Weed Seed Biology

Scott Steinmaus, PhD
Professor
Biological Sciences

Salinas Weed School
November 8, 2011

CAL POLY

Ideal weed characteristics

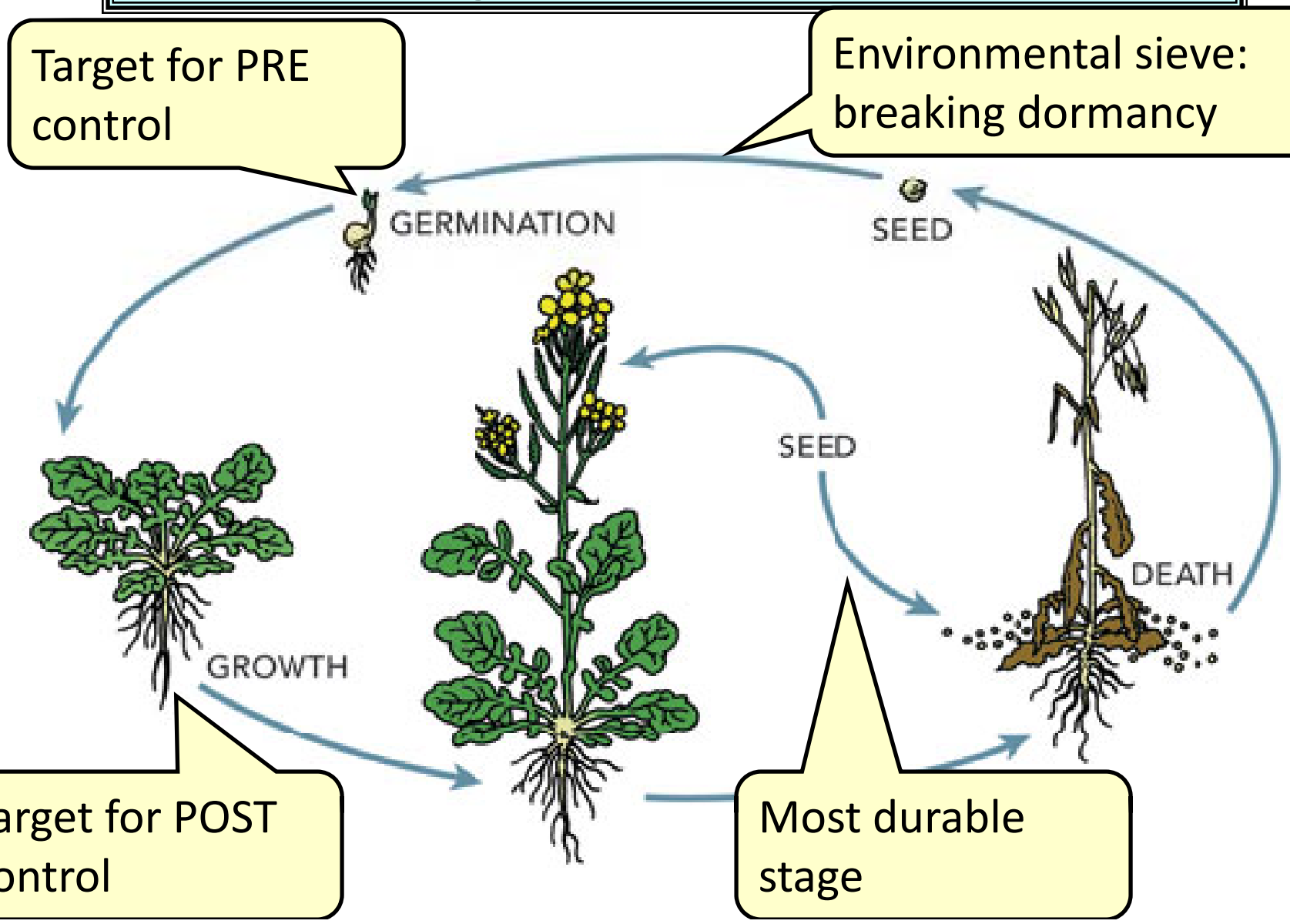
- **Non specialized germination**
- **Seed dormancy**
- **Fast reproduction**
- **Long seed production interval**
- **High seed production**
- **Continuous seed production**
- **Seed dispersal**

- Vigorous perennial
- Brittle perennial
- Vegetative reproduction
- Able to compete with other plants
- Rapid seedling growth
- No special pollinators

Left column are all related to seeds

Baker 1974

Annual plant life cycle:
Strengths? Weaknesses?



Weed seedbanks

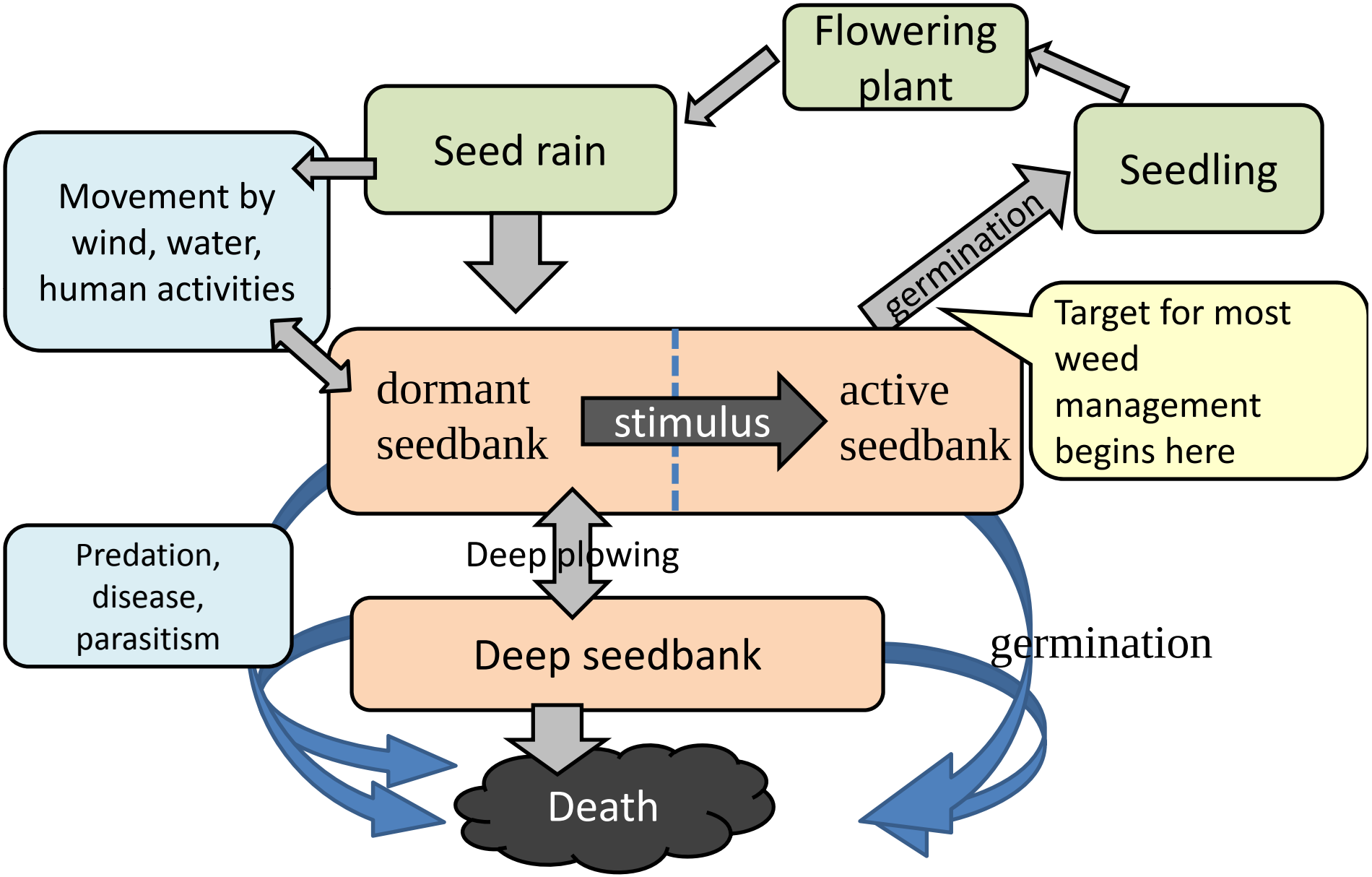
Weed seeds in soil produced during previous growing seasons

Importance of weed seedbanks

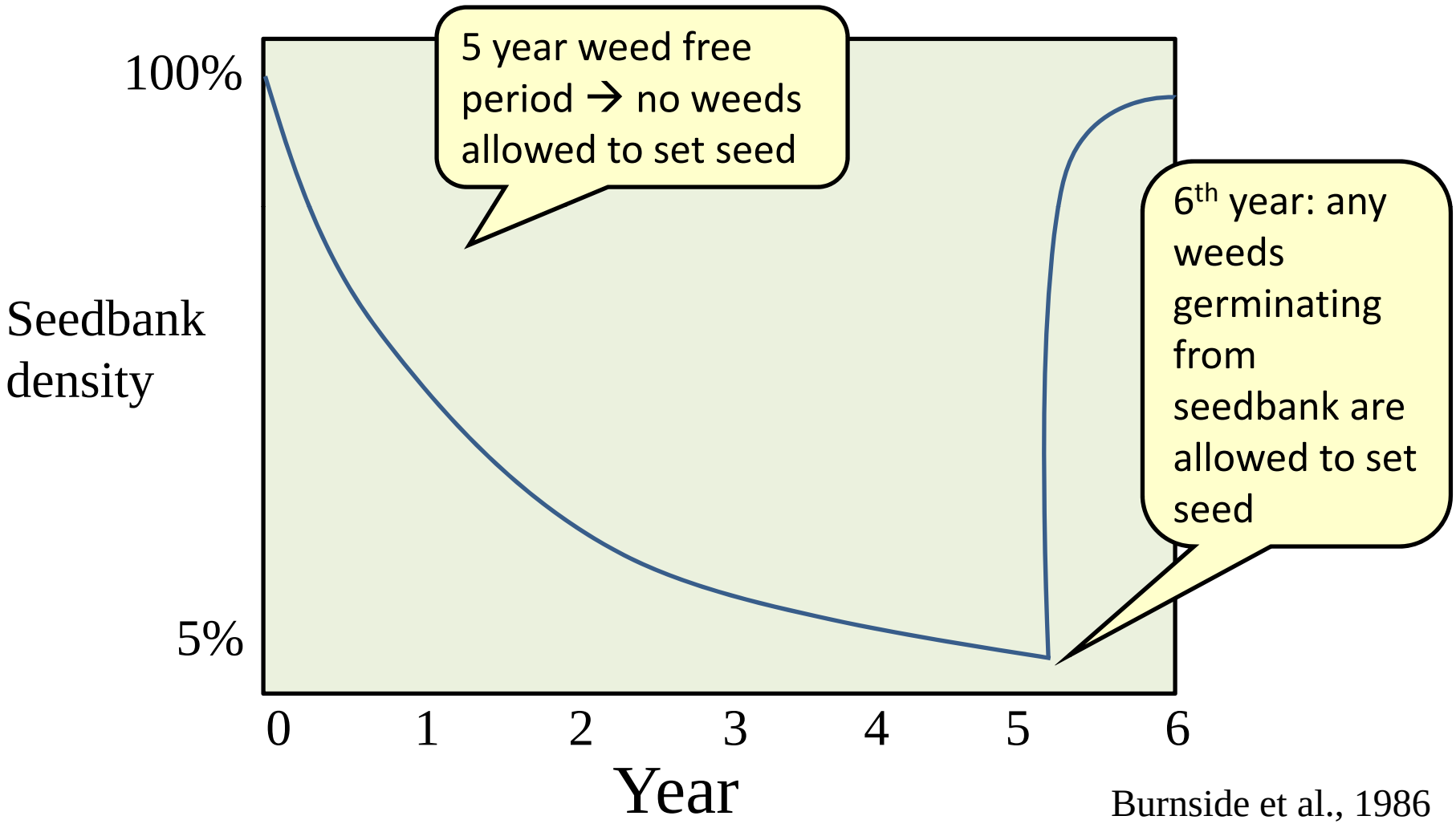
- Heavily infested weed seedbanks = heavy weed pressure = high weed control costs = high cost of production.
- Once seedbanks are established, it requires huge effort (and cost) to reduce.
- Weed seedbanks represent a “memory” of past management practices

Seedbank = memory and momentum

The Weed Seedbank: it's in the soil



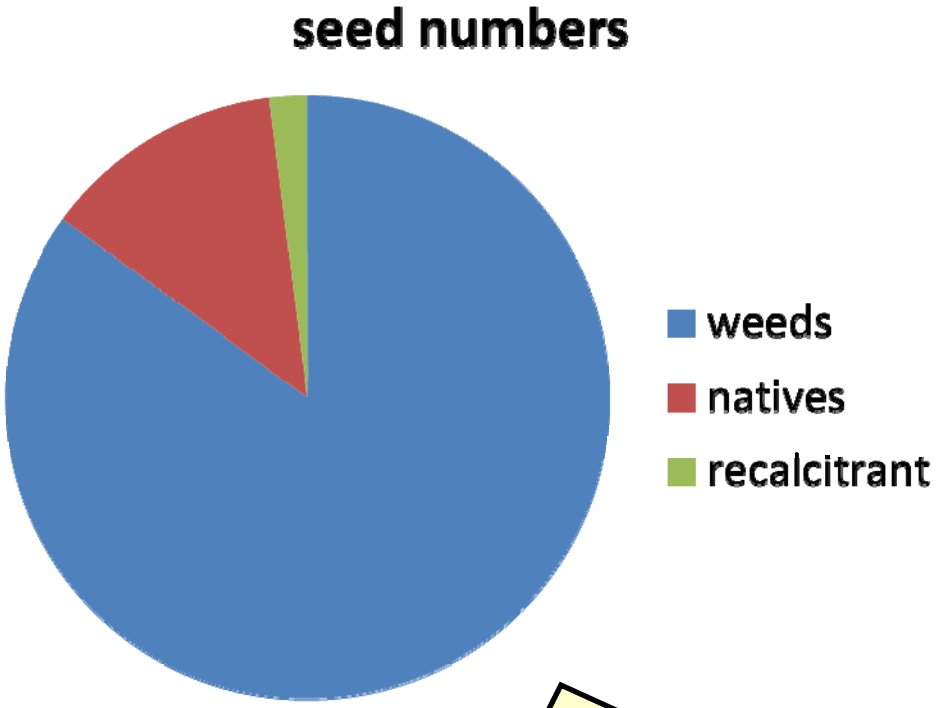
Seedbank Dynamics



Burnside et al., 1986

Seedbank composition

- weeds (3-6 species) tolerant of management system
- natives (>20 species) adapted to geographic region
- recalcitrant (3-10 species) from previous seedbank, newly introduced species, or volunteers



GOOD NEWS: not many species of weeds to worry about
BAD NEWS: they're really nasty

Weed seedbanks in California fields

- In the Sacramento Valley, seedbank densities ranged from 7.9 to 60.9 million seeds /A. (Battista 1998).
- In the Salinas Valley, seedbank densities ranged from 6.3 to 140.2 million seeds /A. (Fennimore, unpublished results).

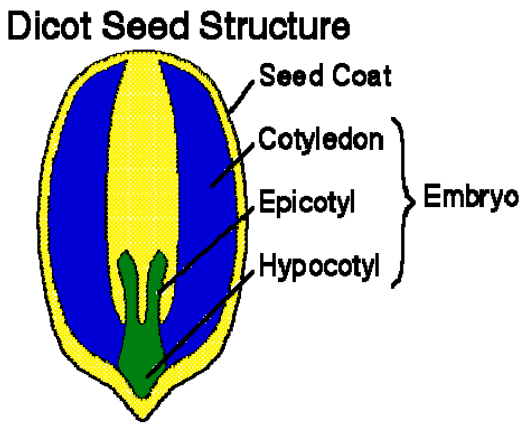
Weed seed dormancy

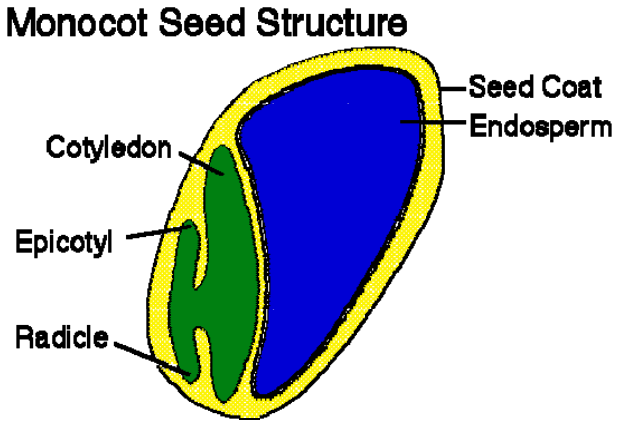
The inability of seeds to germinate due to factors associated with:

1. the embryo
2. seed coat
3. environment

A pappus aids with dispersal in space

Dormancy insures dispersal in time





Seed dormancy

I° dormant seed
INNATE

seed
formation

light
temperature
after ripening

II° dormant
seed
INDUCED

non-dormant
seed
ENFORCED

high temperature
anoxia

water
temperature

1.) Innate: seed is produced with innate dormancy

Chemical inhibitors in the fruit that prevent germination until these compounds breakdown or leach away

Doesn't make any sense to germinate inside a fruit, does it?

little mallow (*Malva parviflora*)

→need a stimulus that indicates the seed is in the soil and the proper environmental conditions are met such as:

Breaking innate dormancy:

- **Light:** indication that seed is outside fruit
- **stratification:** cold period passes → indication that winter has passed
- **Photoperiod:**indication of proper seasonality
- **Just being free of the fruit**: inhibiting compounds from fruit gone
- **Embryo matures:** inhibition signals from immature embryo ceases

2.) Induced : the condition that a seed doesn't germinate FOLLOWING the breaking of innate dormancy by conditions such as high temperatures or excessive moisture--also called ***secondary dormancy***.

a hostile condition will send seed into induced (secondary) dormancy

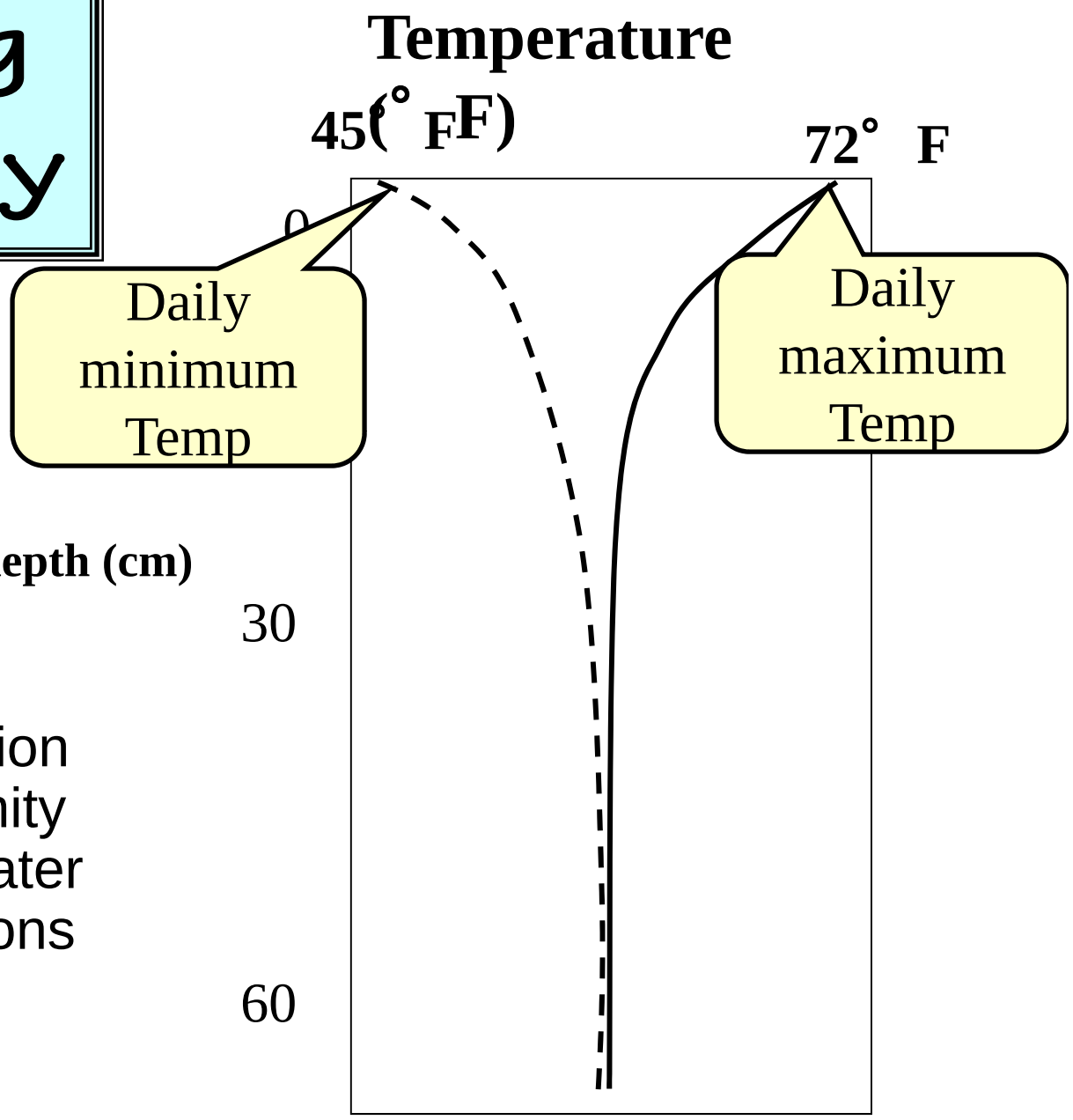
3.) **Enforced**: germination is prevented by absence of external environmental factors needed for germination (if absent too long → secondary dormancy).

Water, light and O_2 need to be at the proper levels. Seeds need >14% moisture to germinate.

Factors that break dormancy:

- **scarification:** indication that tillage has occurred so no competing vegetation and allows water to penetrate seedcoat

Breaking dormancy



fluctuating temperature: indication of season and proximity to soil surface → greater temperature fluctuations occur at soil surface

Depth of weed emergence

Species	Optimum depth (in)	Maximum depth (in)
Cm. chickweed	0.4	0.8
Lambsquarters	0.2	2.0
Lg. crabgrass	0.4	1.6
Shepherd's-purse	0.2	0.8
Wild mustard	0.4	2.3
Wild oat	1.0	7.0

Germination: environmental requirements

- water: imbibation is first requirement ~14%
- oxygen: respiration→growth
- temperature: optimal temperature for germination coincides with native climate
- nutrients: usually not, why not?
- light: small-seeded species stimulated, light can inhibit germination for large seeded species, why?

Germination of species such as redroot pigweed (*Amaranthus retroflexus)* may increase in response to added fertilizers (P)

Seed longevity

1.) physical and chemical make up of seed coat

2.) palatability of seed/seedcoat to microorganisms and predators→defensive chemicals/strictures carry a biological cost

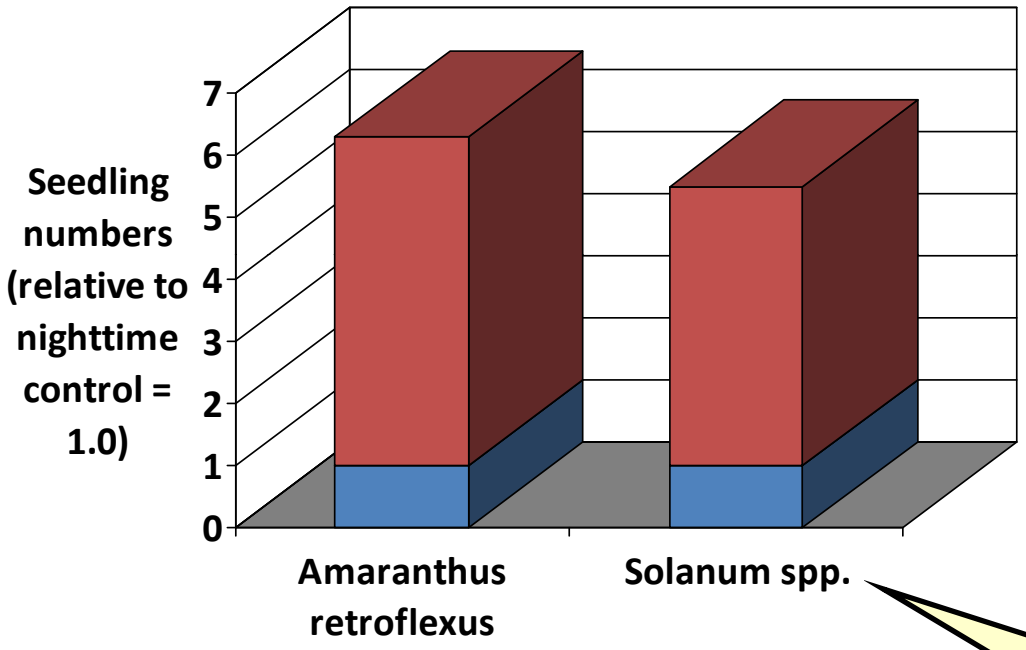
3.) inherent metabolic rate of seed (e.g. respiration needed to maintain membranes and cells)

The benefit of longevity cannot be realized without dormancy:

Seed Longevities

Species	Common name	Longevity (years)	Decay rate
Chenopodium album	Common lambsquarters	1700	0.105
Polgonum aviculare	Prostrate knotweed	400	0.156
Poa annua	Annual bluegrass	68	0.237
Capsella bursa-pastoris	Shepherdspurse	35	0.244
Stellaria media	Chickweed	600	0.252
Medicago lupulina	Balck medic	26	0.340
Senecio vulgaris	Common groundsel	1700	0.340
Abutilon theophrasti	Velvetleaf	50+	
Spergula arvensis	Corn spurry	1700	0.340

Night tillage vs. day tillage



VLF Response: Very Low Fluence response: certain species become very sensitive to a flash of light after being buried for a long period. Response tied to phytochrome pigment system.

Numbers > 1 indicate more weed seedlings for plots tilled during day

Weed Seed Production

Weed species	No. seed/plant
C. lambsquarters	72,450
C. purslane	52,300
C. ragweed	3,380
P. smartweed	19,300
Prickly lettuce	27,900
RR pigweed	117,400
Shepherdspurse	38,500
Wild oat	250
Yellow foxtail	6,420

Bottomline: weeds produce more than what is needed to replace parent plant even after high seed mortality

Stevens 1954, 1957

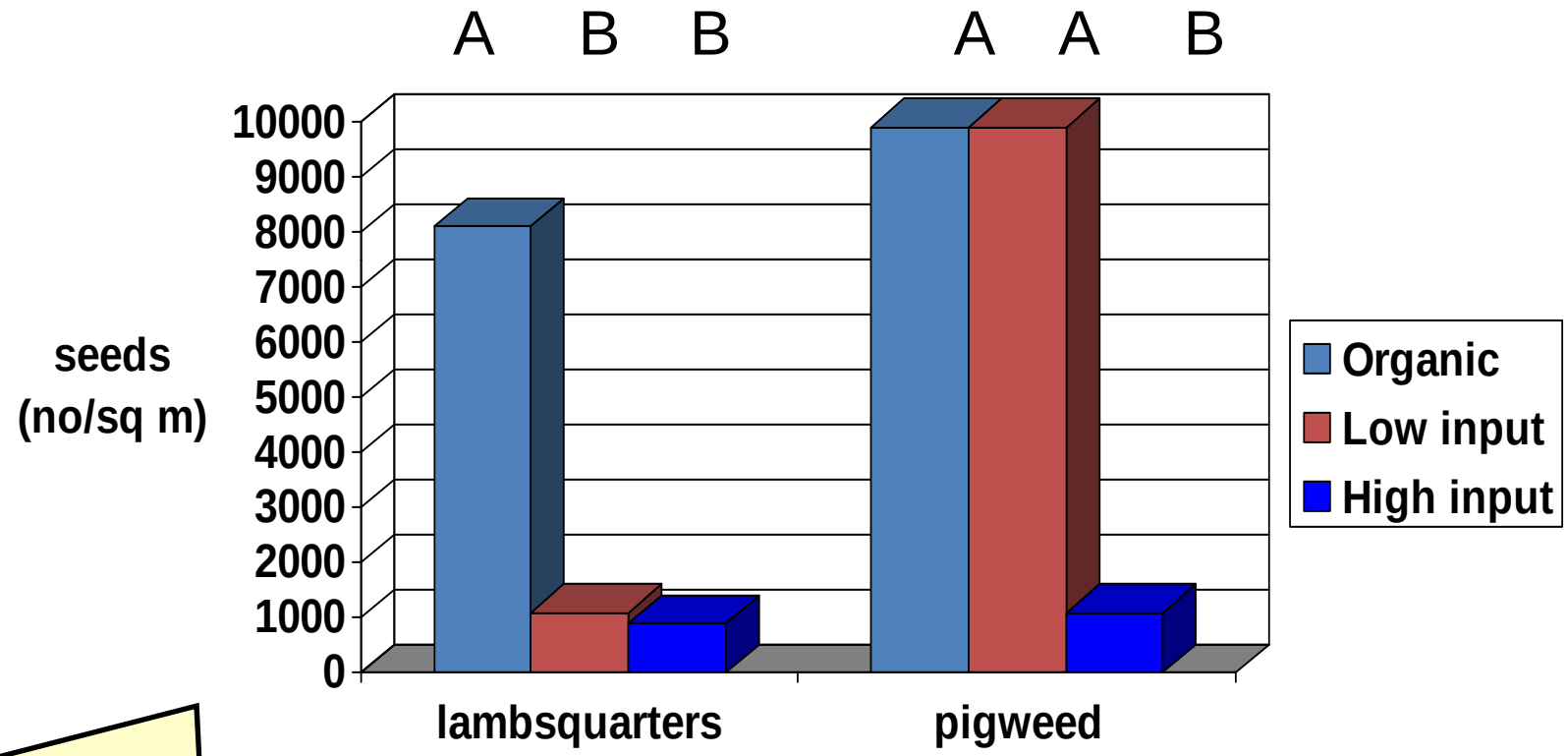
Seed production

- At UCD Norris grew BYG plants that produced >1,000,000 seed and the previous highest reported number was about an order of magnitude less.
- Steinmaus grew a velvetleaf plant that produced >100,000 seed and the previous highest reported was 17,000

We can grow weeds in CA better than anybody else!

Steinmaus and Norris 2002

Management impacts on seedbanks



High input systems use herbicides to control weeds… they're pretty effective on most weed species!

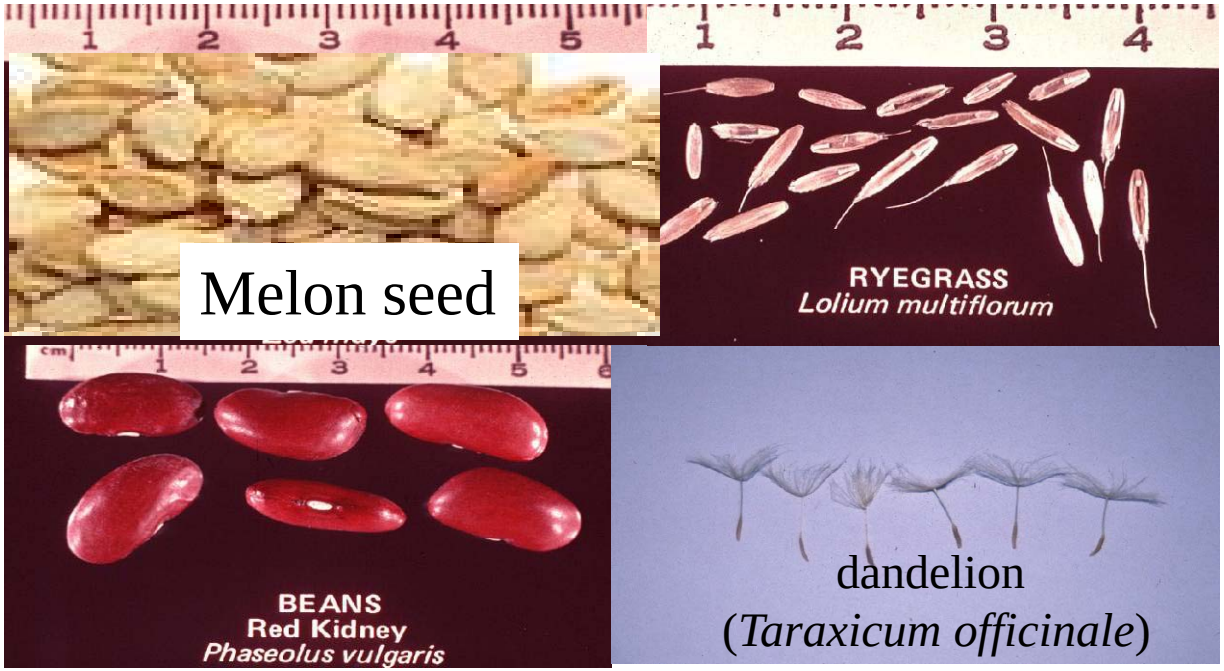
Battista 1998

Management effects on seedbanks

1. Tillage impact on seedbank is through its affect on burial and germination.

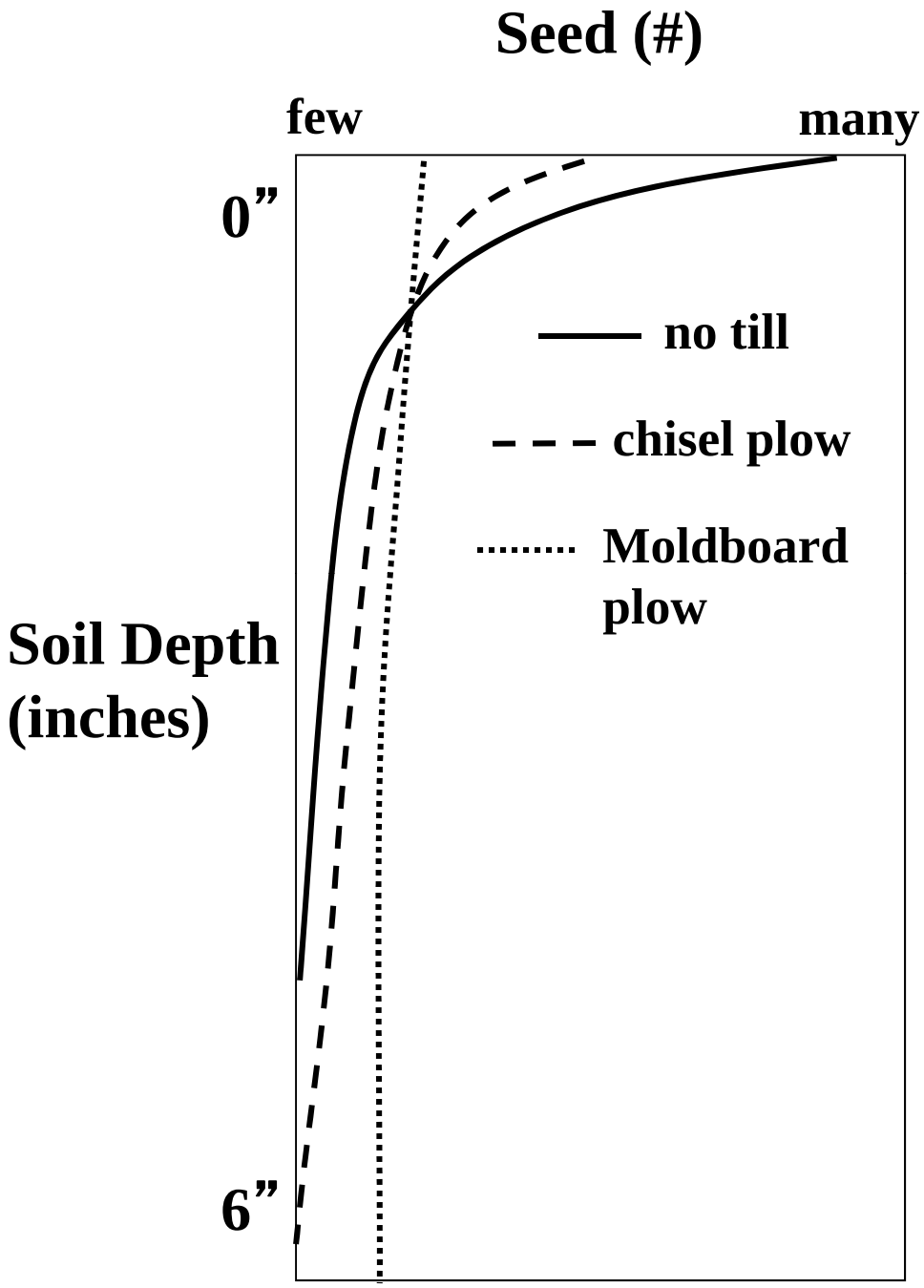
- moldboard plow systems: seedbank is down to plow depth=20cm (8”)
- no till systems: not plowed (e.g. pasture), most weed seeds <10cm (4”).
- small seeded species killed by burial
- large seeded species favored in continuous plowing (long-lived species with VLF response)

Tillage effects:
seed sizes for crop vs. weed



- small seeded species controlled → most weed seeds are relatively small
- *Asteraceae* and *Poaceae* species tend to be small (wind dispersed)

Seed distribution with different soil management methods



Management effects on seedbanks

2.) **Cover:** seed on soil surface is drastically reduced by rodents and birds→ over 99% of barnyardgrass, lambsquarters,pigweed seed eaten by field mice under alfalfa cover.

as cover goes up, predation goes up

Cover favors seed-eaters

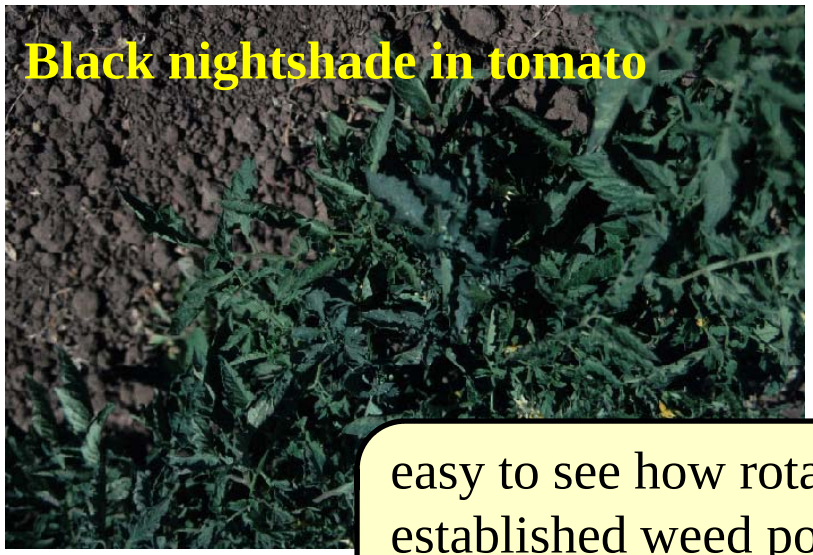
Management effects on seedbanks

3.) Crop rotation effects seedbank species composition and abundance

→different cropping systems favor different weed species

rotational effect >tillage effect

Weed-Crop associations:



easy to see how rotation could affect established weed populations but can you rotate to a sufficiently different crop easily??

Dispersal

- **dormancy represents dispersal in TIME**
- **we will now talk about dispersal in SPACE.**

- LOCAL dispersal→due to adaptive species characteristics (e.g. cocklebur like velcro)
- GLOBAL dispersal→primarily due to human activity

Human related dispersal

Cultivation equipment: will spread seeds locally both horizontally and vertically in the soil profile.

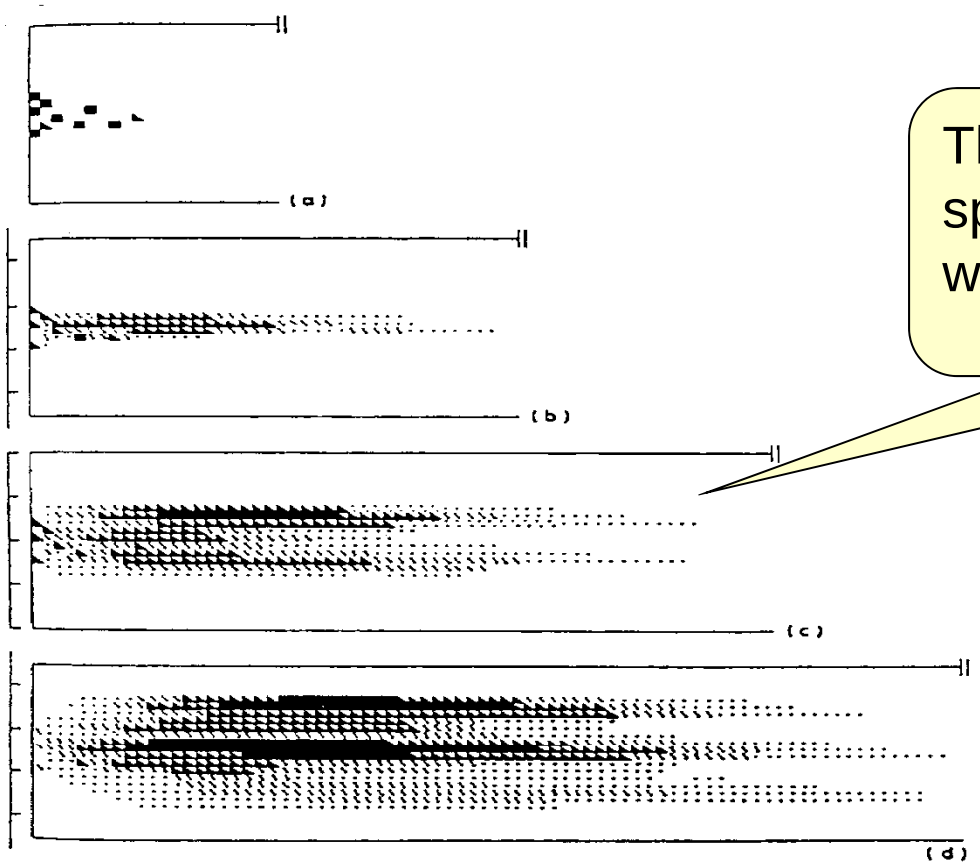
Horizontal dispersal
(disk plow)

Vertical dispersal
(moldboard plow)

Soil stuck to cultivation equipment can spread seeds. They also break up vegetative propagules of perennials

Human related dispersal

Harvest equipment Harvesters select for weed species that have the same size and weight as crop species.



The "perfect" seed spreaders for late maturing weeds?

Human related dispersal

Inadvertent transport: puncturevine (goatheads) on tires, trucks/tractors leaving a field can carry mud/dirt that has weed seed.

Puncturevine stuck to tires

Species dispersal characteristics

WIND:

- pappus on Asteraceae species: sowthistle, dandelion, horseweed
- tumbleweed: Salsola spp., and tumble pigweed

Russian thistle, *Salsola* spp

Species dispersal characteristics

WATER:

→corky structure that enables seed to float--floating seed will go furthest compared with submersed seed, the "cheesewheel" seed cluster of *Malva* is corky.

→air filled bladders--docks (*Rumex* spp.)

→surface tension (can be viewed as the 'skin' on the water surface

Seed dispersal by water

Weed species	No. seed /A ft^{-1} water
Barnyardgrass	354
Curly dock	29
Foxtail, yellow	24
Lambsquarters	1490
Lettuce, prickly	83
Mustard, tumble	316
Redroot pigweed	320

Kelley & Bruns 1975

Species dispersal characteristics

ANIMALS:

→barbs, hooks, bristles, spines catch on fur, hair make animals unwitting carriers---foxtail, brome, burclover, puncturevine, cocklebur

→sticky substances: mistletoe

→ability to survive digestive tracts of birds or cattle→ a small %age will survive

This is why animals need to be quarantined so that their digestive tracts are cleared before being allowed into new pastures.

Dispersal in manure

- **UC researchers in the San Joaquin Valley monitored dairy manure samples for the presence of weed seeds.**
  - **They found 4,170 to 21,800 weed seed per ton**
  - **At 10 ton /acre this adds 41,700 to 218,000 weed seed /acre**

Cudney et al. 1992

Summary (part 1)

- Seeds are the ‘strength’ of annual weed species
- Once a seedbank is established it represents a ‘memory’ and a ‘momentum’ that is very difficult to alter
- Dormancy and longevity are the characteristics that contribute most to unpredictability and problems
- Perform practices that contribute to breaking dormancy to bring weed seeds out of seedbank (germination)

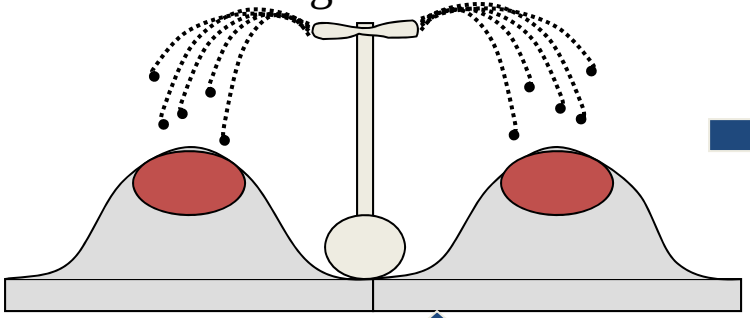
Common purslane (*Portulaca oleracea*)

Summary (part 2)

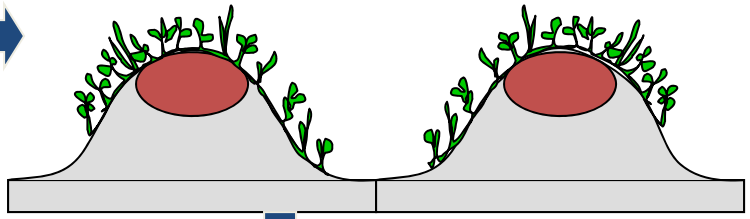
- Crop rotation minimizes the opportunity for one species to dominate a field
- Plowing results in more even weed seed distribution in the soil profile
- Preirrigation, shallow tillage, and planting into moisture can be used to deplete the weed seedbank
- If weed seeds are allowed to be produced they are dispersed in many ways → prevent human associated dispersal
- All this points to one conclusion: it is best to prevent weed seed production in the first place

Pre-irrigation/cultivation cycle: purge weed seedbank

1. Irrigate listed beds

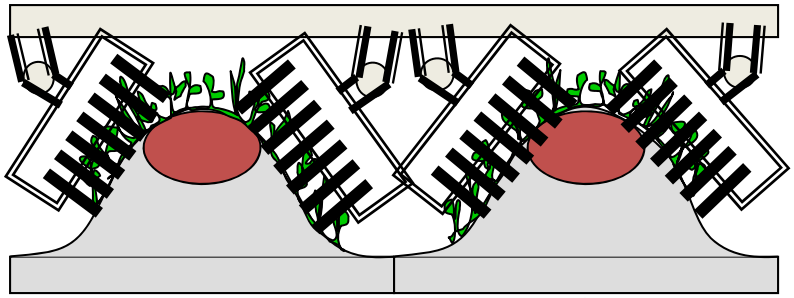


2. Allow weeds to reach 2-4 leaf stage



Repeat up to 3 times

3. Cultivate with rotary cultivator or postemergent herbicide



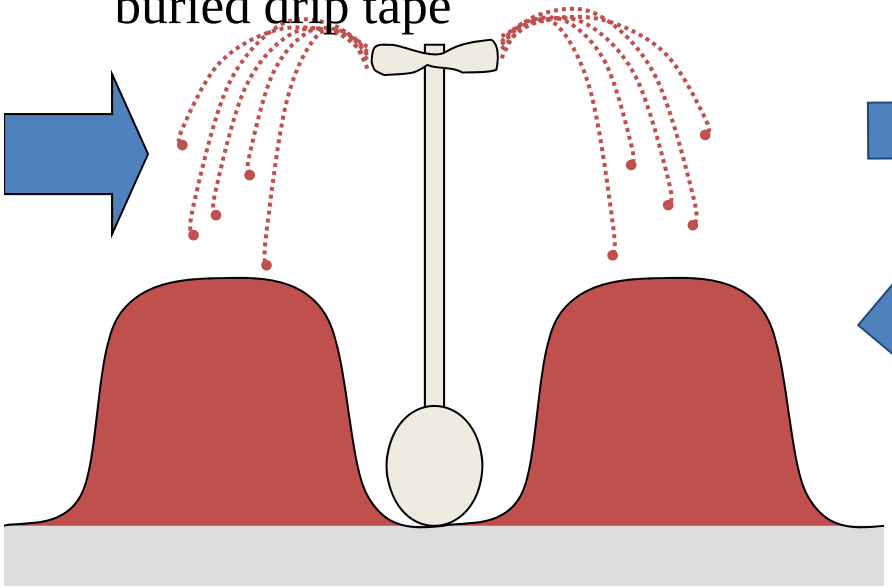
On last cycle

Sweeps (on bed tops) and shovels (in furrows) not shown

Final seedbed formed on last cultivation

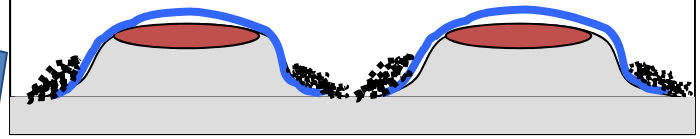
This is beginning of process of planting into moisture:

Irrigate to field capacity or buried drip tape



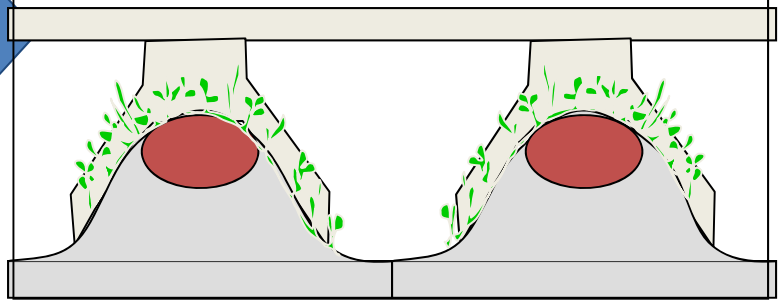
or

Lay out 3 mil solarizing plastic 2-3 weeks



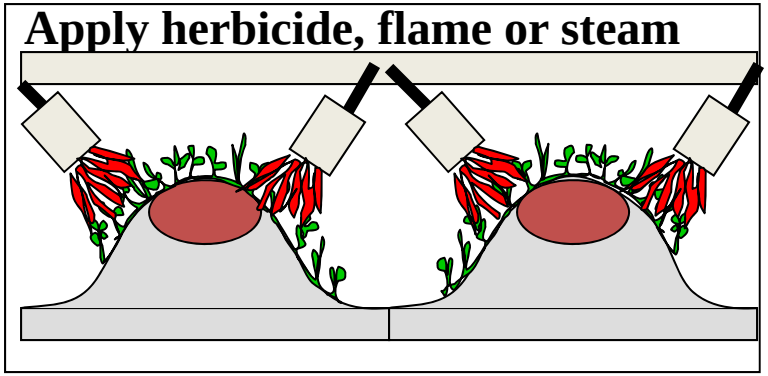
or

Shallow cultivate with bedshaper



or

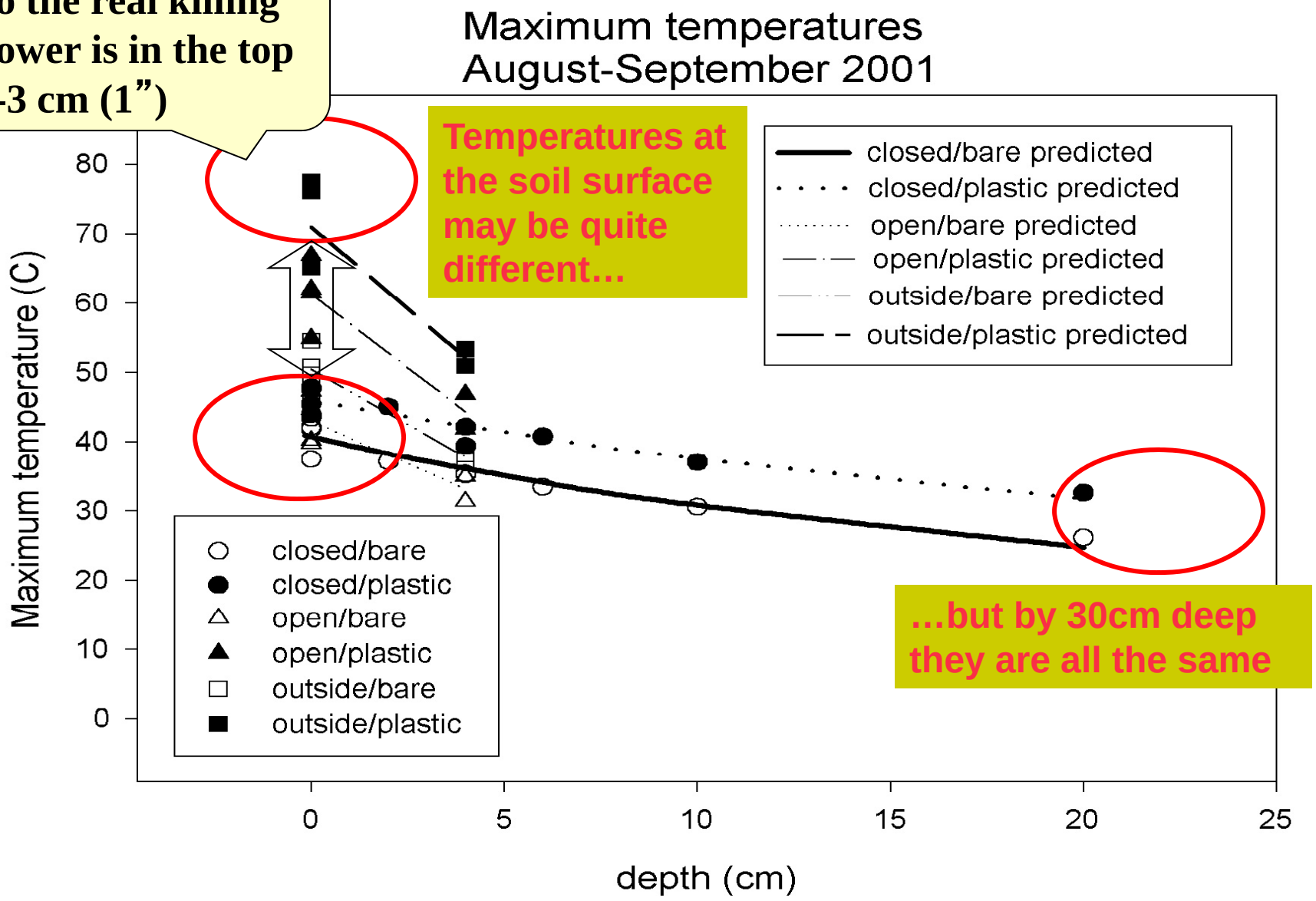
Apply herbicide, flame or steam



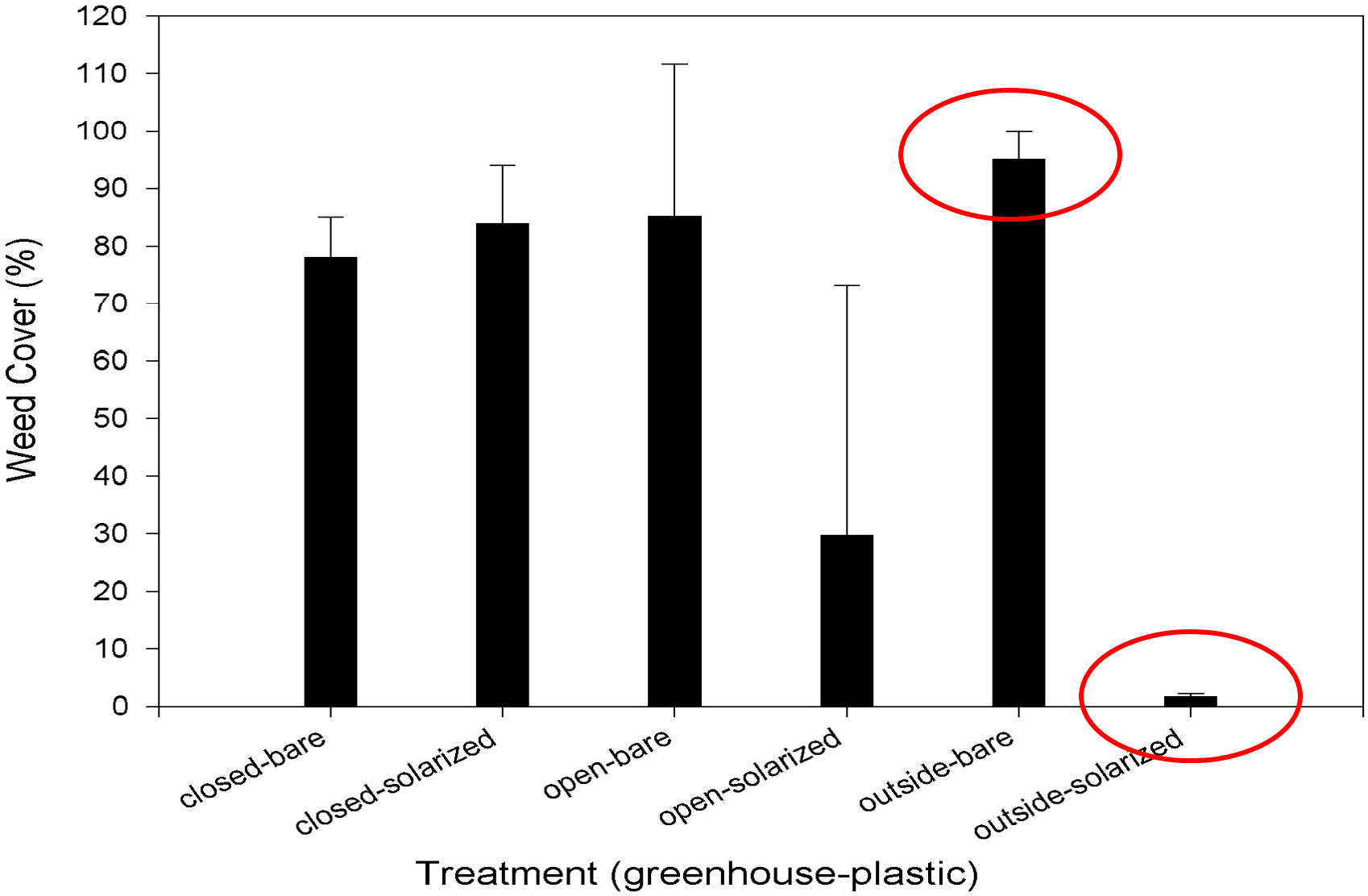
Solarization

Temperature penetration into soil

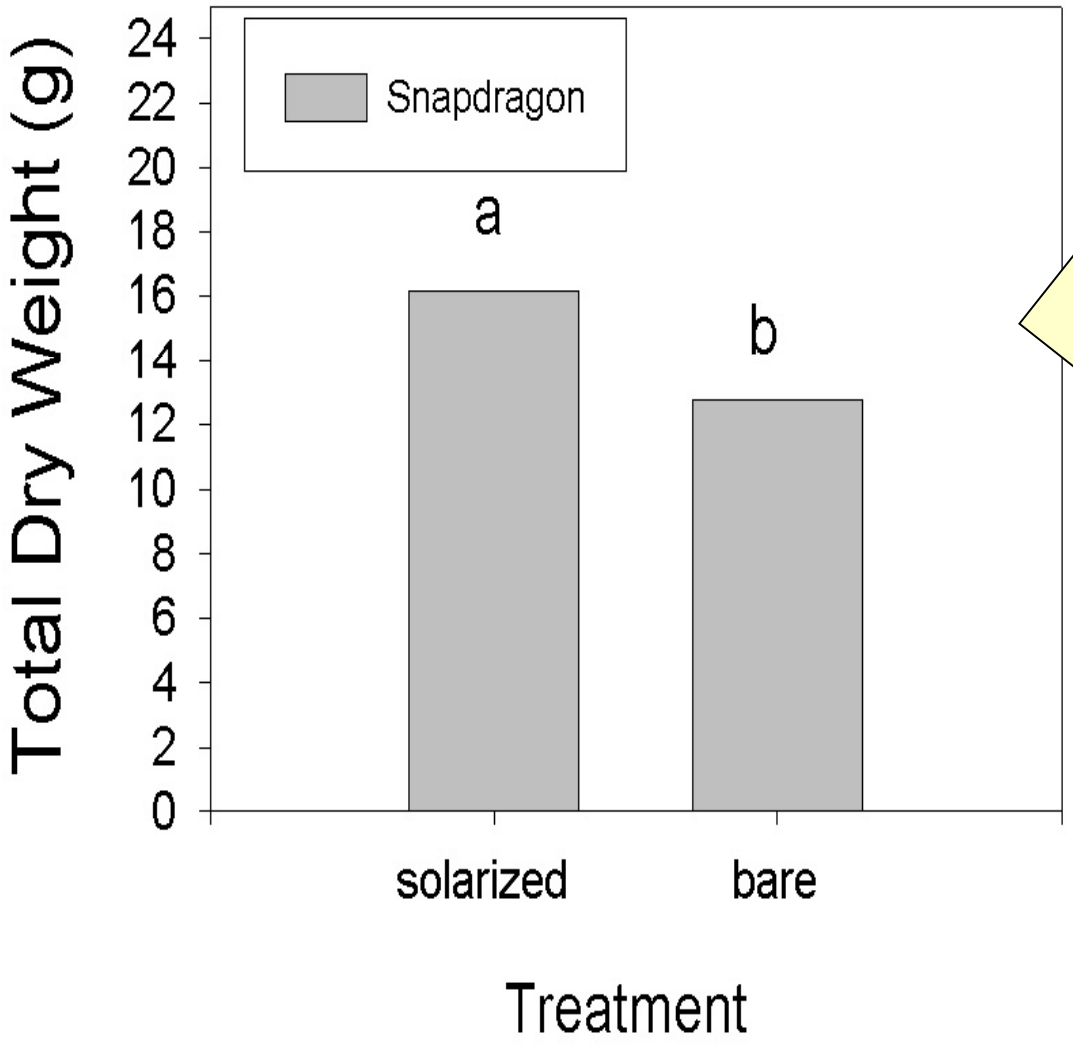
So the real killing power is in the top 2-3 cm (1”)



Weed control with Solarization



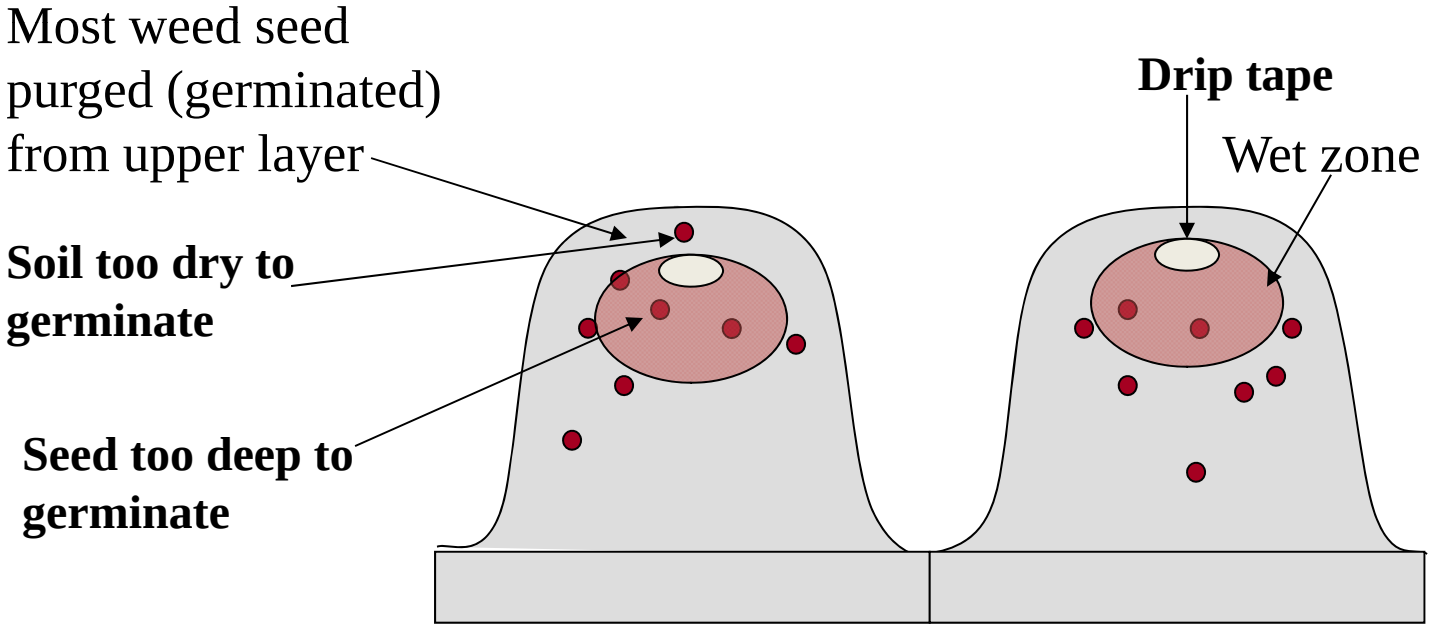
Enhanced growth with solarization



Plants grown in previously solarized soils tend to grow better but we don't know exactly why.

Putting moisture only where the crop will be…buried drip tape

On last cultivation, bury drip tape just above crop root zone

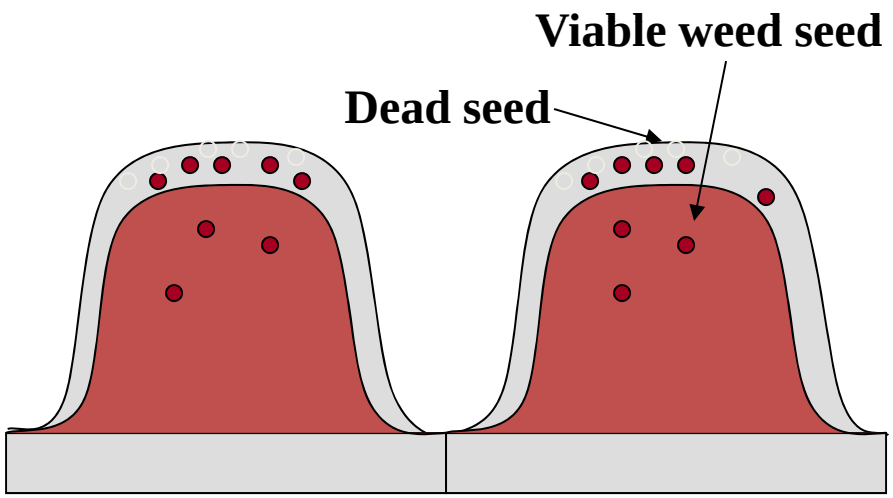


Buried drip tape is another way to establish a wet zone below dry “mulch” layer

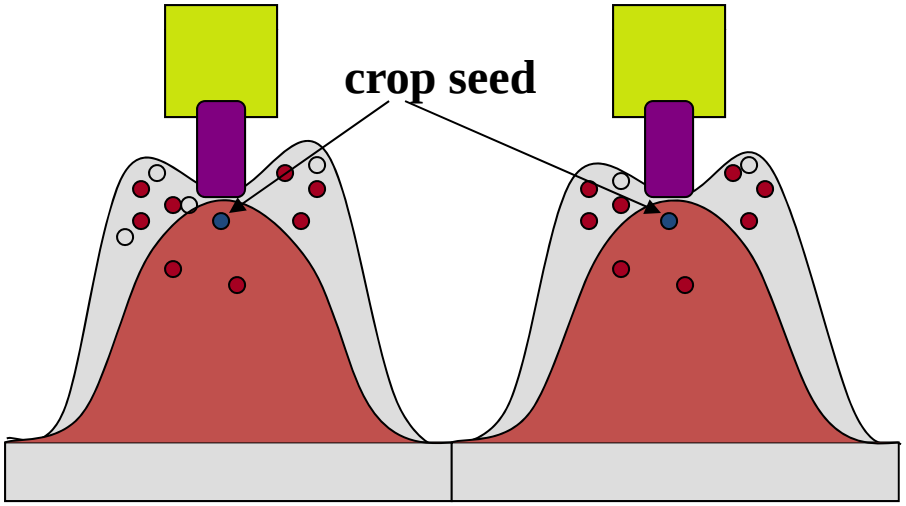
Planting into moisture: establishing a "dry mulch layer"

After removing plastic, rotivating, or herbicide/flaming on last irrigation:

Allow surface layers to dry without disturbing



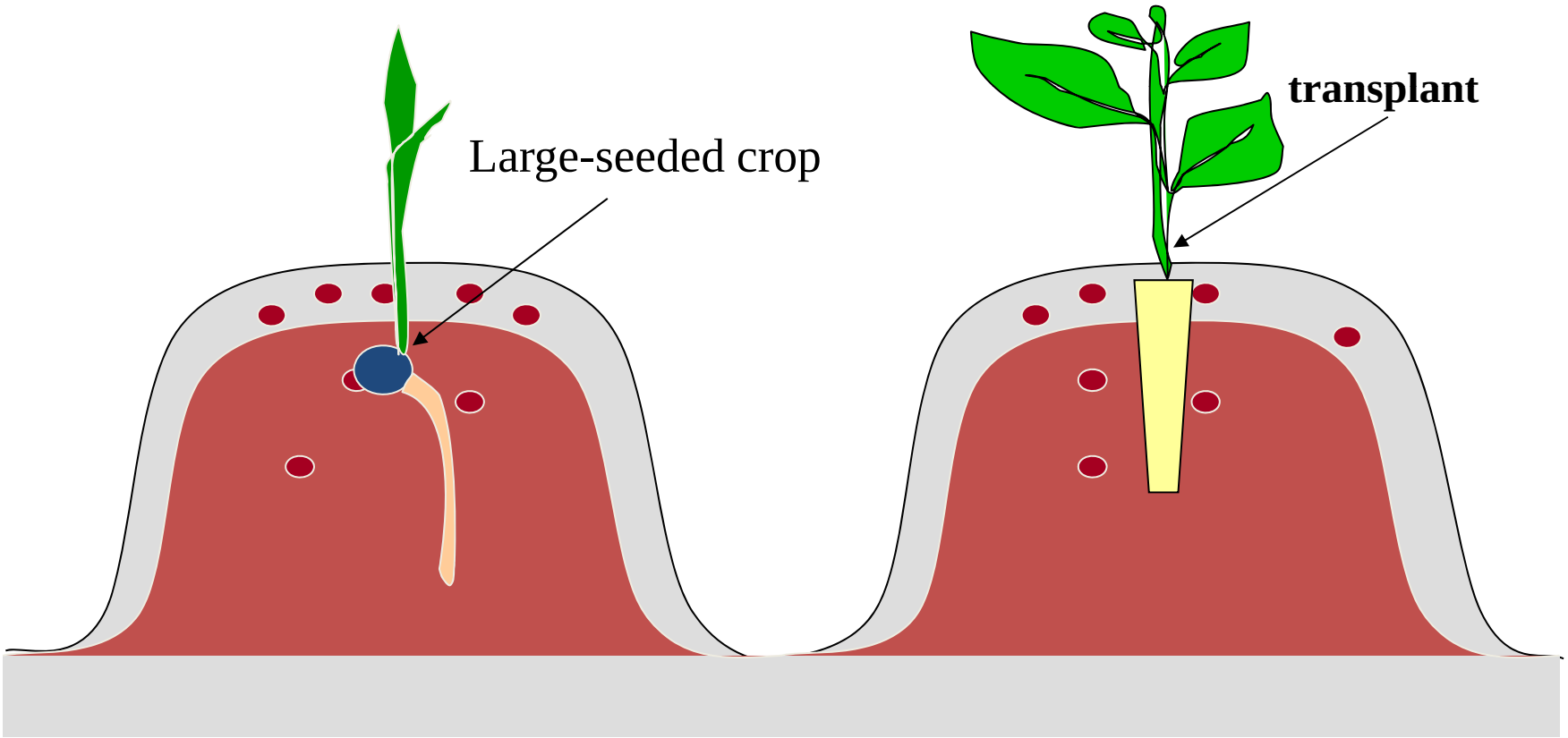
Bed tops are split and crop seeds planted into underlying moisture



Dry "dirt mulch" on surface 1-2". Weeds seeds will usually not germinate from below 1-2" and will not germinate in dry soil

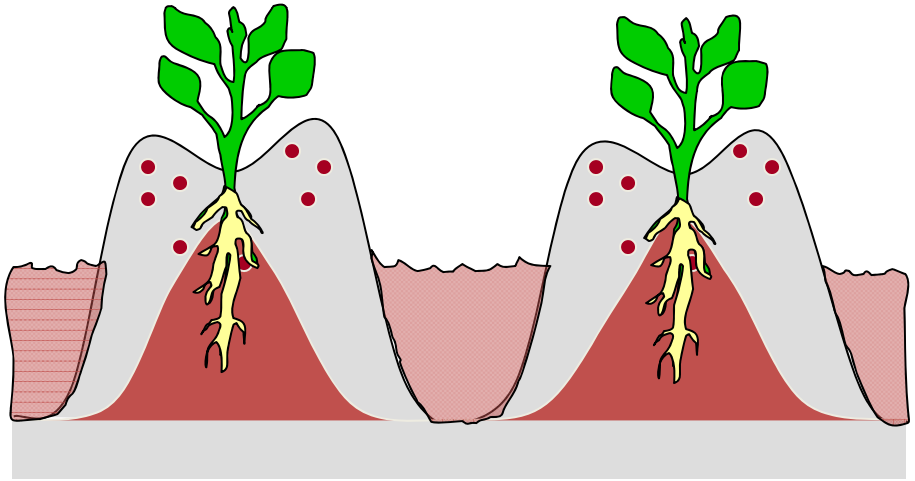
Giving the crop a head start by taking advantage of its initial size

Instead of splitting the bed top, large-seeded crops (e.g.corn, bean, squash) or transplants could be planted deep into the bed.

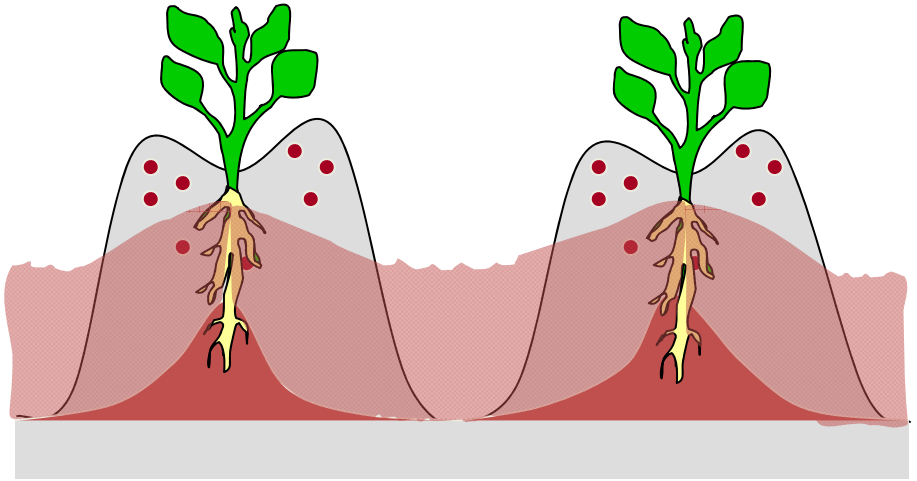


Planting into moisture

Hold off on irrigation until crop plants need it. Crop roots follow moisture downward.

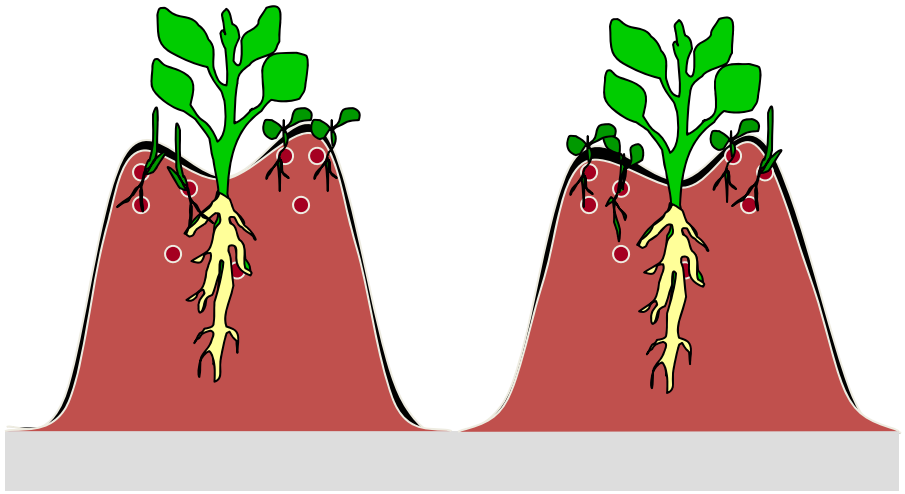


Furrow irrigation will soak across bed from below---leaving weed seeds in dry "mulch"

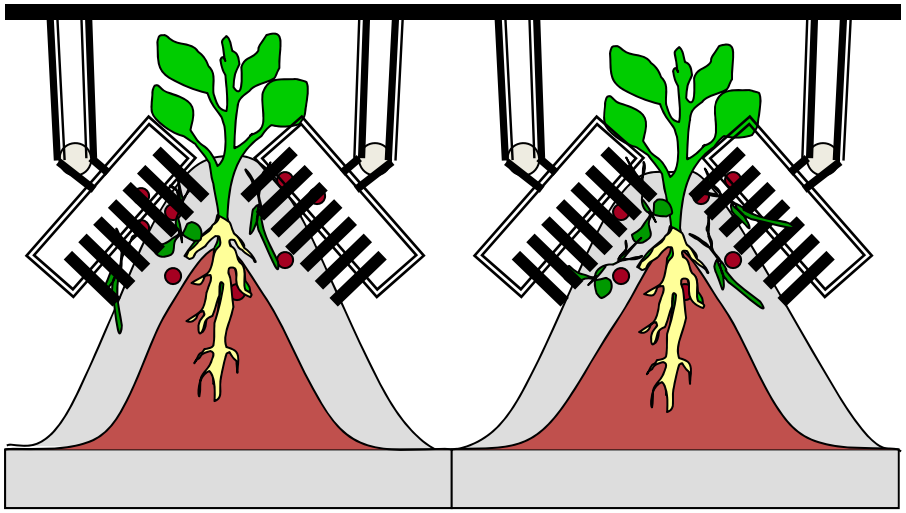


Changing Bed Height to Eliminate Weeds

Eventually weeds may germinate because surface will get wet—most weed seed should be dead (or germinated) if soil is not disturbed from last pre-irrigation



When they do, allow beds to dry then use the rotary cultivator to dislodge and bury them by piling soil up against the established crop stem



The next cultivation occurs only when new weed seedlings pop up → then it should tear down the bed