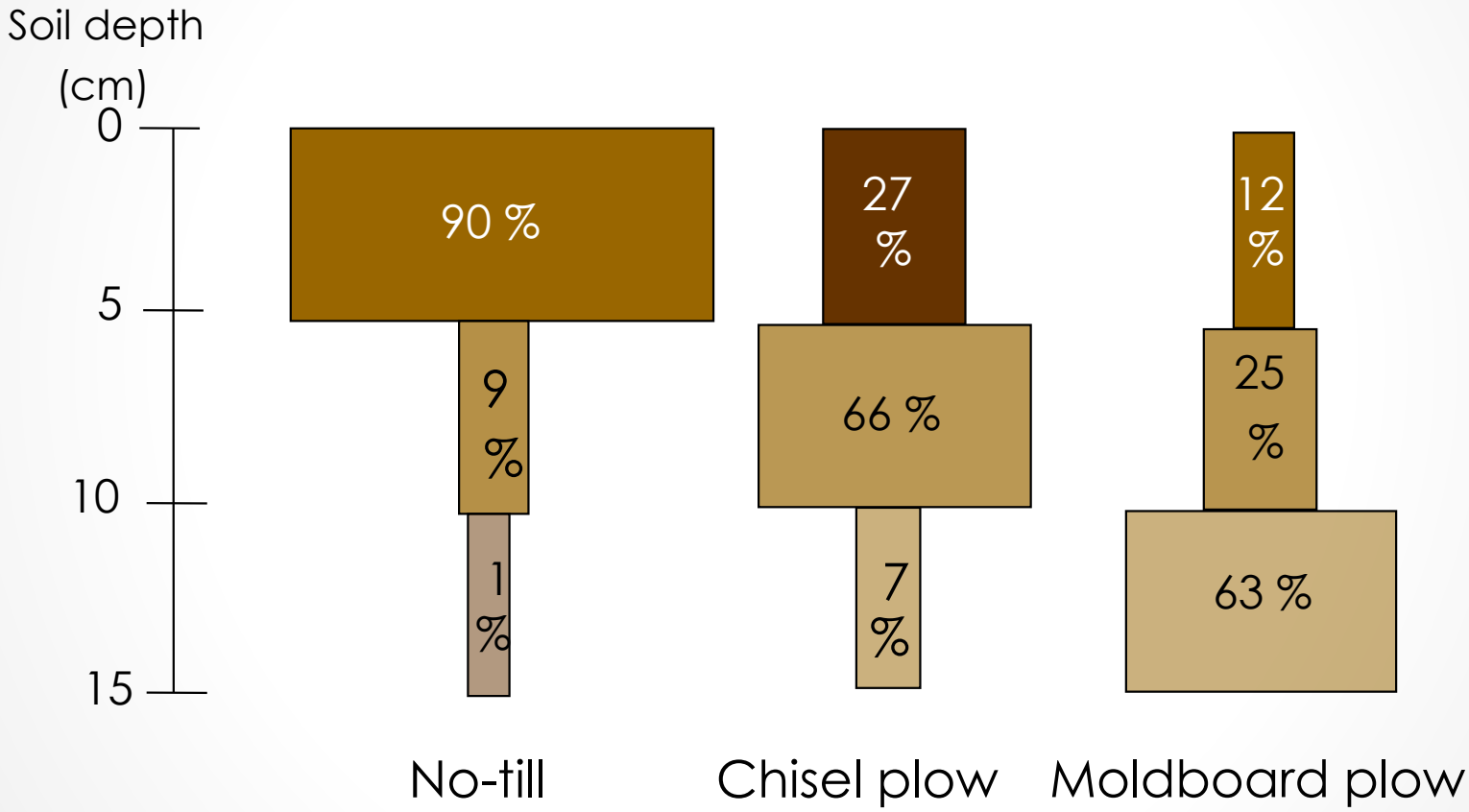




Vertical distribution is influenced by tillage type

Weed Seed Bank Dynamics

(Reserves of viable seeds present on the surface and in the soil)



Influence of tillage type on the vertical distribution of weed seeds in a loamy sand soil.

Population explosion?

Knapweed (*Centaurea* sp.)

- 100 seeds introduced accidentally
- 4% germination, 25% of these survive
- 1000 seeds/plant
- Seeds remain viable in the soil for 8 years
- Takes 1 year for knapweed to germinate and produce seed
- Knapweed lives for about 5 years
- How many seeds and plants in 10 years?

Population explosion?

Year	Plants	Seeds
0	0	100
1	1	1096
2	12	13,052
3	143	155,530
4	1,698	1,847,309
5	20,171	21,944,417
6	239,614	260,680,640
7	2,846,408	3,096,661,414
8	33,812,879	36,785,673,858
9	401,667,920	436,982,165,807
10	4,771,469,407	5,190,972,273,123

A field taken over by Fiddleneck in Parlier

How many years did it take to reach this situation?


DON'T
INVEST
WEED
SEED
BANK

How to limit the seed bank?

- Manage weeds along field edges
- Minimize weed escapes ~ clipping weeds
- Post harvest management of weeds
- Burying seeds deeper into the soil may help
- Stimulate seeds closer to the surface to germinate (e.g. pre-irrigation) then control
- Use clean equipment
- Rotate herbicides
- Proceed with caution while applying manure
- Keep canal banks weed free, install screens on canal inlets


Don’t wait too long to control weeds


Manage weeds along field edges


Weeds will continue to grow and produce seeds even after crop harvest


GRDC

Northern Australia: seed longevity relatively short for the invasive weed species, *Calotropis procera* (Roostertree)

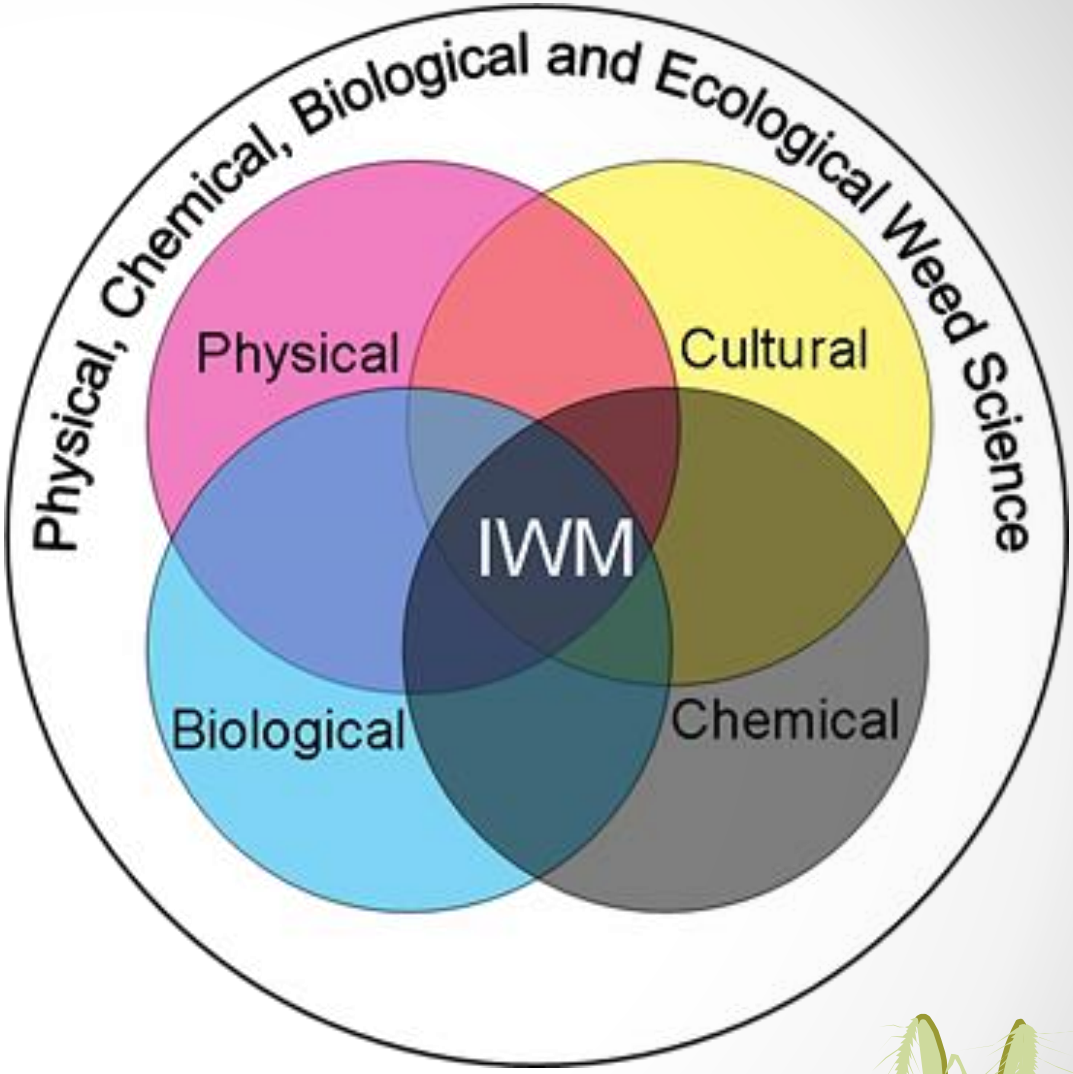
Queensland, Australia: Parthenium weed (*Parthenium hysterophorus*), was found to develop rich seedbanks with long life in pastures and grazing lands. It required decades of continuous management effort to even exhaust half of the seedbank

INTEGRATED WEED MANAGEMENT

- A systems approach to weed management
- The use of alternative “selection pressures” for weed control
- The use of “many little hammers”

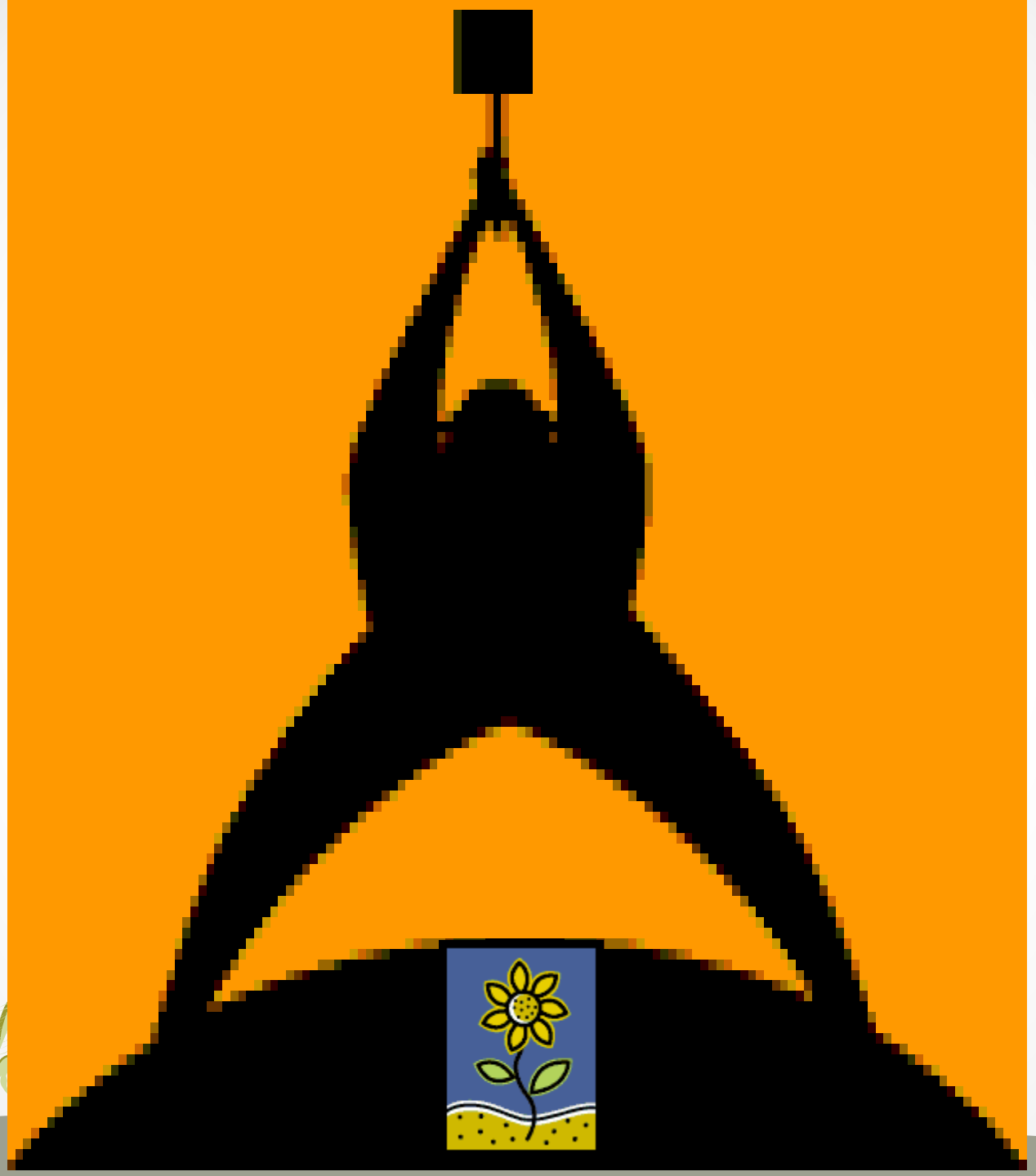
Assumptions

- Continuous use of same practice will select for species that become adapted to that practice
- Multiple control tactics will prevent adaptation



INTEGRATED WEED MANAGEMENT (IWM) – first discussed in 1981

Why is Integrated Weed Management needed?



Continuous use of the same tactic will select for weeds that adapt to that system


Continuous French Plow ~ Bermudagrass


Bezzerides cultivator undercuts weeds


Horseweed
Hairy fleabane


Yellow nutsedge
Foxtail grasses


Mowing ~ low growing species like Fluvellin
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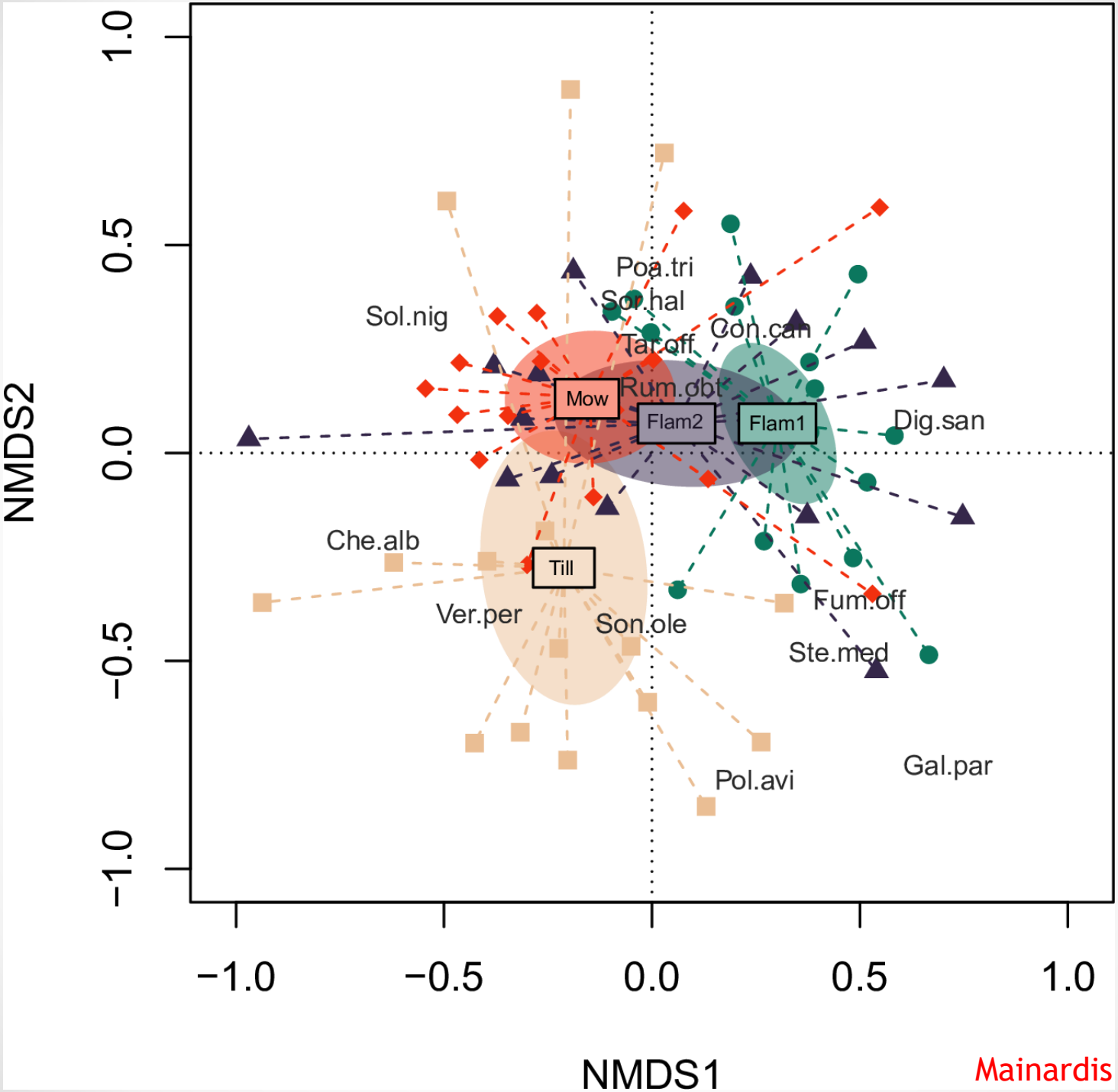
Continuous Flaming & Steaming


Flame/steam tolerant species
- Regrowth



Mainardis et al. (2020)

Flaming favored smaller perennial plants with shallow root system, often with storage organs

- e.g., crabgrass, bitter dock, horseweed

Tillage favored annual species reproducing only by seed

- e.g., chickweed, common lambsquarters, Veronica,

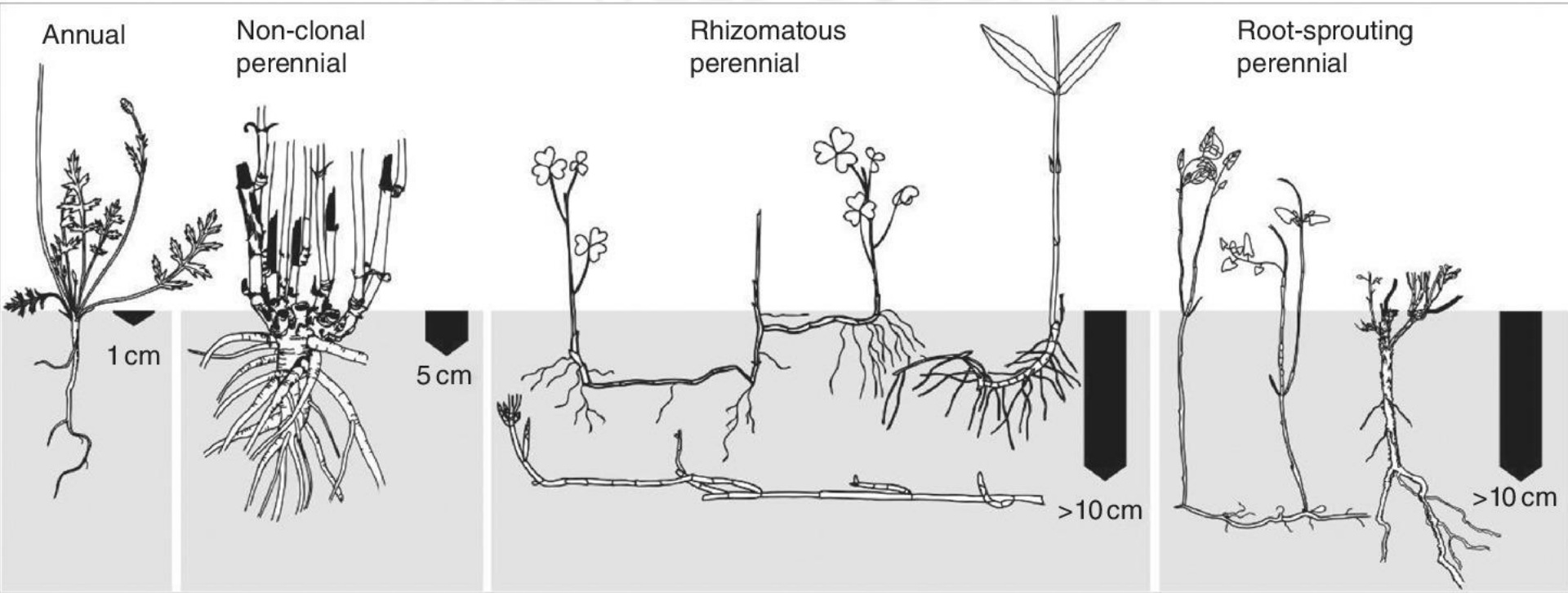
Mowing favored perennial species that re-sprouted from vegetative organs (e.g., rhizomes, runners, taproots)

- e.g., grasses

Cultivators

Bezzerides Vineyard Berm Rake

THE WEED BUDBANK



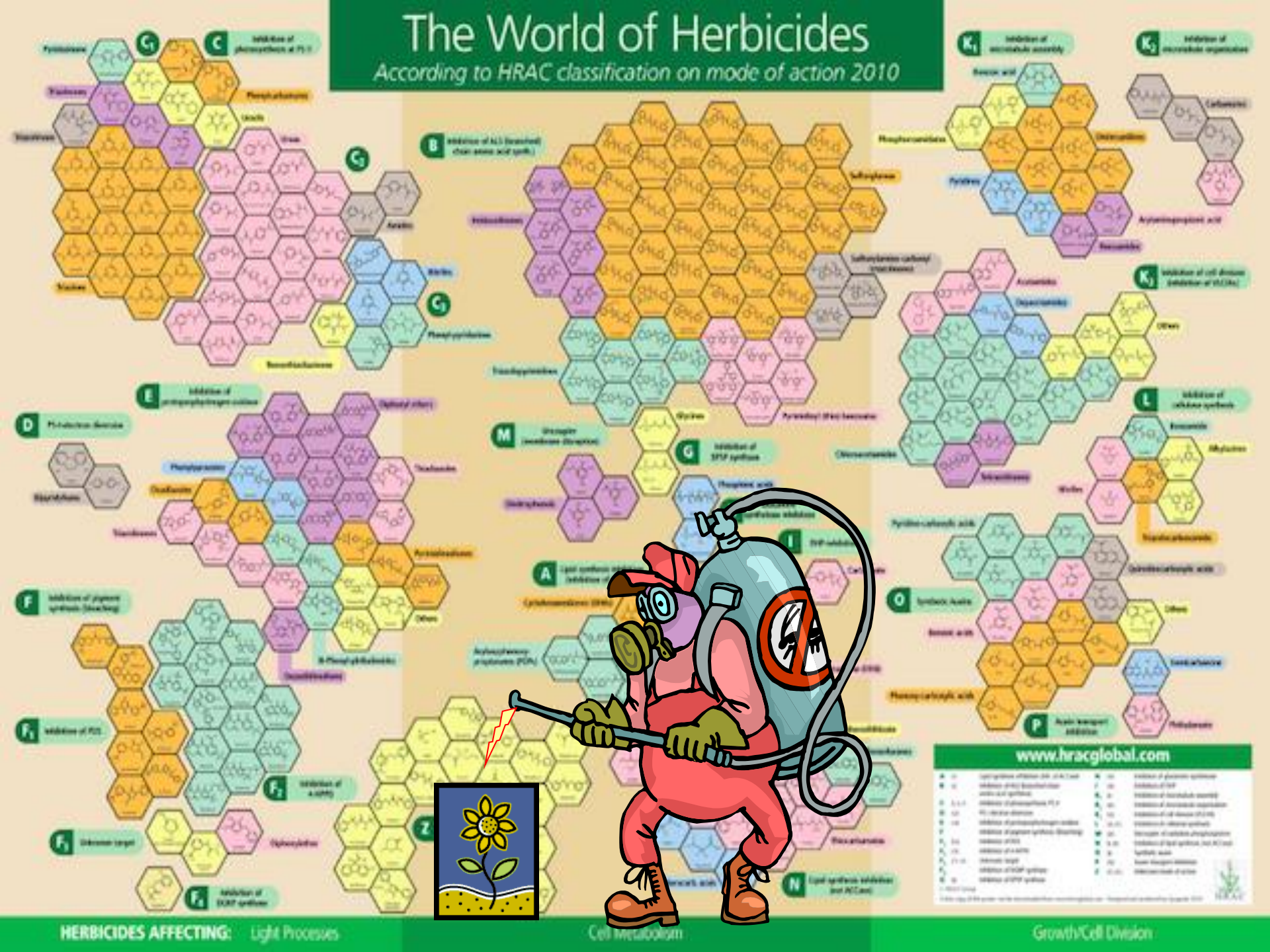
Klimešová & Martínková (2021)

Photo: S. Chaudhari, Michigan State University

ROTATE MECHANICAL TOOLS !!!

The World of Herbicides

According to HRAC classification on mode of action 2010



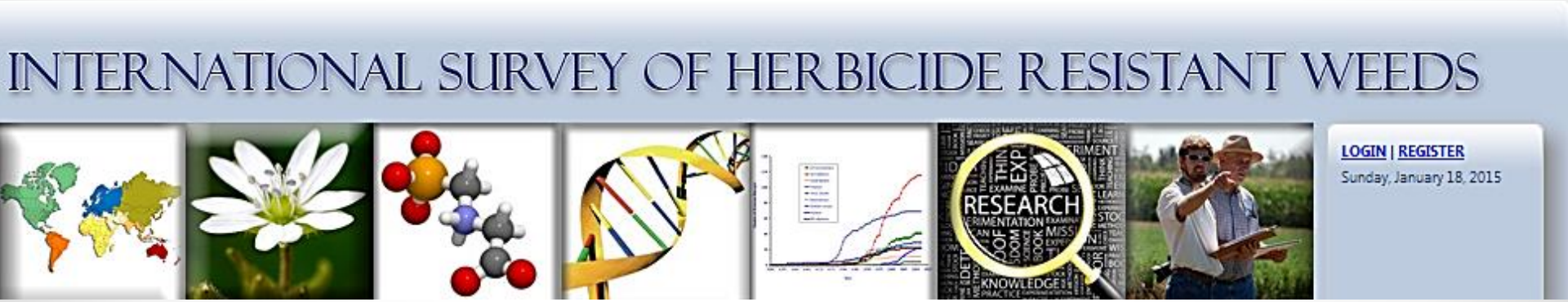
www.hracglobal.com

HERBICIDES AFFECTING: Light Processes | Cell Metabolism | Growth/Cell Division

Herbicide Resistance- *Around the World*

- 505 unique cases of resistant weeds
- 263 Species (153 dicots and 111 monocots)
- About 21 of the 31 herbicide sites of action; 164 herbicides
- 95 crops in 71 countries

Repeated use of the same herbicides has selected for resistant weeds



Source: Heap, I. The International Survey of Herbicide Resistant Weeds (www.weedscience.org)
September 29, 2021

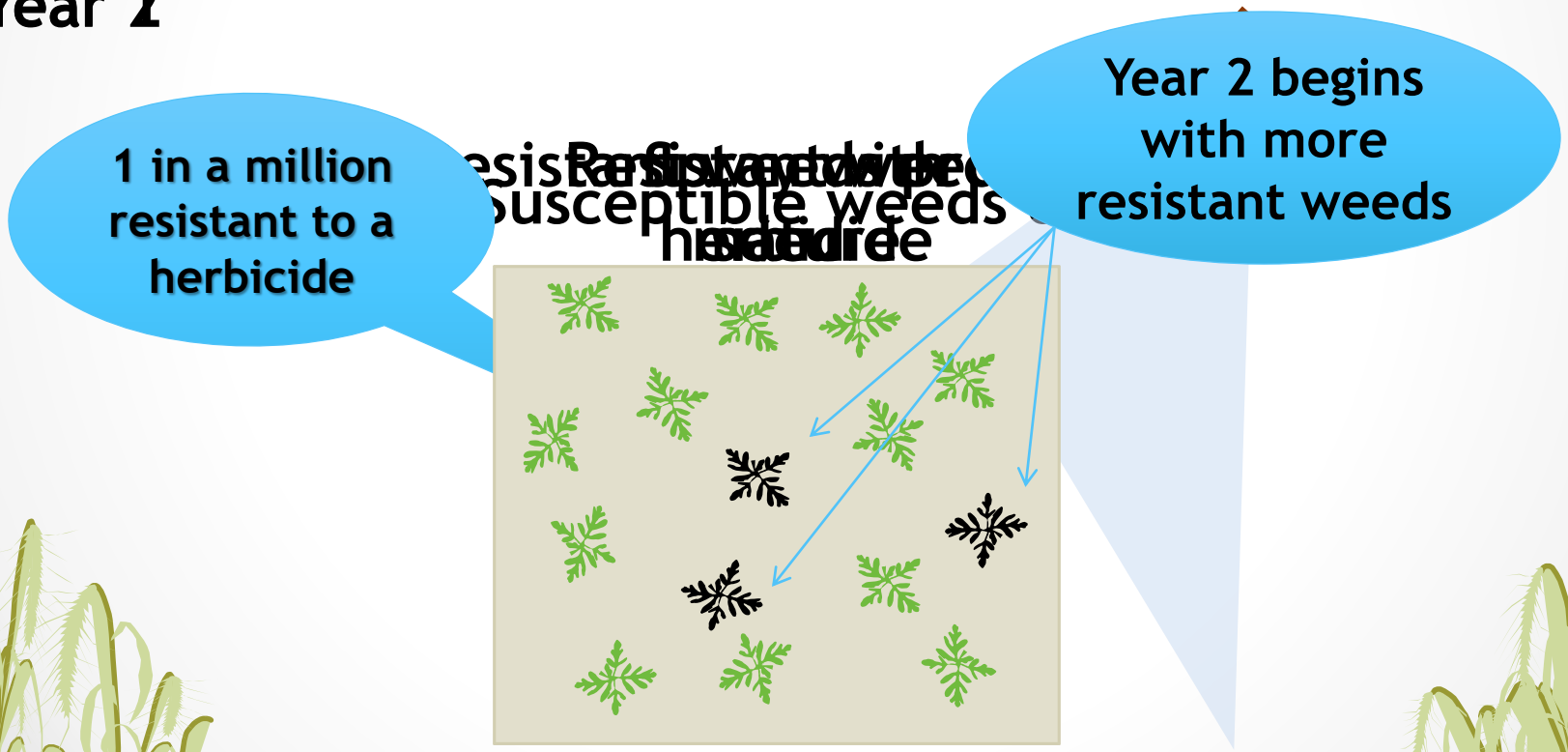
How does resistance occur?

- Resistance (R) occurs with repeated use of a specific herbicide
  - most commonly it is selection pressure

Selection by Herbicides Changes the Population Over Time

Example

Year 1



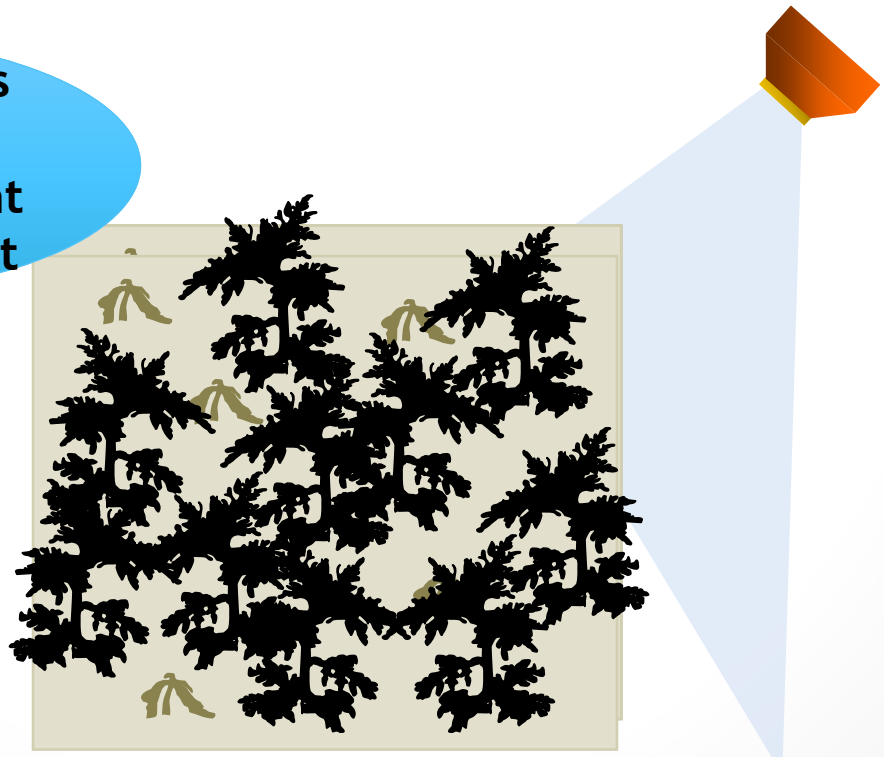
Slide: From WSSA Herbicide Resistance Management Lesson

Selection by Herbicides Changes the Population Over Time

Example

Year 2

And in later years even more herbicide-resistant weeds are present



Slide: From WSSA Herbicide Resistance Management Lesson

Herbicide resistant weeds in CA (30 biotypes)

Weed	Situation	Herbicide
Common groundsel	Asparagus	Photosystem II inhibitors (Atrazine)
Perennial ryegrass	Roadsides	ALS inhibitors
Umbrella sedge	Rice	ALS inhibitors
California arrowhead	Rice	ALS inhibitors
Russian thistle	Roadsides	ALS inhibitors
Redstem	Rice	ALS inhibitors
Ricefield bulrush	Rice	ALS inhibitors, PS II inhibitor
Longleaved loosestrife	Rice	ALS inhibitors
Late watergrass	Rice	ACCase inhibitors, thiocarbamates
Barnyardgrass	Rice	ACCase inhibitors, thiocarbamates
Littleseed canarygrass	Onion	ACCase inhibitors
Early watergrass	Rice	ACCase inhibitors, thiocarbamates
Smooth crabgrass	Rice	Synthetic auxins

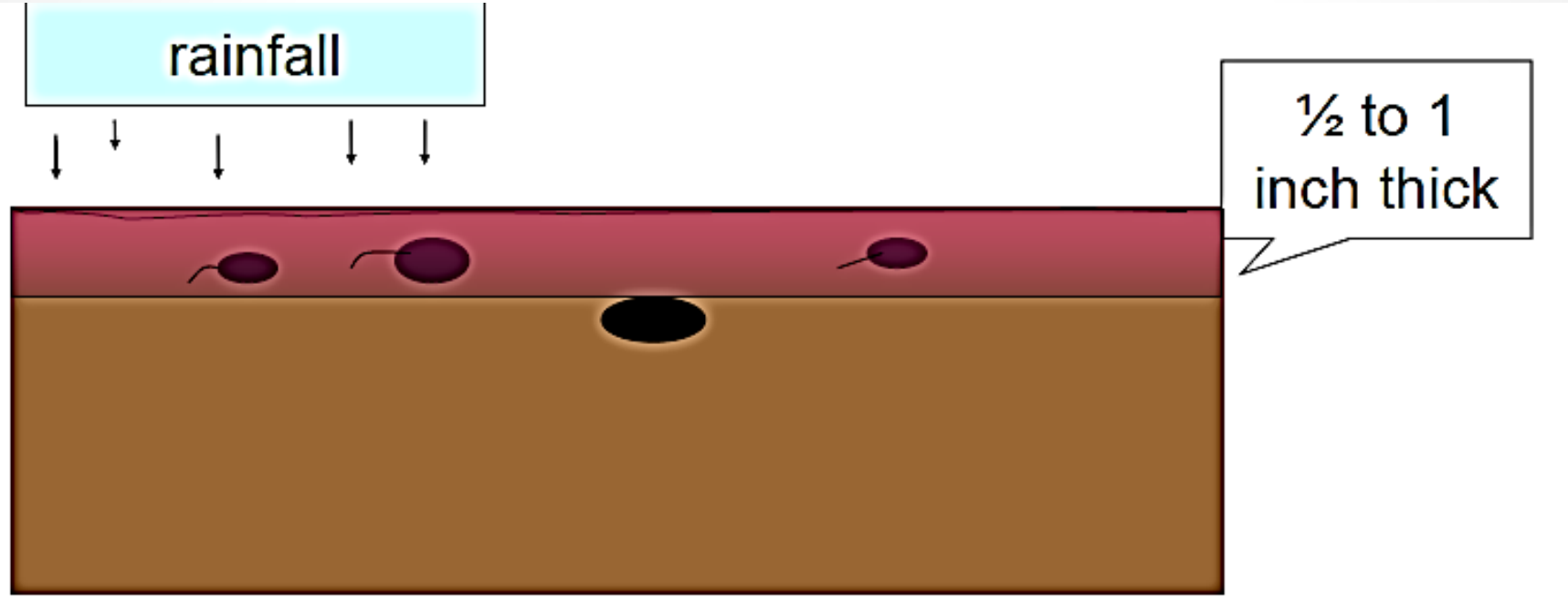
Herbicide resistant weeds in CA (30 biotypes)

Weed	Situation	Herbicide
Wild oat	Barley, wheat	Pyrazoliums
Italian ryegrass	Almond	Glycines (glyphosate), glufosinate
Rigid ryegrass	Almond	Glycines (glyphosate)
Horseweed	Canal banks	Glycines (glyphosate), bipyridilium
Hairy fleabane	Roadsides	Glycines (glyphosate), bipyridilium
Junglerice	Almond	Glycines (glyphosate)
	Roadsides	
Annual bluegrass	Orchards	Glycines (glyphosate)
Palmer amaranth	Corn	Glycines (glyphosate)
Rigid Ryegrass	Orchards	Glyphosate, Glufosinate, ACCase, ALS

Integrate pre- and post-emergence herbicides effectively

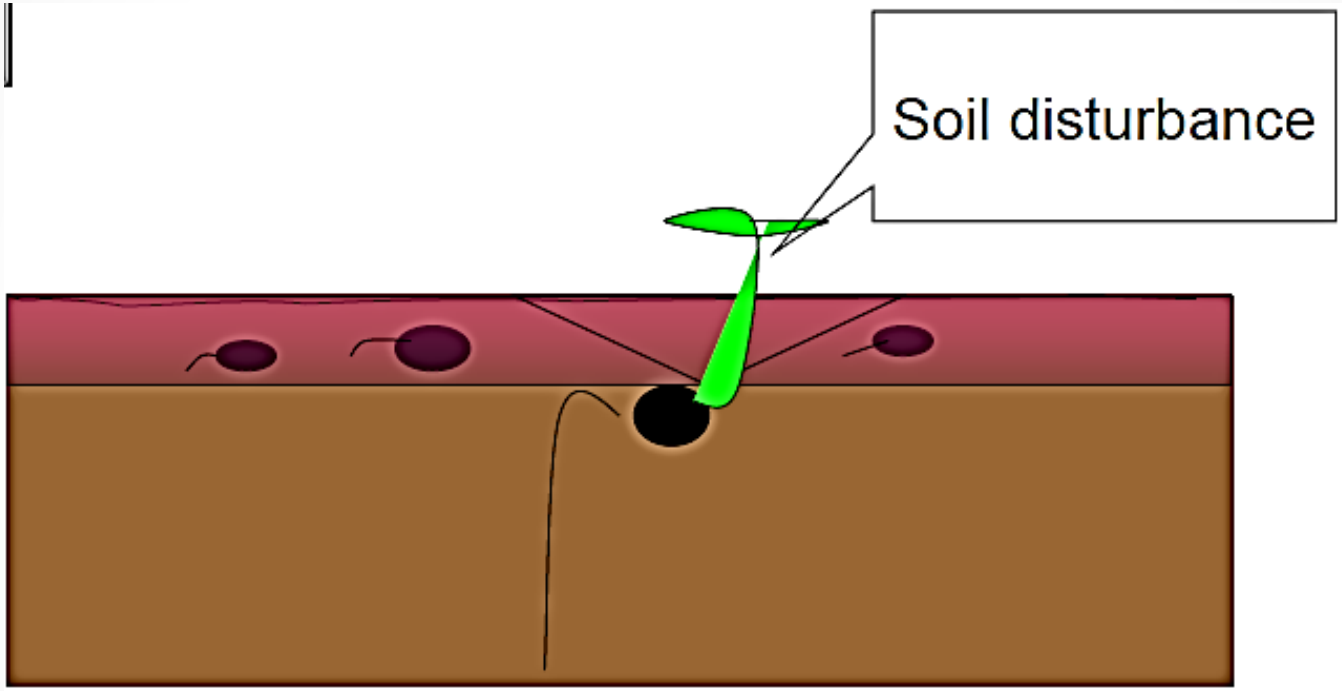
- **Pre-emergence**
  - Remove debris
  - Enough water to activate herbicide
  - Avoid frequent wetting and disturbance of soil
- **Post emergence**
  - Timing
  - Volume
  - Spray deposition
  - Nozzle selection
  - Addition of adjuvants
  - Water quality
  - Preventing drift

Pre-emergence herbicides



Activation is needed, rainfall or irrigation

Pre-emergence herbicides



time cultivation to complement and not disrupt herbicide barrier


Debris can interfere with herbicide efficacy


Frequent wetting and soil disturbances can promote more rapid herbicide degradation

Growth Stage is Important with Postemergence herbicides

4 - 6 Leaf Stage

>6 leaf stage

Native Plants

- Co-evolved with other plants, animals, microbes
- Comprise ecosystem
- Disturbance or unfilled niche in an ecosystem can provide opportunity for another species
  - Succession
  - Invasion

Tarweed

Salvia (sage)

California poppy

California needlegrass

NATIVE SPECIES OF CALIFORNIA

Invasive Weeds

- **Invasive weed** - unwanted plant that is not native to the area of infestation and is likely to cause harm (vs naturalized plant)

- They can originate in different countries or areas within the same country

- For more info: http://www.invasivespeciesinfo.gov

Invasive Weeds

- Invasive weeds tend to proliferate more in non-crop lands
  - 70% of CA is forests, range, and scrublands
  - 8% of CA is wetlands, riparian areas, water surfaces

- 1100 non-native species that are naturalized in CA
  - 81% are in non-ag lands
  - about 16% are considered significant problems

What makes a plant “invasive”?

- Overcomes barriers
  - Geographical
  - Survival
  - Establishment
  - Dispersal

- Causes harm

Source: National Invasive Species Council (NISC)
(http://www.invasivespeciesinfo.gov/docs/council/isacdef.pdf)

Invasive Weed Characteristics

- Adapt to wide range of conditions
- Grow rapidly
- Reproduce prolifically
- Have few local enemies

Invasive Weed Impacts

- Displace native plants and reduce biodiversity
  - Degrade wildlife habitat
  - Further risk to threatened and endangered species
- Alter ecosystem processes
  - Hydrology (yellow starthistle)
  - Fire regimes (downy brome)
  - Soil chemistry (salt cedar)
- Reduce recreational value

Mile-a-minute

Top Invasive Weeds

Fresno, Madera, Mariposa Co.

- Yellow starthistle
- Spotted and diffuse knapweed
- Bull and Italian thistle
- Scotch and Spanish broom
- St. Johnswort
- Giant reed (Arundo)
- Perennial pepperweed
- Himalayan blackberry

Other CA Invasives

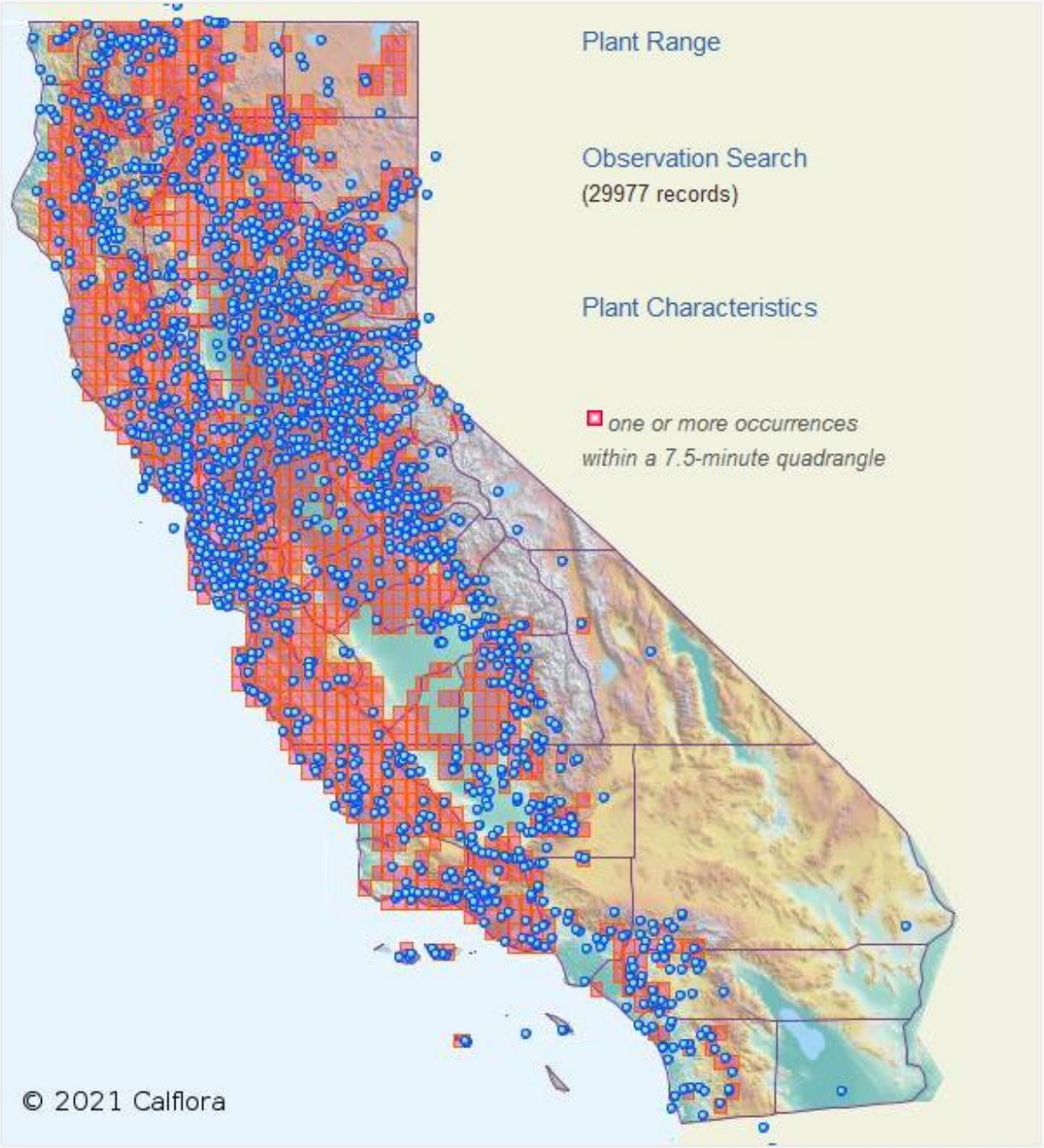
- Purple Loosestrife
- Leafy spurge
- Hydrilla
- Salt cedar (tamarisk)

Yellow Starthistle

(*Centaurea solstitialis* L.)

- Winter annual species
- Native to the Middle East and south-central Europe
- Introduced in North America around 1850
  - as a seed contaminant in Chilean-grown alfalfa seed
- Believed to infest 15 million acres in CA
  - found in 56 of 58 counties

http://wric.ucdavis.edu/yst/yst.html



Name Status:
Accepted by JEF + PLANTS

Alternate Names:
PLANTS Leucantha solstitialis

California's #1 Invasive Species

Yellow starthistle (YST) ***(Centaurea solstitialis)*** causes brain lesions and death in horses, uses large amounts of water and degrades rangelands through competition with desired beneficial plant species.

22 million acres infested in California.

YST is invasive in rangelands, orchards, vineyards, pastures, parks, roadsides & natural areas.

Spotted knapweed

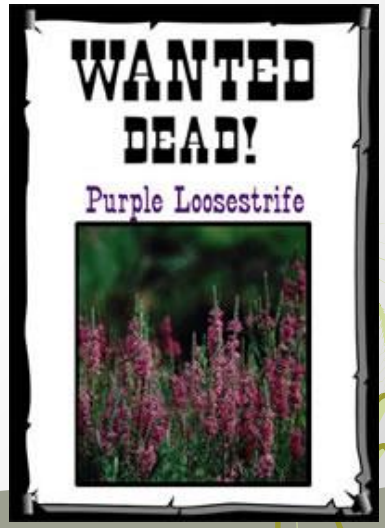
Spotted knapweed (*Centaurea stoebe* L. subsp. *micranthos* (Gugler) Hayek)

- Biennial to short-lived perennial
- 13 species exist in CA
- White, pink, or purple flowers
- Plants exist as basal rosettes until erect, highly branched flowering stems are produced late spring/summer

Purple loosestrife (Red Alert weed)

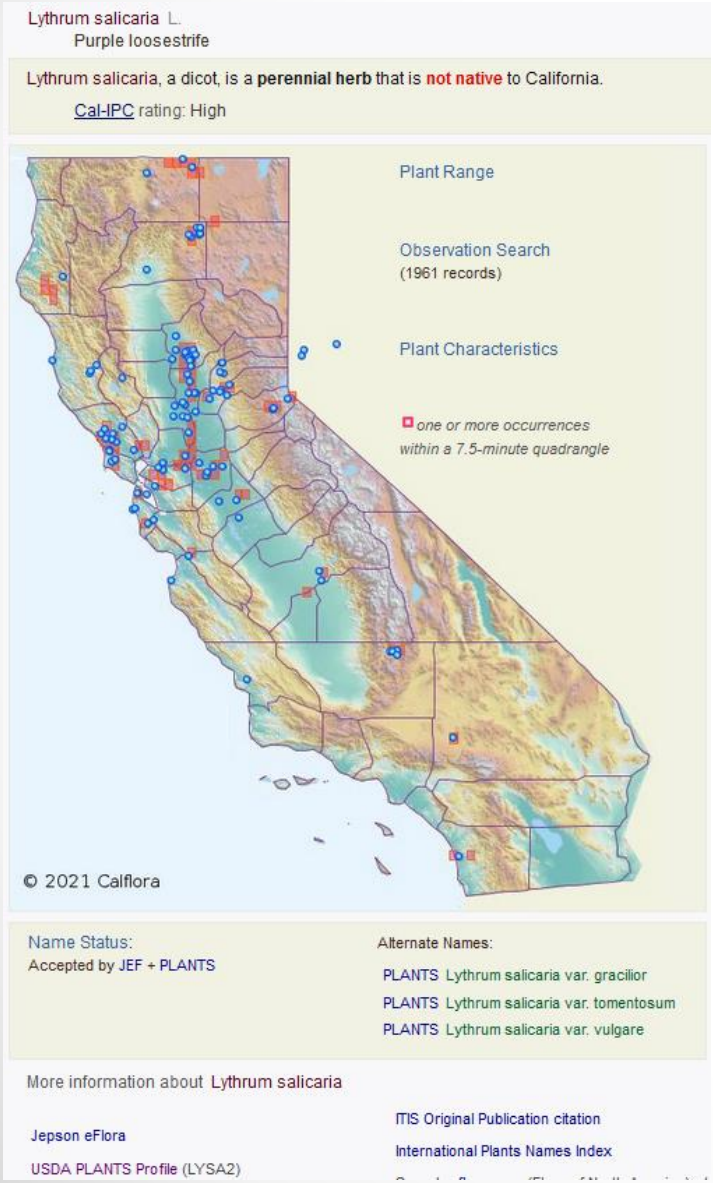
(*Lythrum salicaria* L.)

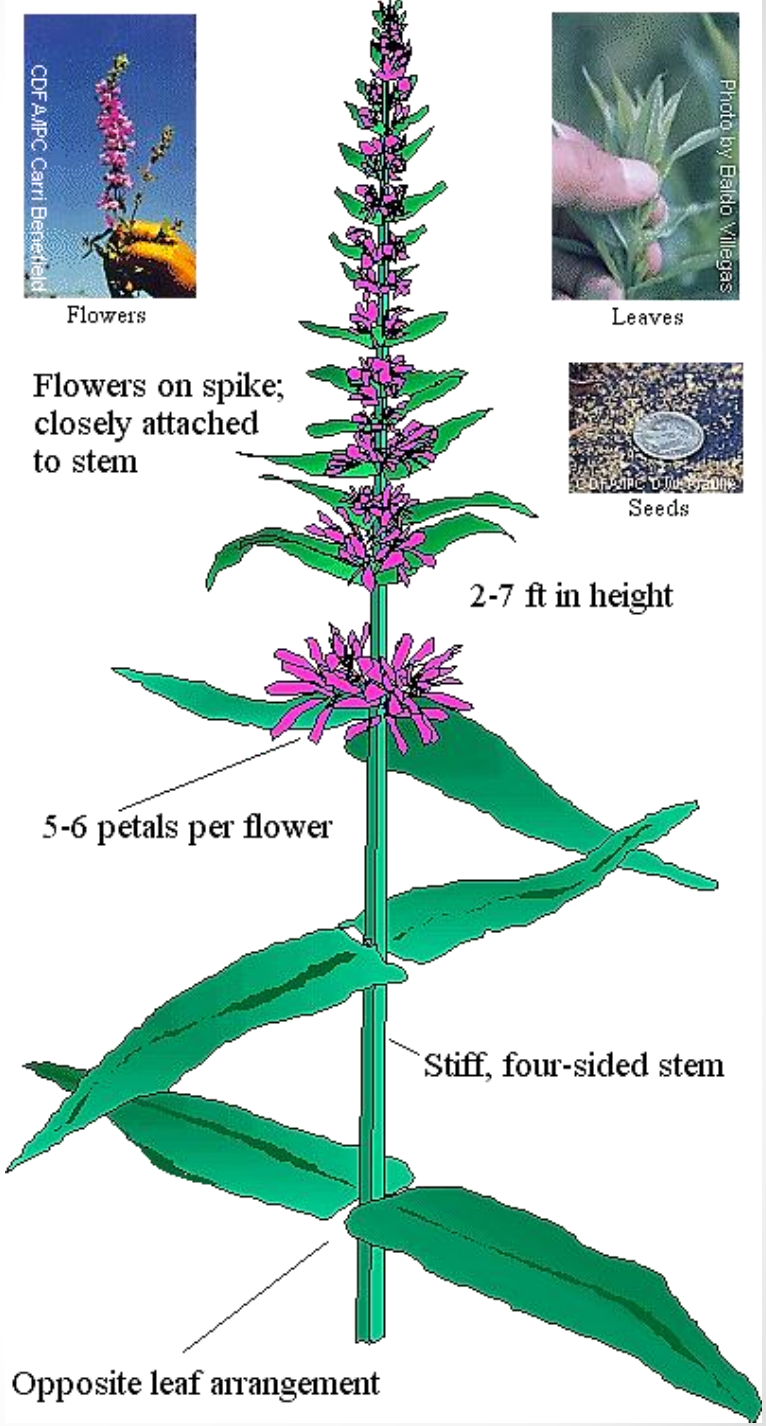
- A wetland perennial plant from Europe and Asia
- Introduced into the NE U.S. in the 1800s
- First spread along roads, canals, and drainage ditches
  - recently has been distributed as an ornamental
- Found in 42 states and rated as a serious invasive weed in most



Purple loosestrife

- Up to 2.7 million seeds per plant





Purple loosestrife

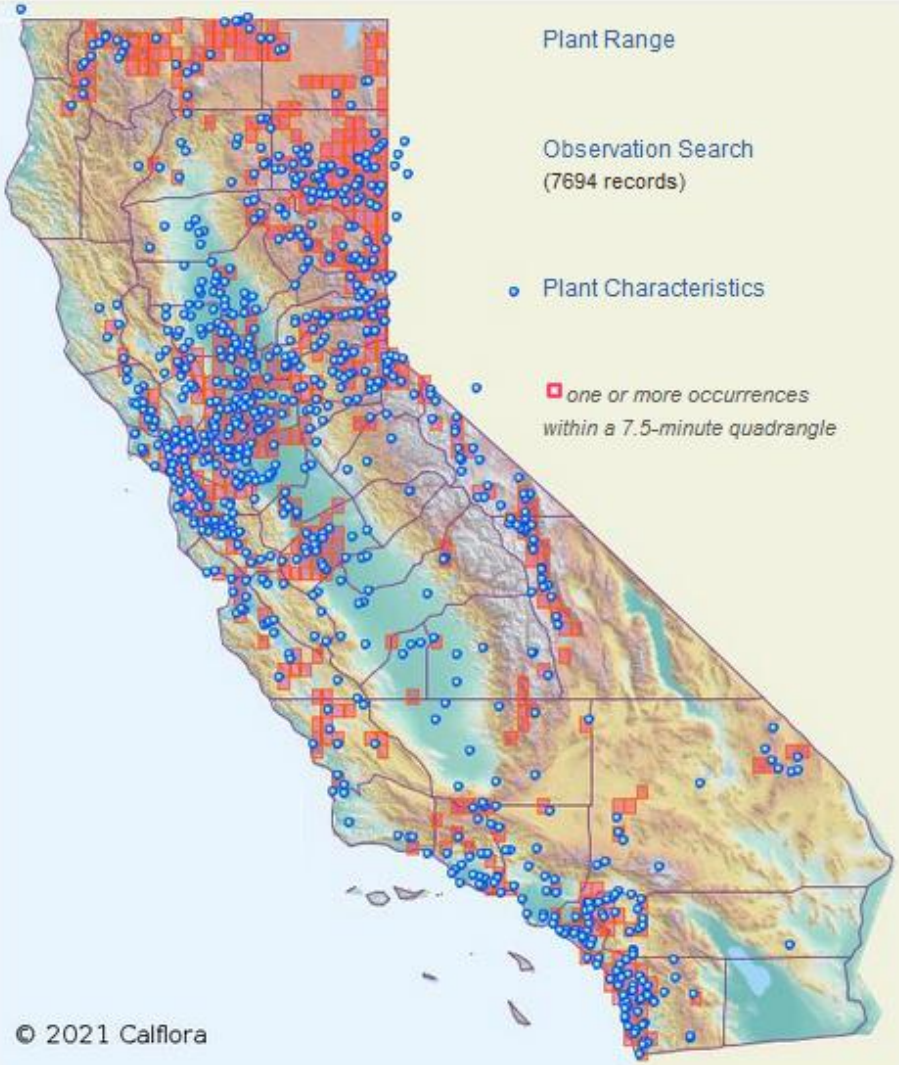
Perennial Pepperweed

Lepidium latifolium L.

Broad leaved pepper grass, Broadleaved pepperweed, Perennial pepperweed

Lepidium latifolium, a dicot, is a **perennial herb** that is **not native** to California.

Cal-IPC rating: High



Bloom Period

Photos from Calflora / CalPhotos

Family: Brassicaceae

Genus: Lepidium

© 2020 Joel A. Germond, Psy.D.

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photo size:

Name Status:

Accepted by JEF + PLANTS

Alternate Names:

PLANTS Cardaria latifolia

Wetlands: Equally likely to occur in wetlands and non wetlands

Habitat: disturbed

Communities: wetland-riparian, weed, characteristic of disturbed places

Perennial pepperweed (*Lepidium latifolium*)

- Introduced from Eurasia
- Erect noxious perennial up to 2 m tall
- white flowers and extensively creeping roots
- reports of horses becoming ill after being fed contaminated hay
- Wetlands, riparian areas, meadows, salt marshes, flood plains, beaches, roadsides, irrigation ditches, agronomic crops, especially alfalfa, orchards, vineyards, irrigated pastures, ornamental plantings.
- Typically grows on moist or seasonally wet sites. Tolerates saline and alkaline conditions.

Can rapidly form large, dense stands that displace desirable vegetation.

Populations easily spread along waterways and can infest entire stream corridors, riparian areas, or irrigation structures.

Flooded streams often wash away roots growing along the steambank, and new infestations develop downstream.

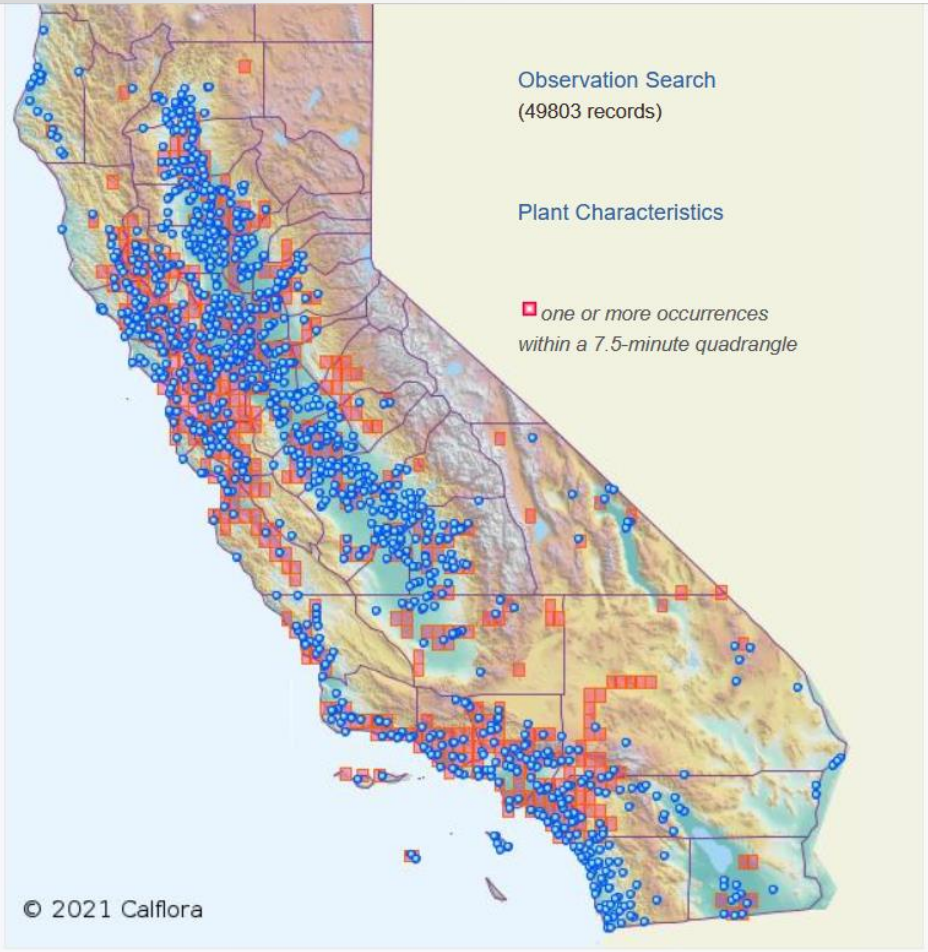
Once established, perennial pepperweed is persistent and difficult to control in crops, natural areas, and ornamental plantings.

Perennial pepperweed also reduces forage quality in hay or pasture.

Giant reed (*Arundo donax*)

- robust perennial grass 9 to 30 ft tall
- growing in many-stemmed, cane-like clumps, spreading from horizontal rootstocks below the soil, and often forming large colonies many meters across.
- Individual stems or culms are tough and hollow, divided by partitions at nodes like bamboo.
- can be confused with cultivated bamboos and corn, and in earlier stages with some large-stature grasses such as *Leymus* (ryegrass), and especially with *Phragmites* (common reed)


© Larry Allain



Name Status:
Accepted by JEF + PLANTS

Alternate Names:
PLANTS Arundo donax var. versicolor
PLANTS Arundo versicolor

Displaces native plants and associated wildlife species because of the massive stands it forms

reduces habitat and food supply, particularly insect populations

reduces habitat quality for aquatic wildlife

In the Sacramento-San Joaquin Delta region *Arundo donax* interferes with levee maintenance and wildlife habitat management

Dense growth presents fire hazards, often near urbanized areas, more than doubling the available fuel for wildfires and promoting post-fire regeneration of even greater quantities

Japanese dodder (*Cuscuta japonica*)

- An exotic, potentially invasive parasitic vine recently introduced to California.
- Broad host plant range, from annual herbaceous plants to woody trees and shrubs.
- Rapid growth: up to six inches per day!
- Reproduces vegetatively (through stem fragments) and by seed.
- Native to Asia.
- Probably introduced via Asian immigrants or visitors as an herbal remedy.

Cuscuta japonica Choisy
Japanese dodder

Cuscuta japonica, a dicot, is an **annual herb or vine (parasitic)** that is **not native** to California.

Plant Range

Observation Search
(86 records)

Plant Characteristics

Bloom Period

Photos from Calflora / CalPhotos

Family: Convolvulaceae
Genus: Cuscuta
Subspecies and Varieties:
... var. formosana

© 2009 Barry Rice

© 2009 Barry Rice

Name Status:
Accepted by PLANTS

More information about Cuscuta japonica

USDA PLANTS Profile (CUJA)
BONAP Distribution Map

International Plants Names Index
Search efloras.org (Flora of North America) / Google Images
Consortium of California Herbaria 2

Add an Observation
Location Suitability
Distribution by County

Japanese dodder

- is a very aggressive parasitic plant
- is an “A” rated noxious plant
- is under an eradication program
- Japanese dodder looks very similar to thick diameter spaghetti noodles that are bright yellow-orange
- It can completely engulf host plants and often drapes to the ground
- It can kill large portions or the entire host plant within two to three years after infestation
- Was found for the first time in California in the summer of 2004 in Redding

The Weed Wrench

Biological Control

Biological control is a challenging but effective method of controlling invasive species.

Grazing a tool to control cheatgrass

A University of Nevada, Reno study finds that grazing rangelands in the fall can drastically reduce cheatgrass that can fuel catastrophic wildfire.

The practice can prevent buildup that can fuel catastrophic wildfires.

Heather Smith Thomas | Sep 22, 2021

The little hammers of weed control

- Mechanical
- Cultural
- Physical
- Biological
- Chemical

ADAPTIVE STRATEGIES OF WEEDS

- Avoidance Strategy
  - Weeds mature quickly and produces seeds before the next disturbance event (annual plants).
  - Weeds subjected to mowing or grazing produce flat rosettes on the soil surface
- Tolerance Strategy
  - Weeds store buds and carbohydrates out of reach of disturbance.
- Resistance Strategy

Picture:
Dr. Matthew Fidelibus