Herbicide Resistance
and Kochia

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What is Herbicide Resistance?

Herbicide Tolerance :

The inherent ability of a species to survive and reproduce after herbicide treatment.

Herbicide Resistance :

The ability of a plant to survive and reproduce following exposure to a dose of herbicide normally deadly to the wild type.

Target Enzyme system

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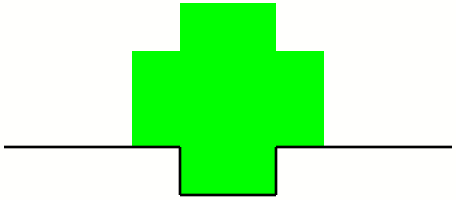
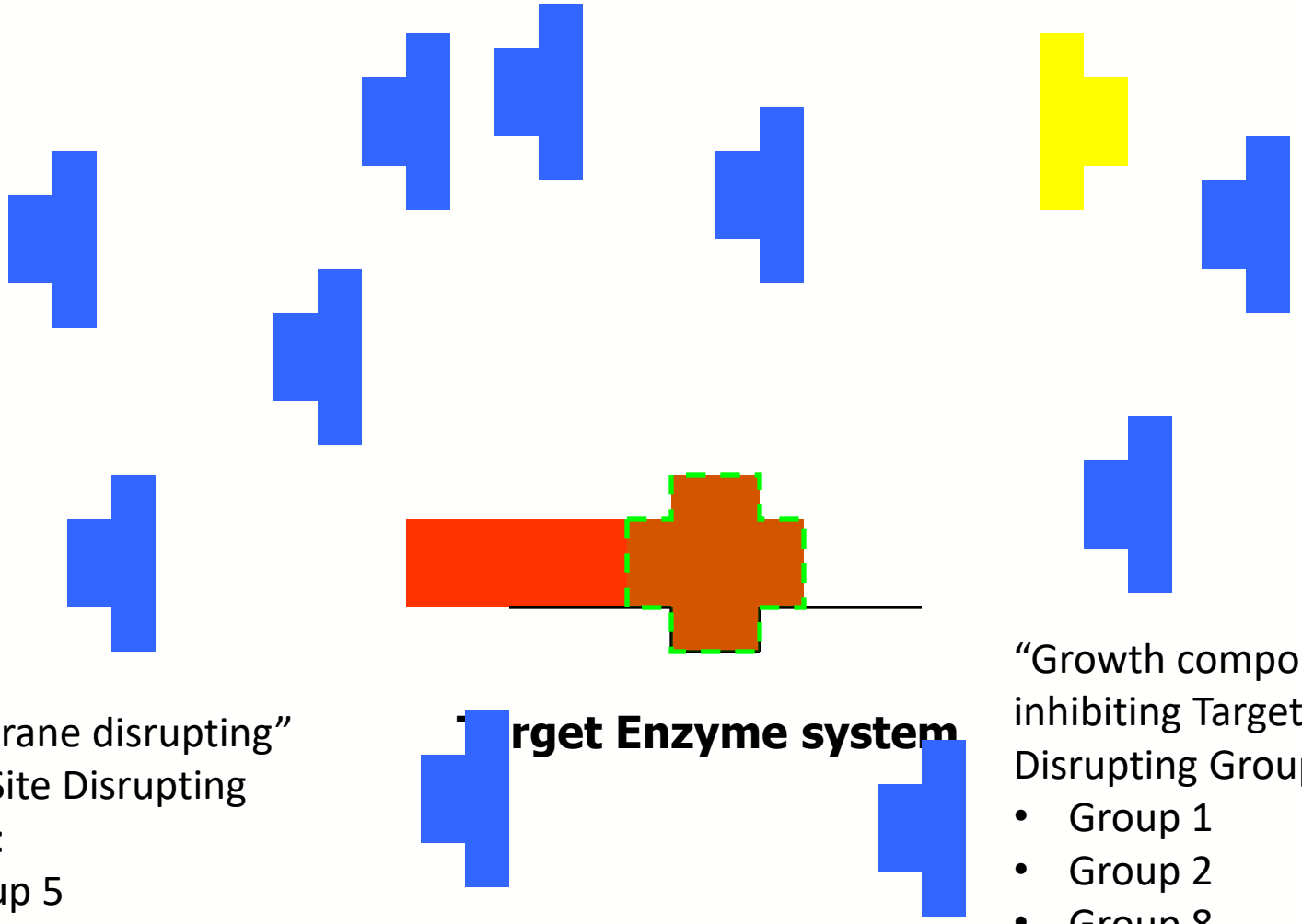


Target Enzyme system



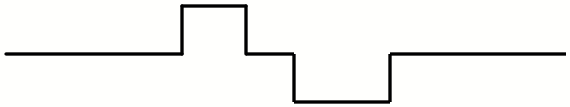
"Membrane disrupting" Target Site Disrupting Groups:

- Group 5
- Group 6
- Group 7
- Group 10*
- Group 14
- Group 22

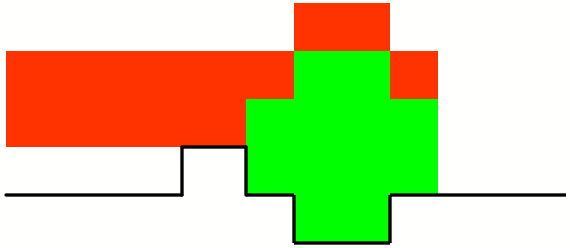
"Growth component" inhibiting Target Site Disrupting Groups:

- Group 1
- Group 2
- Group 8
- Group 9
- Group 10*
- Group 13
- Group 15
- Group 28

HR Enzyme system



HR Enzyme system



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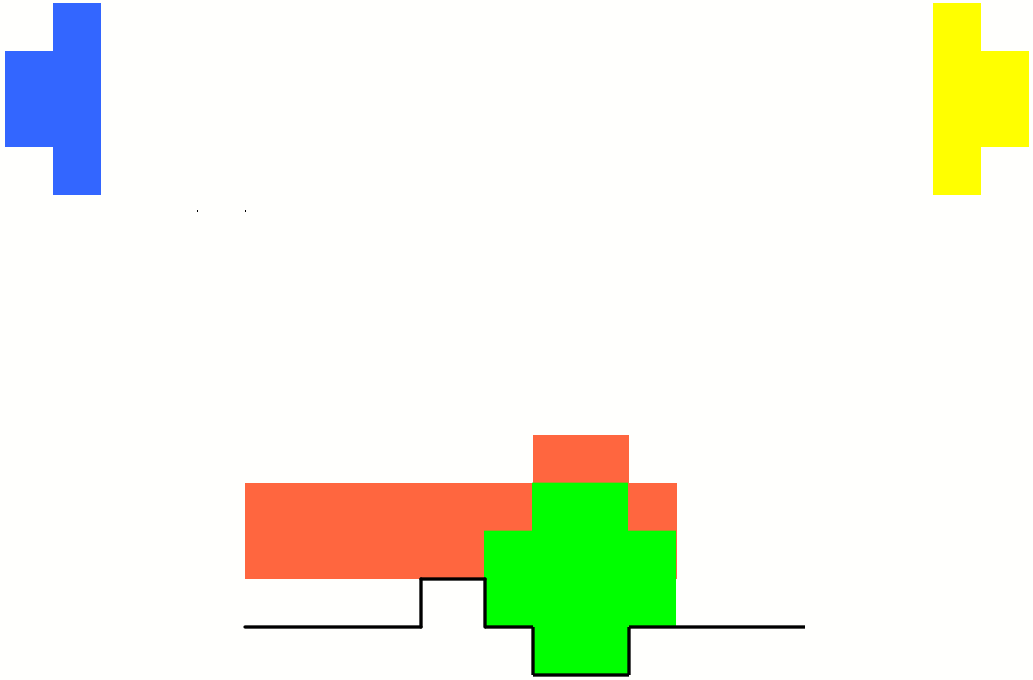

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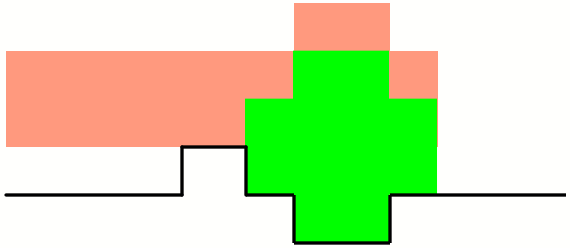

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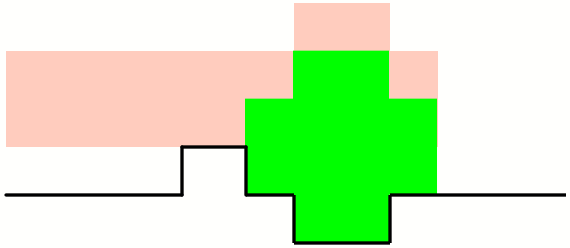
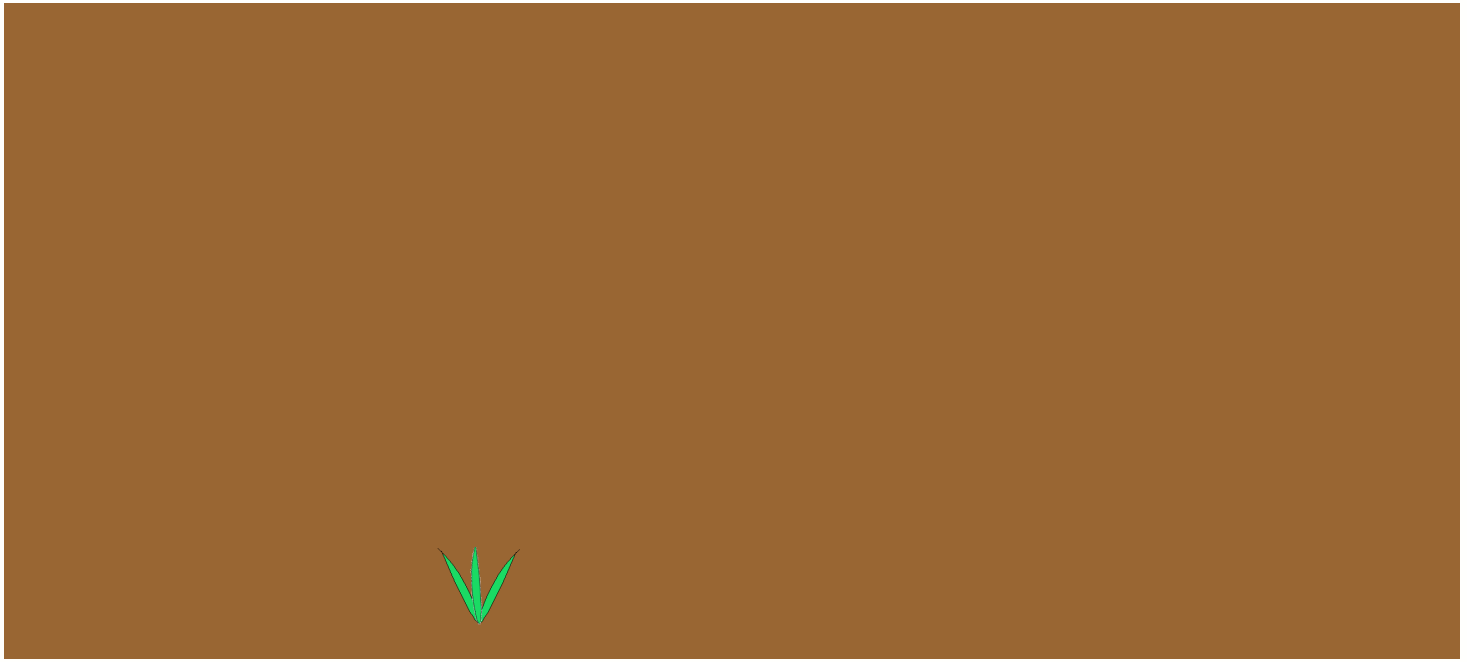


HR Enzyme system

How does resistance increase



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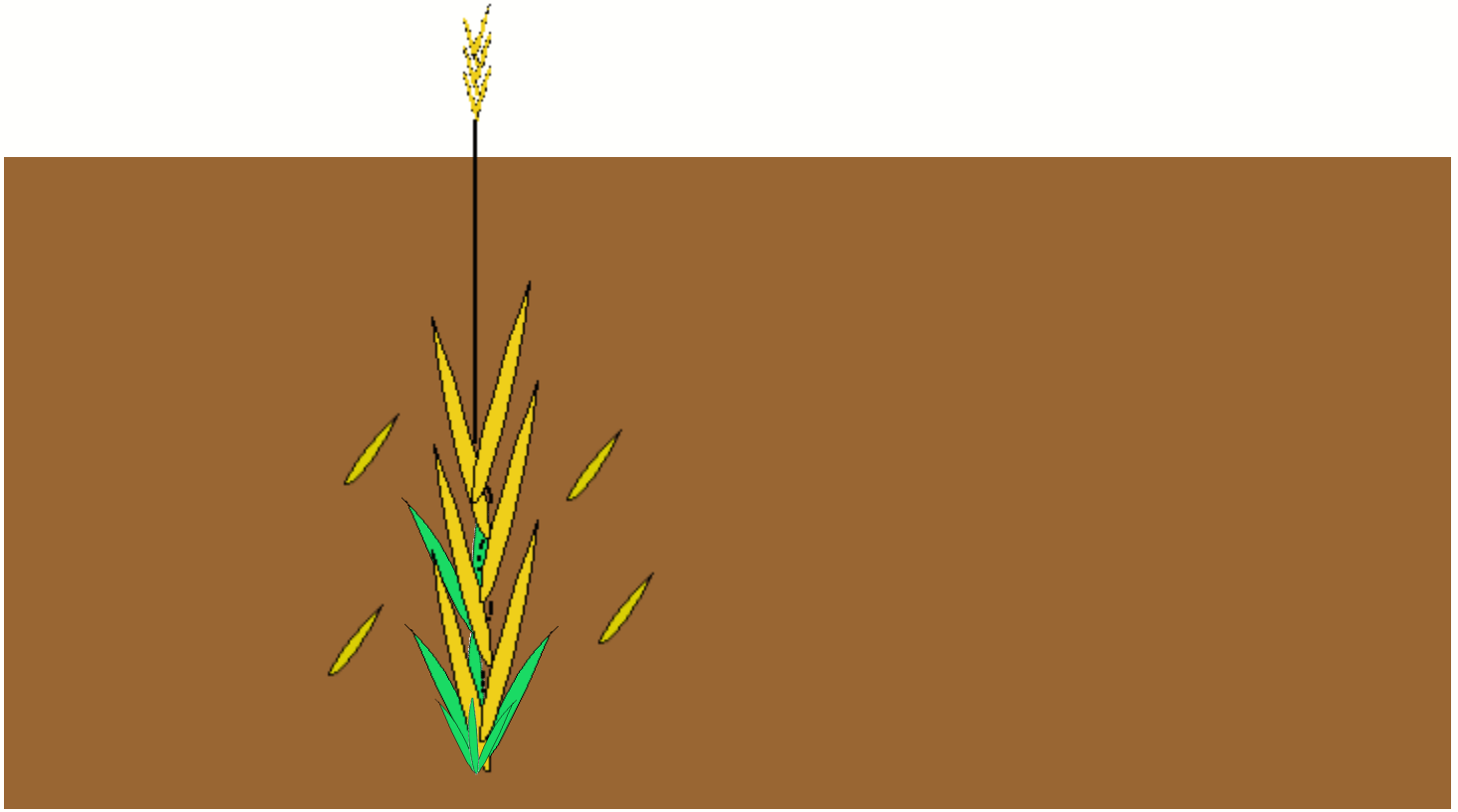

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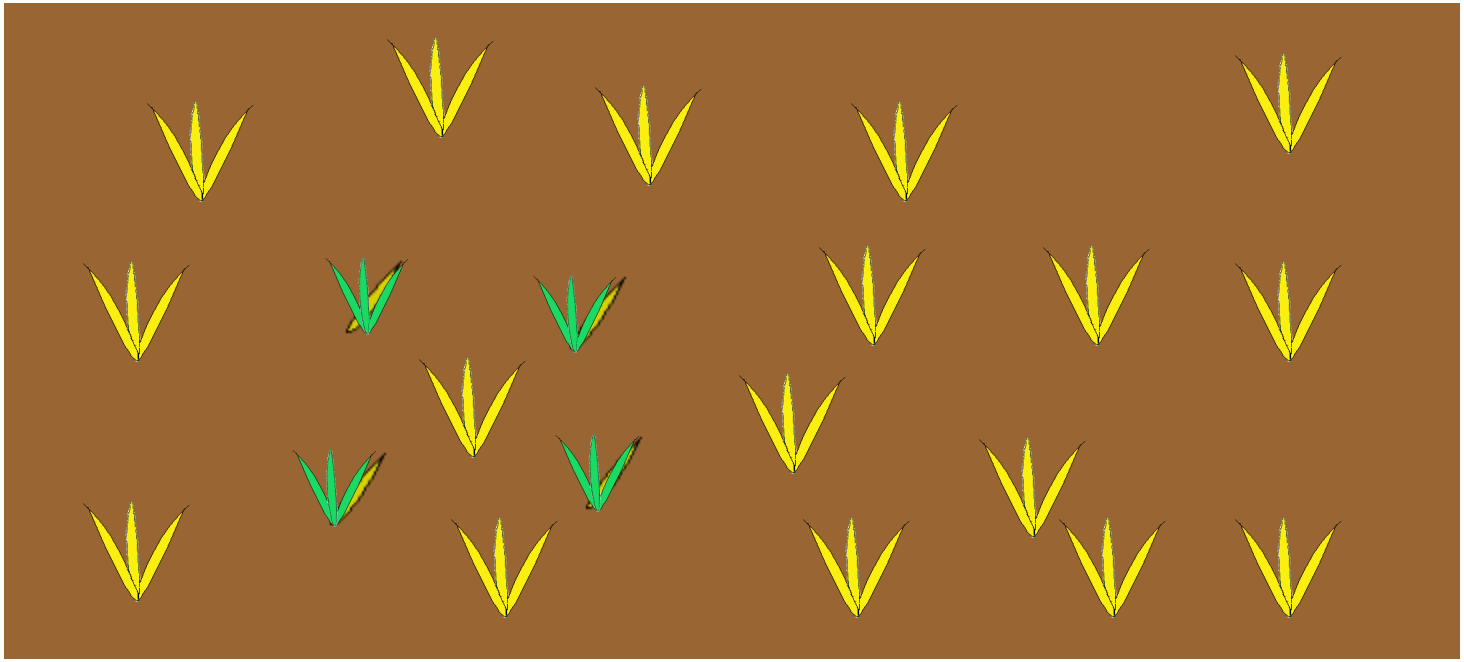


How fast does resistance increase?

Progression of resistant weeds exposed to annual applications of Group 2 herbicides (Glean scenario)

Treatment Year	Percent of Population made up of Herbicide Resistant Biotypes
Base population	.0001%
1st application	.001
2nd application	.02
3rd application	.3
4th application	4.2
5th application	60.5

= (1 plant in a million)

Excellent to good weed control

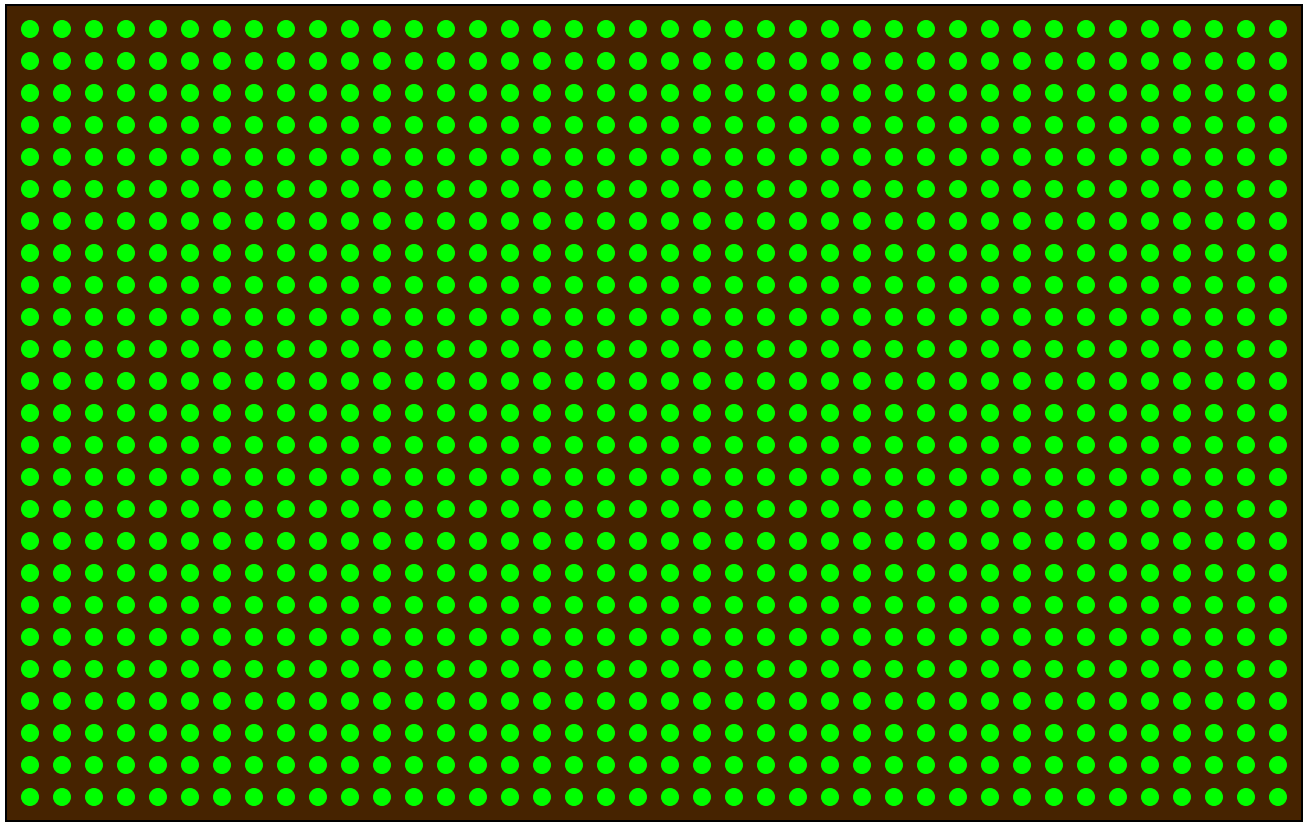
Weed control failure

Frequency of ‘Successful’ Mutations in Base Populations

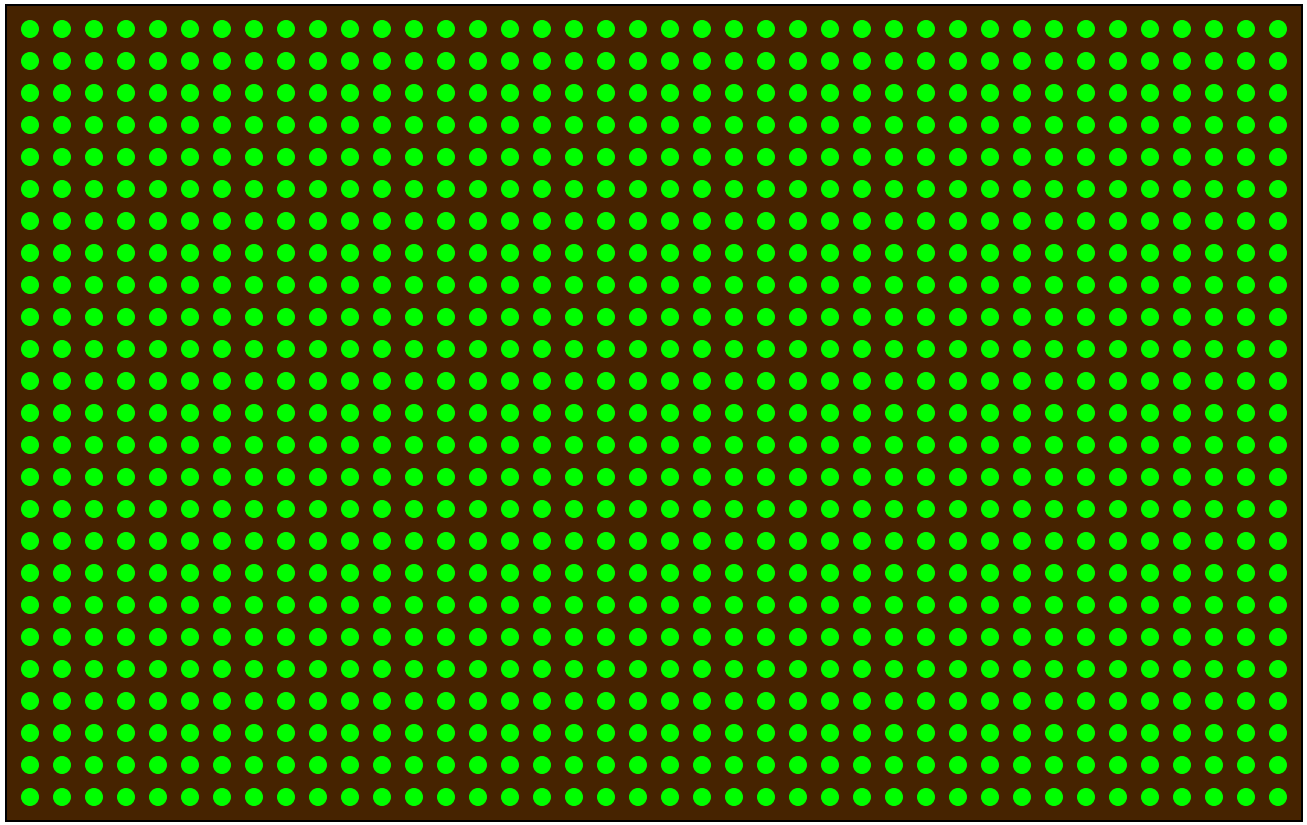
- Group vs. Mutation Rate:
  - Group 2 = 1/100,000 individual plants
  - Group 1 = 1/1,000,000 individual plants
  - Other Groups = 1/10,000,000 individual plants
  - Group 4 & glyphosate = 1/100,000,000 individual plants

The Great Resistance Spreader!

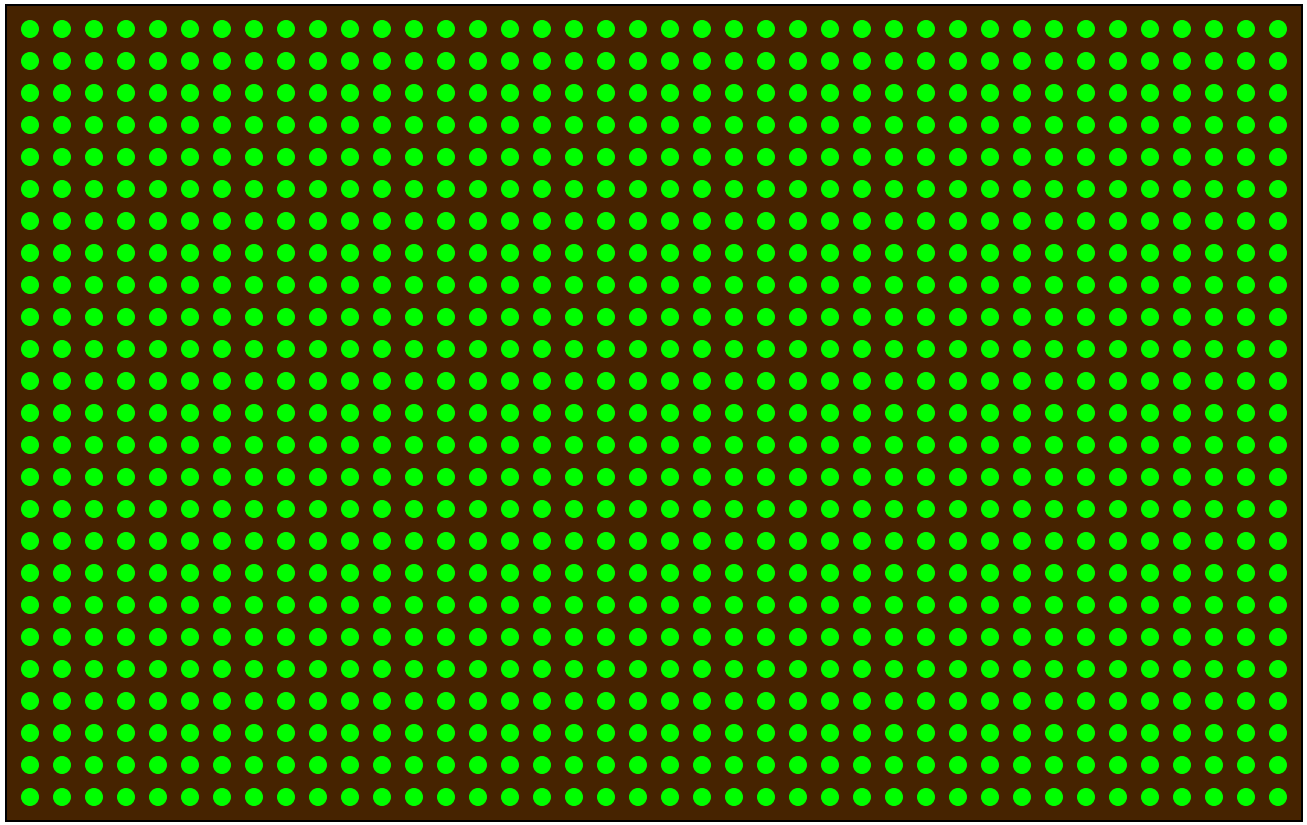
0.0001%



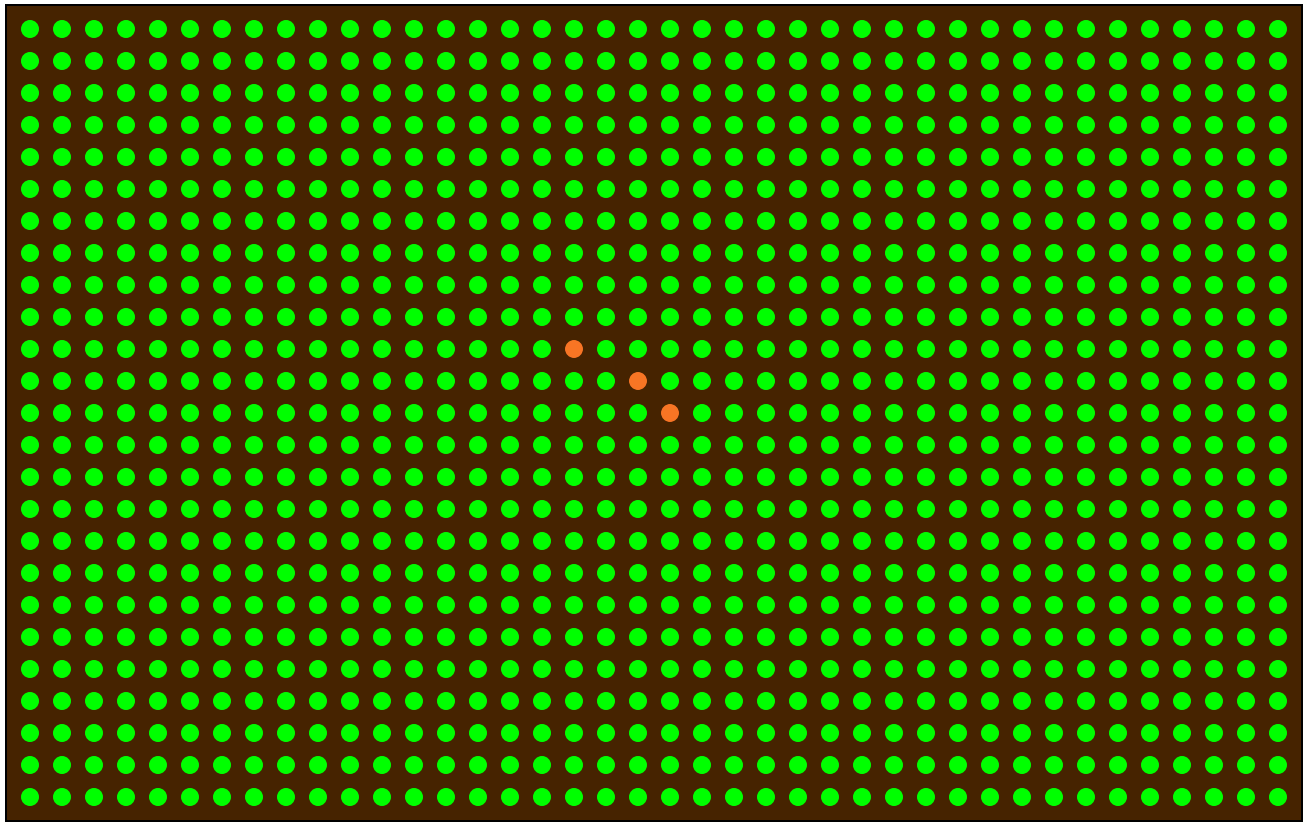
0.001%



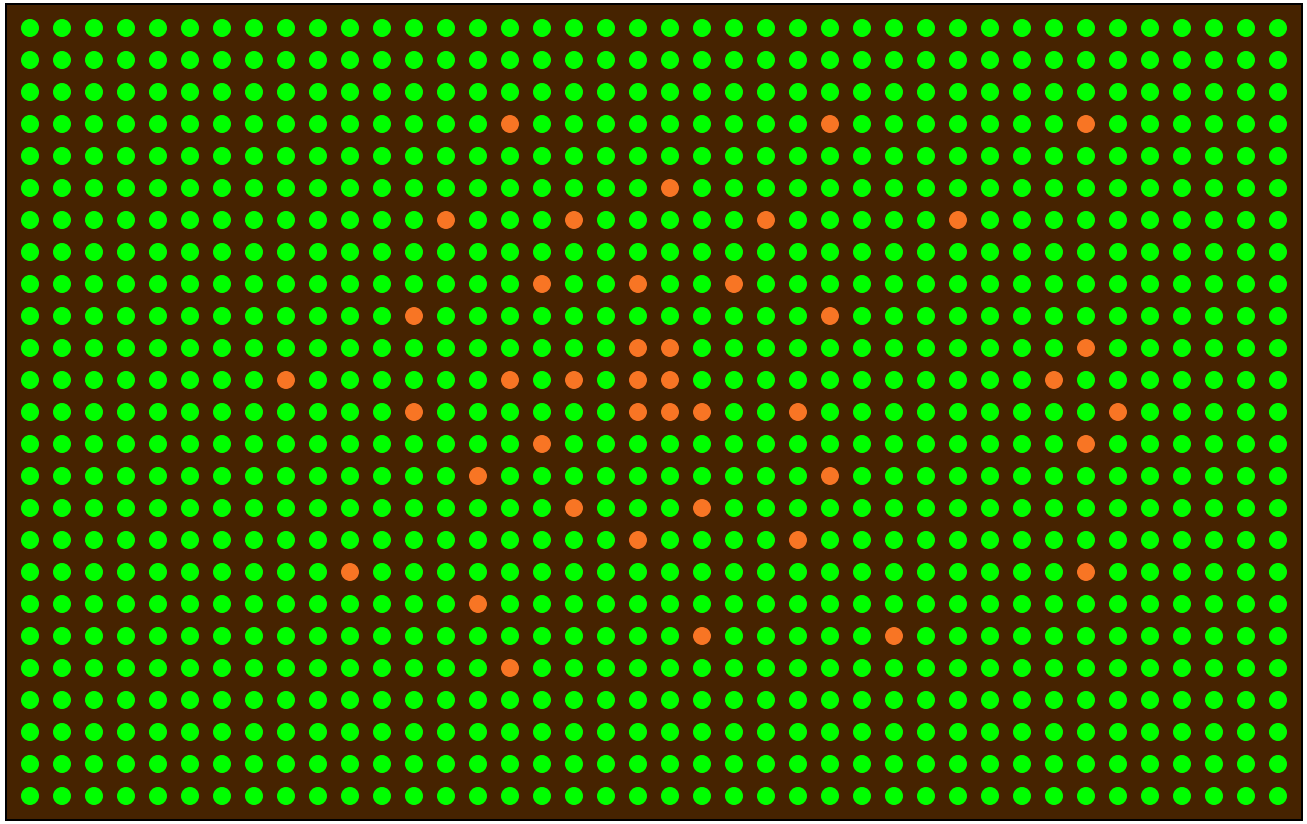
0.02%



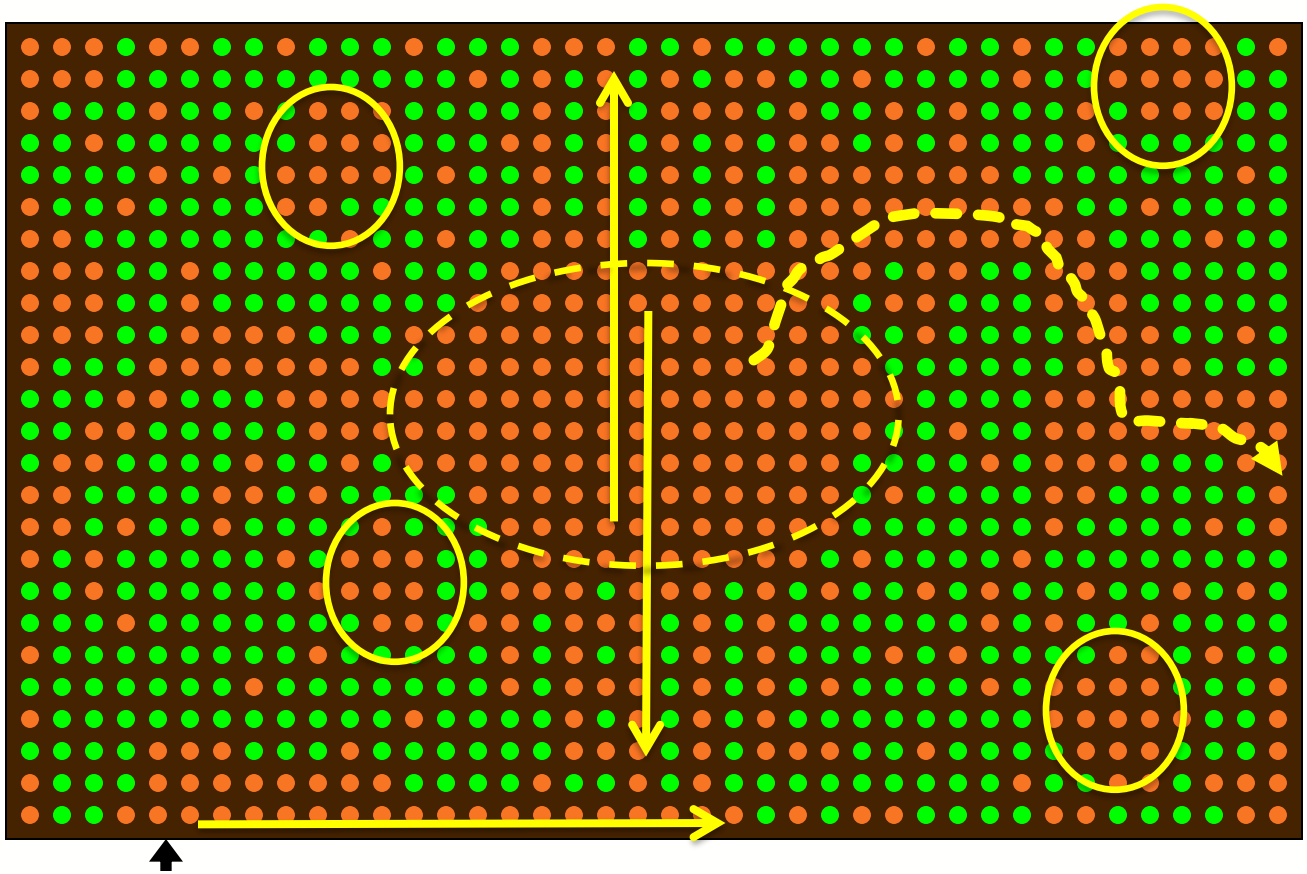
0.3%



4.2%



60.5% (50 shown)



Resistance vs. Application miss

Application miss

- Geometric patterns to weed patches in the field
  - Sharp defined edges
  - Straight boundaries
  - Parallel lines the width of the sprayer wheels
- Multiple species in the missed area

Resistance

- No sharp lines indicating missed application
  - Boundaries less defined
  - May show a general pattern following combine or other disturbance (i.e. tumble weeds in random lines)
- Nearly impossible to get more than one species developing resistance at same time

Resistant Ryegrass Patches in Australia

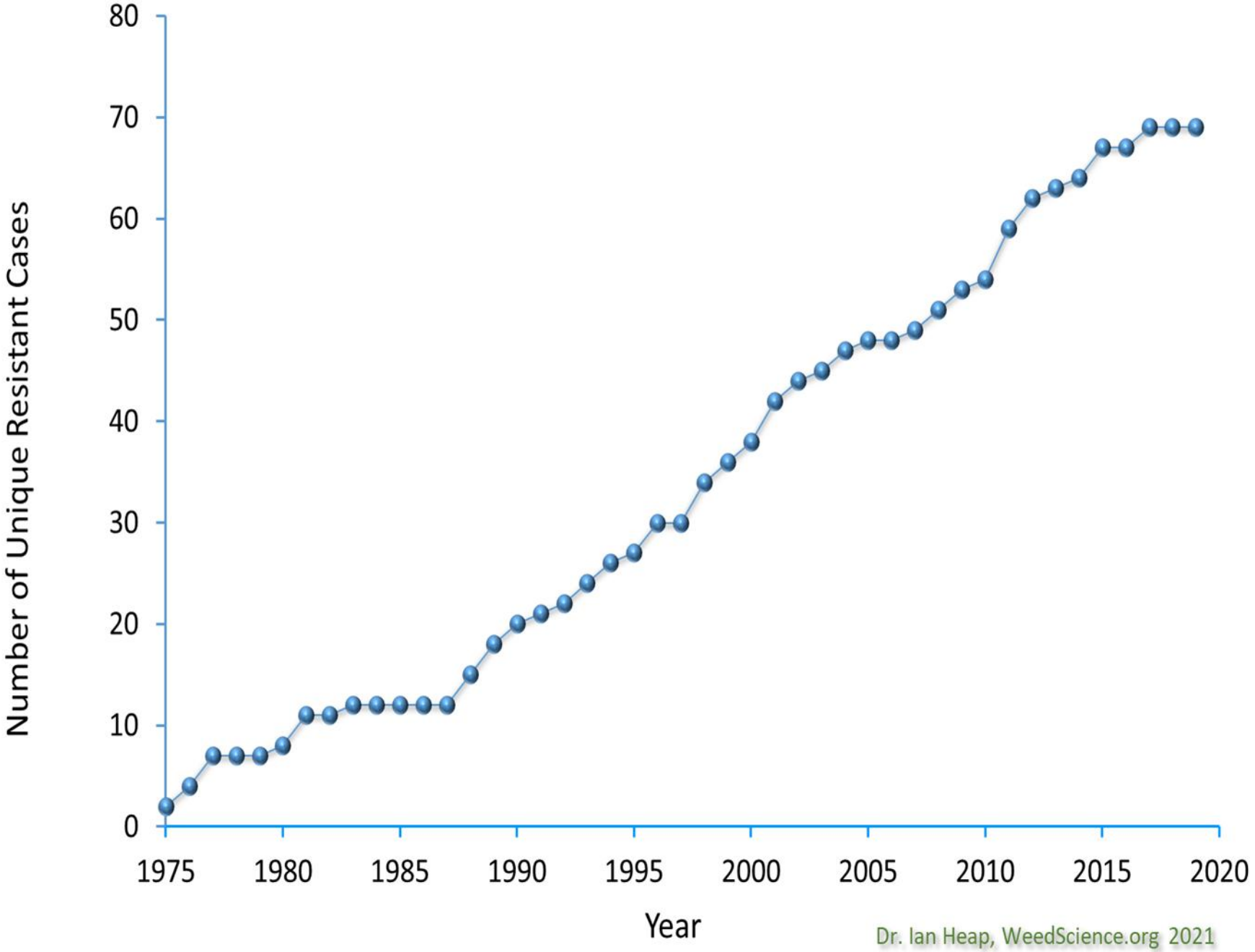
Tumbleweed resistance patterns

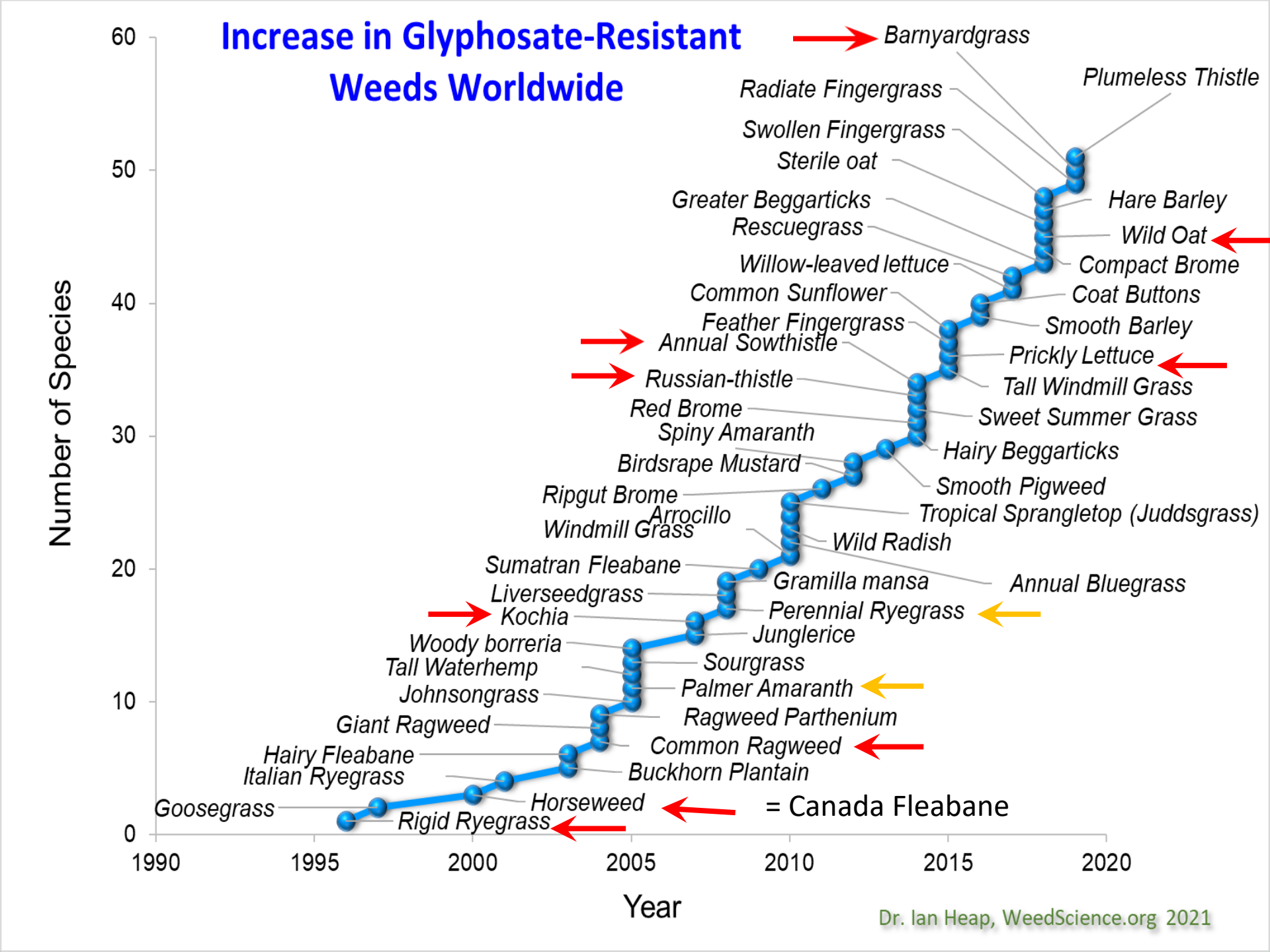
Photos Pioneer Coop AgTeam

Herbicide-Resistant Weeds Worldwide

Global Increase in Unique Resistant Cases

Increase in Unique Resistant Weed Cases for Canada

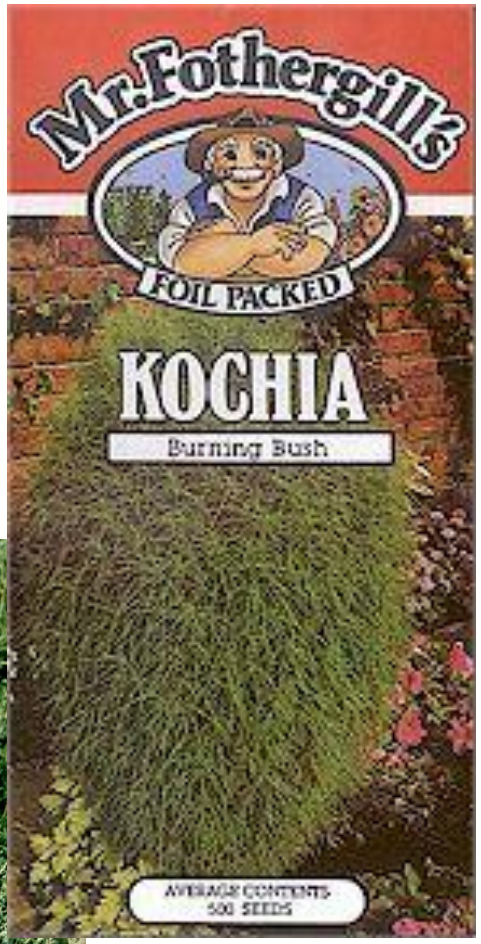



Increase in Glyphosate-Resistant Weeds Worldwide
Number of Species
Year
0
10
20
30
40
50
60
1990
1995
2000
2005
2010
2015
2020
Goosegrass
Rigid Ryegrass
Italian Ryegrass
Hairy Fleabane
Giant Ragweed
Johnsongrass
Tall Waterhemp
Woody borreria
Kochia
Liverseedgrass
Sumatran Fleabane
Windmill Grass
Arrocillo
Ripgut Brome
Birdsrape Mustard
Spiny Amaranth
Red Brome
Russian-thistle
Annual Sowthistle
Feather Fingergrass
Common Sunflower
Willow-leaved lettuce
Rescuegrass
Greater Beggarticks
Sterile oat
Swollen Fingergrass
Radiate Fingergrass
Barnyardgrass
Horseweed
= Canada Fleabane
Buckhorn Plantain
Common Ragweed
Ragweed Parthenium
Palmer Amaranth
Sourgrass
Junglerice
Perennial Ryegrass
Gramilla mansa
Wild Radish
Tropical Sprangletop (Juddsgrass)
Smooth Pigweed
Hairy Beggarticks
Sweet Summer Grass
Tall Windmill Grass
Prickly Lettuce
Smooth Barley
Coat Buttons
Compact Brome
Wild Oat
Hare Barley
Plumeless Thistle
Annual Bluegrass
Dr. Ian Heap, WeedScience.org 2021

Kochia

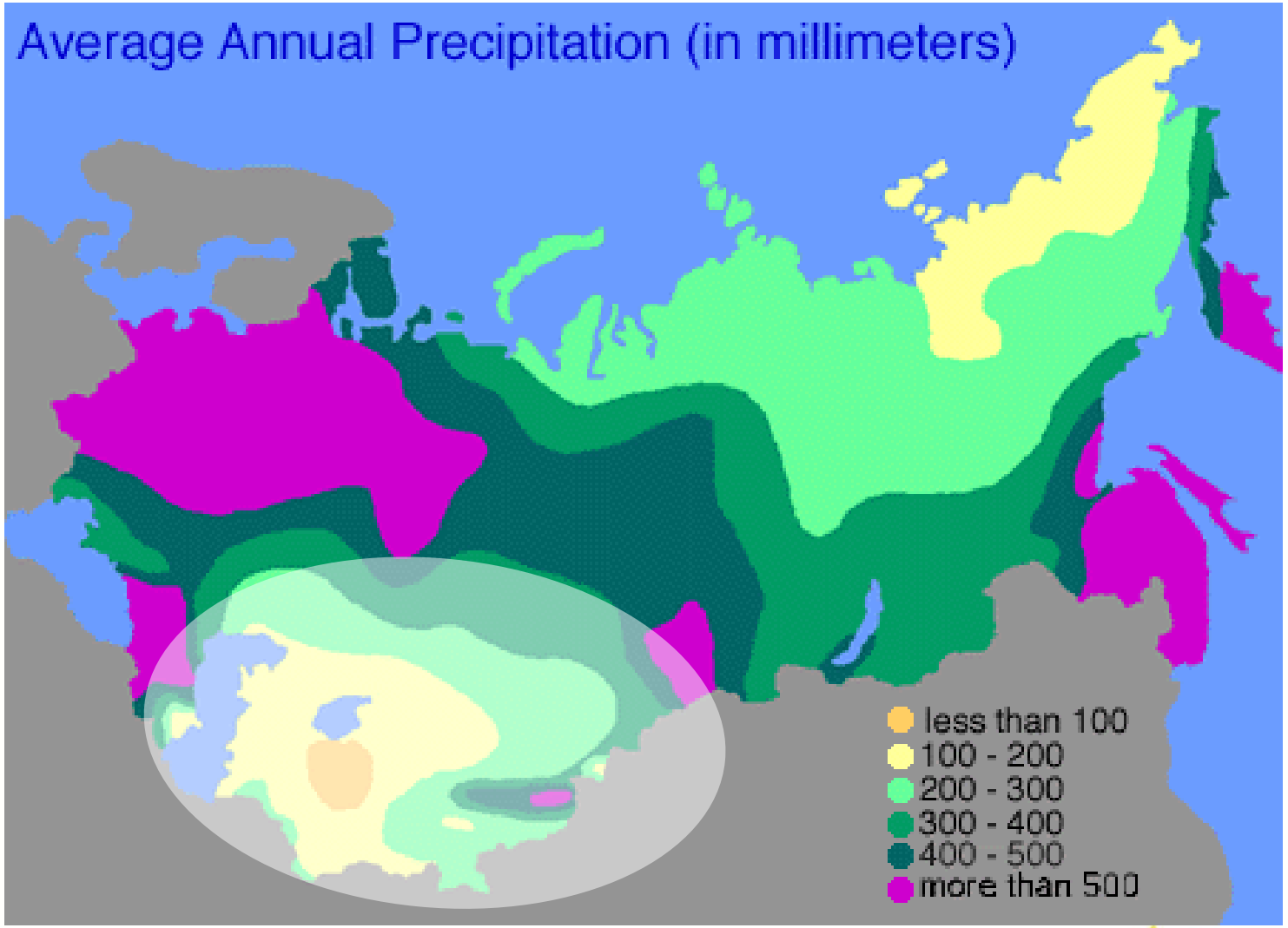
Kochia scoparia L.

- Annual
- Native of central Eurasia
  - Arid to semiarid climate
- Introduced to North America as an ornamental hedge & forage of saline areas
- Nutritive value similar to alfalfa



Kochia Origins

Kochia scoparia L.

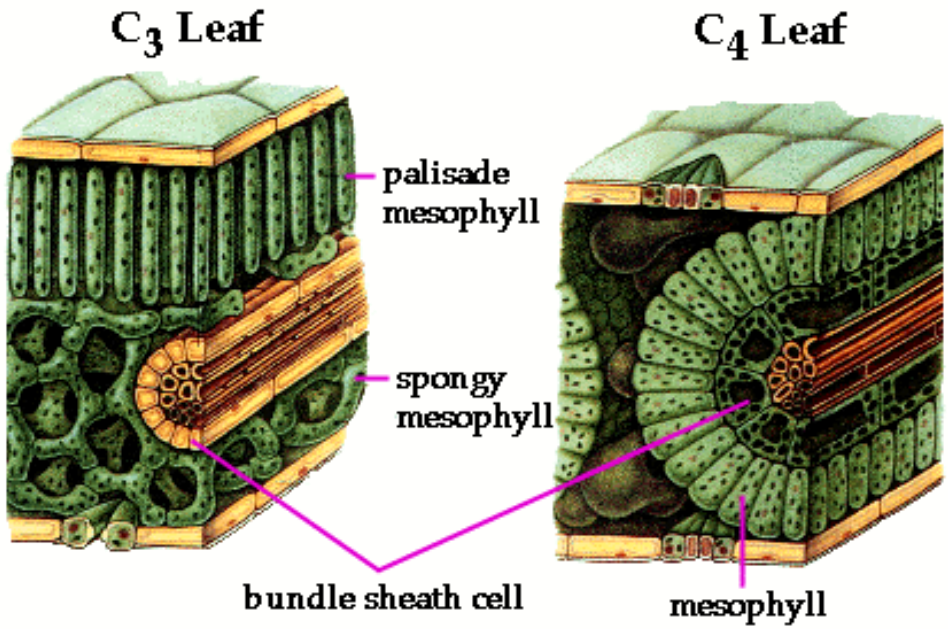


25mm = 1”

Kochia

Kochia scoparia L.

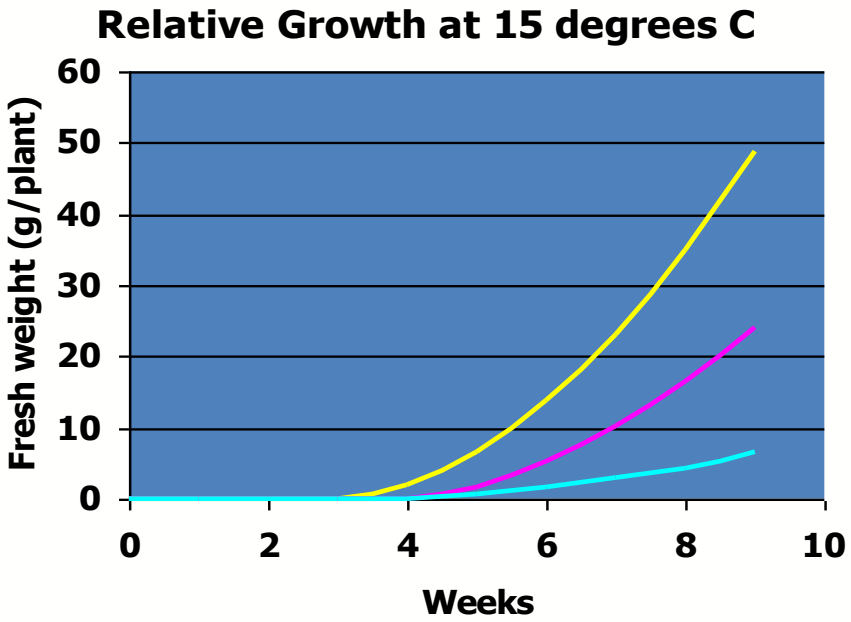
- Kochia is a C_4 plant
  - Grows more efficiently in hot, dry weather
  - Able to convert low CO_2 levels to sugars more efficiently
  - Able to store CO_2 at night to use through the day
  - Other C_4 plants are corn, millets, barnyard grass, pigweeds, & lamb's-quarters
- Most prairie crops are C_3 plants
  - Grow more efficiently in cool, moist, short-season conditions

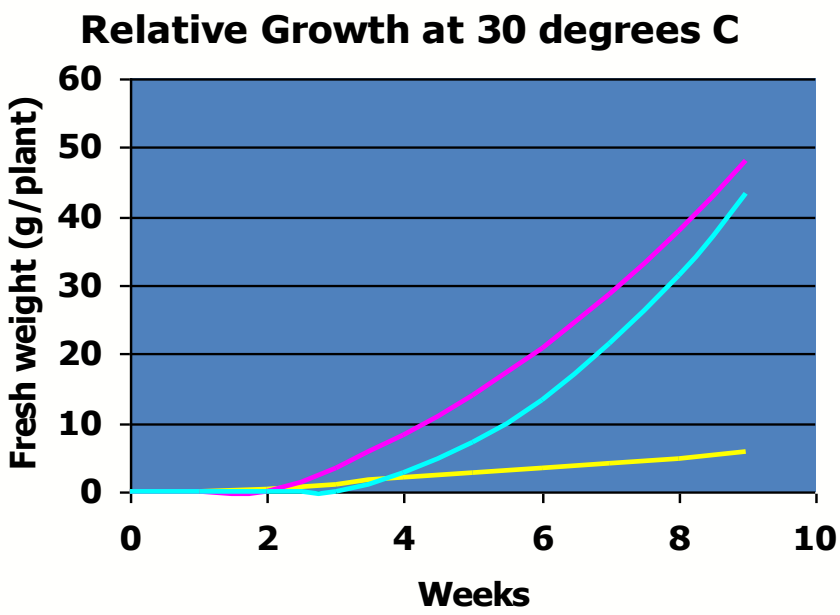


From: University of Wisconsin – Tree Physiology

Relative growth rates at different temperatures

Wheat — Kochia — Russian thistle





Kochia

- Tolerant of saline & dry soils
  - Seed and root can draw needed water from soil under lower available water conditions than other plants
  - Germinate & grow where others can't
  - Will grow in conditions too dry to activate soil applied herbicides

- Well adapted to hot & dry conditions
  - Deep greatly branched tap root
  - Kochia plant is covered with dense hair to slow moisture loss from leaves

Source: Philip Westra - Colorado State University

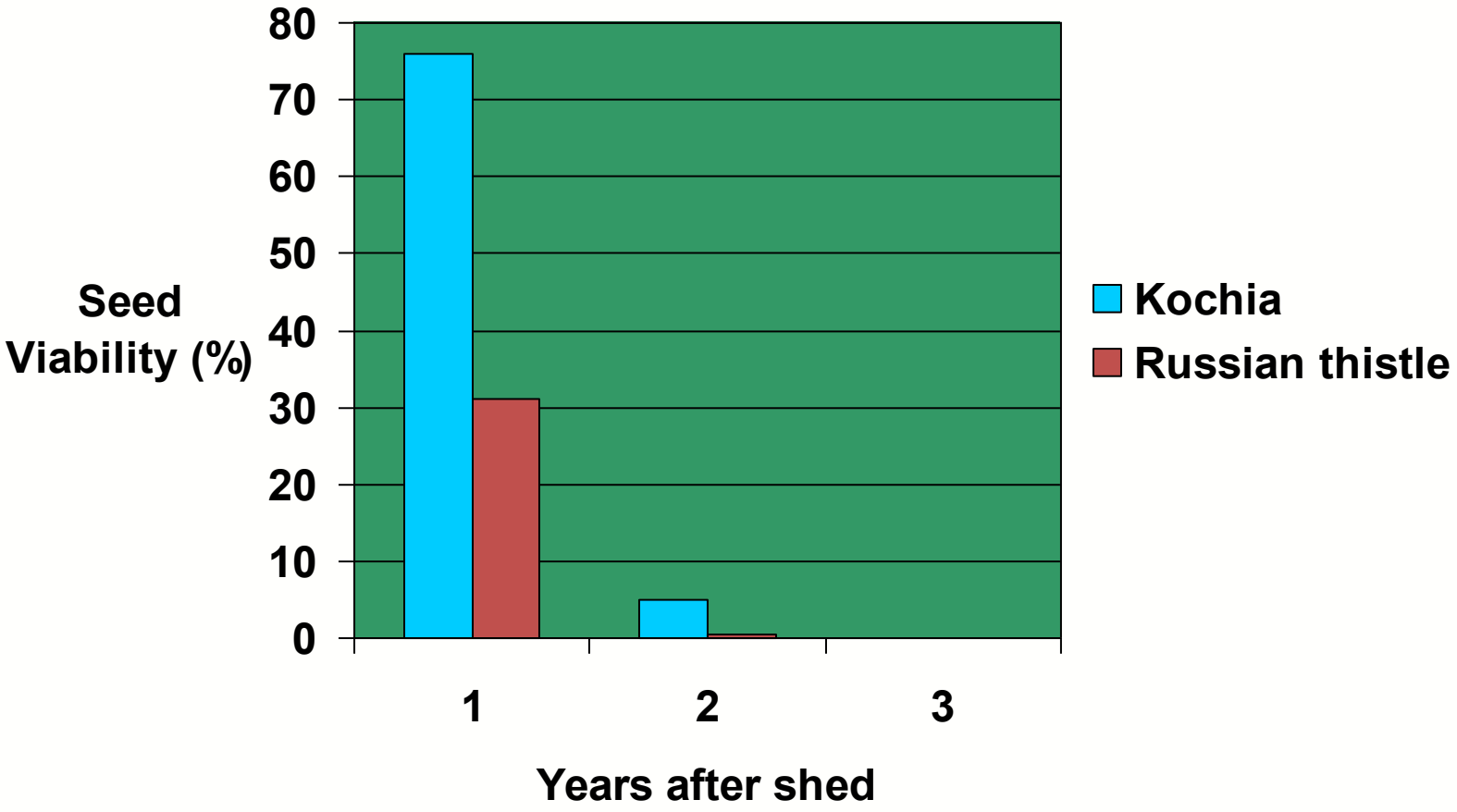
Tumbleweeds
Kochia

Seeds

- Annual plant reproduces only by seed
- Heavy seed producer
  - Avg. ~14,000-15,000 per plant
  - Max ~ 30,000 per plant
- Seeds small - 1/16” long
- Seed germinates over a wide range of conditions (4-40 ° C)
- Short life in soil
- Plant tumbles to disperse seeds

Seed Life in Soil

Kochia & Russian thistle



Adapted from: O. C. Burnside, et al (1981)
& Chepil (1946)

Kochia

Improving the effectiveness of Herbicides:

- Use highest recommended water volumes and adjuvant levels
  - Plant defenses used to prevent moisture loss also act as barriers to herbicides
- Apply at relatively early stages
  - Plants become less susceptible as they grow
- Scout ~ 3 to 4 weeks after application to assess control
  - Catch potentially resistant plants and remove before patches increase in size or tumble
  - Resistance is indicated when kochia appears unaffected and other susceptible weeds are controlled or some plants die and other don't.
- Use cultural methods to reduce reliance on herbicide alone
  - Early seeding, higher populations, narrow rows, etc.

Kochia Cultural Controls

Cultural Controls

- "Tumbleweeds" do not tolerate shading
  - Shallow seeding – rapid crop emergence
  - Early cool-soil seeding
  - Higher seeding rates
  - Narrow rows (reduce from 12 & 15" to 10" or less)
  - No gaps in canopy - seeding misses
- Reclaim saline areas (also helpful for foxtail barley)
  - Plant saline tolerant perennial grasses
    - (NewHy, AC Saltlander wheatgrass, Tall Fescue, etc.)
  - Plant deep rooted forages on boundaries of salt areas
  - Keep in permanent forage
- Help to prevent spread – don't till in the fall
- Target till missed strips in summer
- Mow & shred to prevent seed production and tumbling
  - particularly boundary areas for sanitation

Kochia

Concerns

- Hot dry conditions promote increase of “tumbleweeds”
- Resistance to Group 2 and Group 4 and glyphosate (Grp 9) is reducing the effectiveness of control measures for kochia
  - A high proportion of kochia samples that come to the Crop Protection Laboratory for testing are resistant - if you suspect it’s resistant it likely is.
  - USA predictor of things to come with Group 4 resistance
- Trends towards wider row spacing on seeders
  - More opportunity for seedling establishment before canopy closure
  - Makes spray work harder!
- Trends towards lower water volumes
  - Herbicides are less able to penetrate leaf defenses
  - Makes spray work harder!!

The Harsh Reality

- There are a finite number of pathways in a plant that herbicides will work on!
  - Chemical manufacturers are not holding back on you

The Harsh Reality

- There are a finite number of pathways in a plant that herbicides will work on!
  - Chemical manufacturers are not holding back on you
- Using the 'other Group 1' (clethodim) is not rotation
- Switching to a Group 2 grass control herbicide is not a long term solution to Group 1 wild oats
- Three way (Glyphosate+dicamba+Group2) resistance has happened in western Canada!

The Harsh Reality

- Group 2 herbicides will no longer control kochia. Cleavers, wild oat and wild mustard are not far behind!
- Once a weed is resistant to a herbicide group it will be forever! **There is no going back to a susceptible population over time!**
  - the 'fitness' level most resistant biotypes is equal to that of the susceptible.

How to stop it?

- Grow a vigorous crop = high density, high fertility, high yield.
- Diversify the crop rotation – keep weeds from adapting.
- Pick herbicides in the rotation starting with the crop with the least options and progress to those with the most – avoid using herbicides from the same group in different parts of the rotation.
- Mix herbicides from different herbicide groups ***to control the same weed***
  - Tank mixes only work if both herbicides control the target weed.
- Physically remove weed seeds from the field
  - Mechanical = Chaff catcher or McLeod Harvester
  - Rotate to forages
  - swap land with a livestock producer – he gets phosphate; you get weed control/removal
- If you suspect a patch – don't hesitate – work it under!

Sanitation

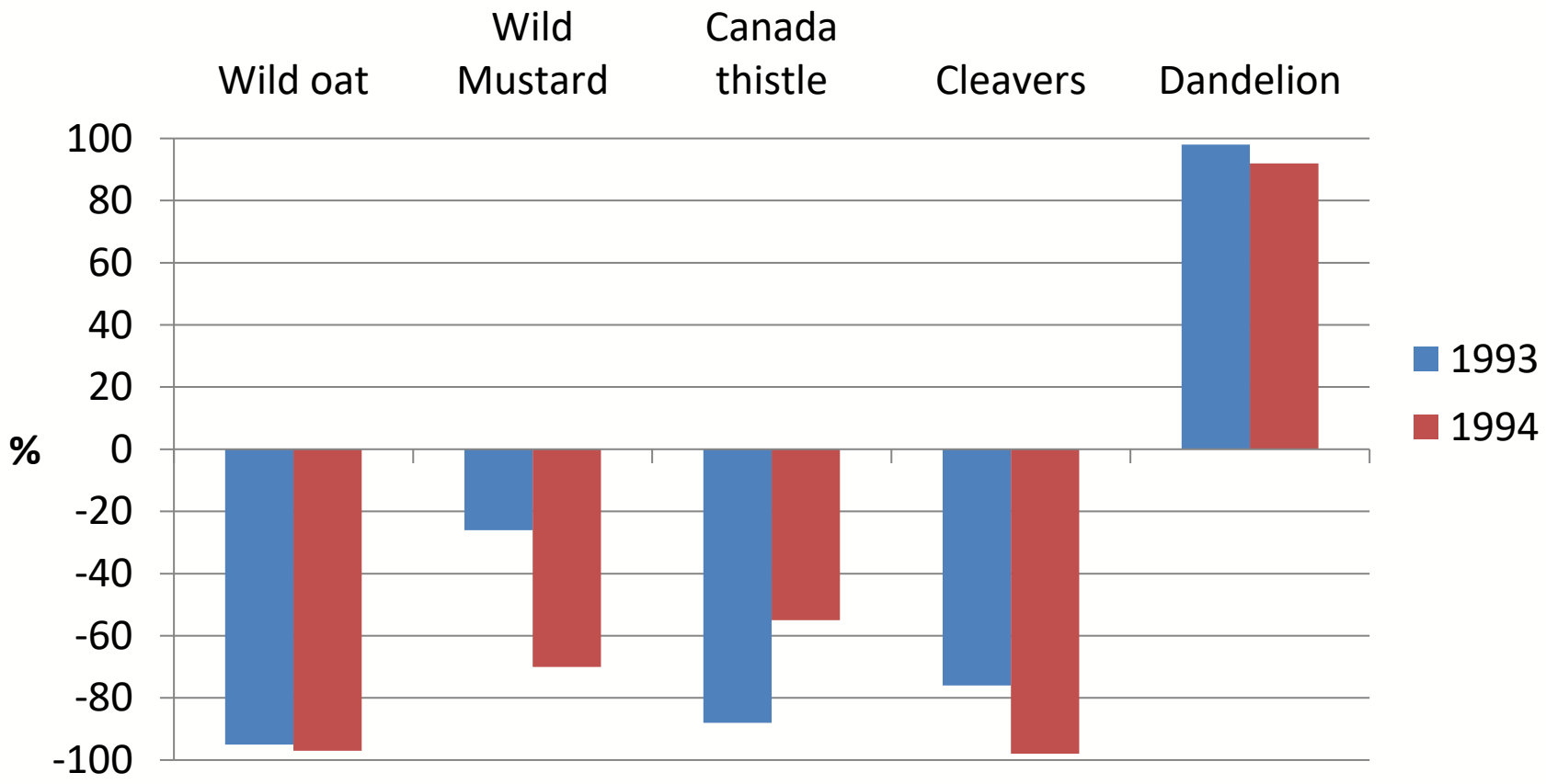
- Prevention – Easiest, cheapest and best weed control is not to let a particular weed species or resistant biotype establish in the first place
- Starting with clean seed
  - cleaned to CSGA standards (*Federal Seeds Act*)
- Clean off/out seeding and harvest equipment
- Early Detection and Rapid Response (EDRR) – biosecurity is becoming the new buzzword at all levels of government
  - managing new or resistant pest species as soon as possible to limit spread
- Solid manure sources should be composted for several weeks with high core temperatures (65-70^{0}C) to destroy weed seeds turning frequently to maintain temperature
- Field boundaries and non-cropped areas (salinity) are nurseries for resistance – sub-lethal doses

Rotation

- Should be well planned in advance
  - 4 years or more
- Should be a mix of competitive & non-competitive crops including grass, broadleaf and legume crops
- Should include **periodic perennial forages**
- Include cover crops or intercrops where compatible

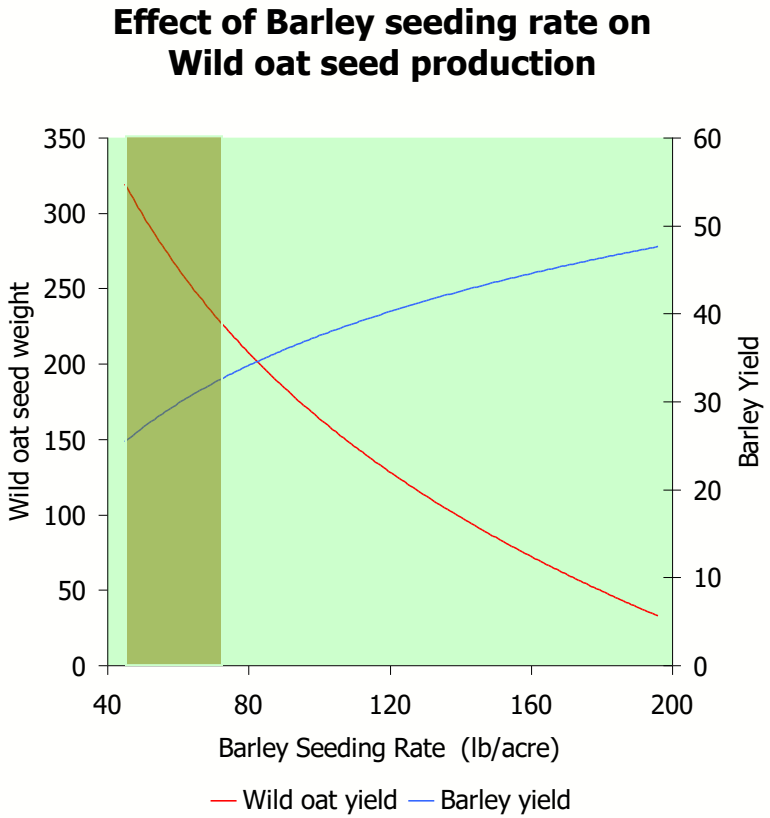
Integration of Forages into Rotation

Relative density change of certain weed species after 3 years of alfalfa or alfalfa/grass hay production



Cropping Practices

- Goal is to improve crop competitiveness and increase diversity
  - Vary seeding date
  - Increase seeding rate
  - Decrease row spacing
- Many of these are foregone because of economic or mechanical efficiencies

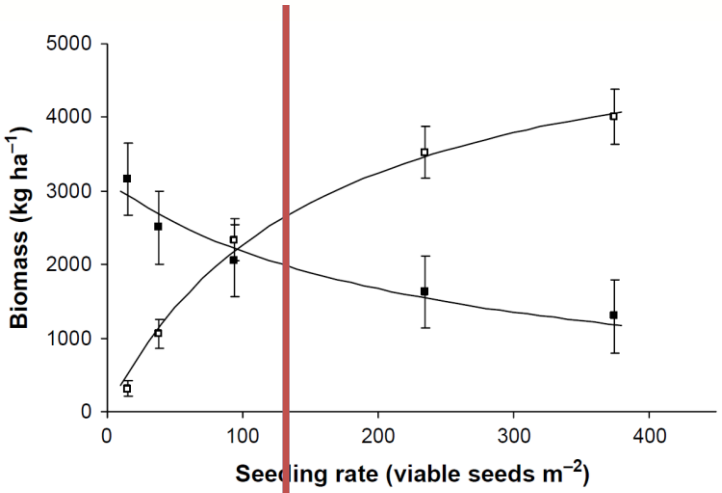


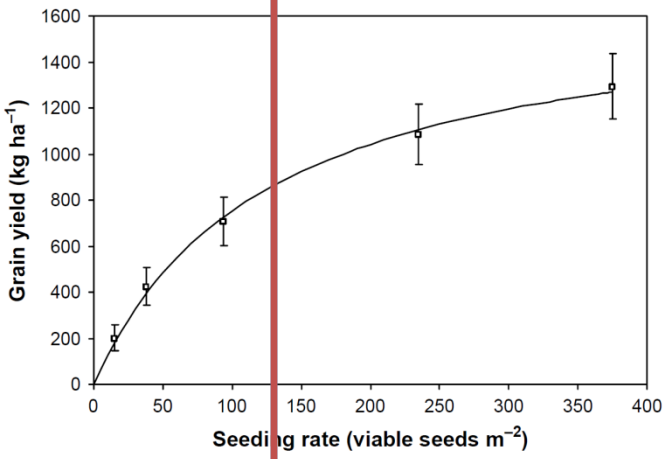
Adapted from: O'Donovan, Blackshaw & Harker (unpublished)
K. Kirkland, AAFC, Scott, SK

Government of Saskatchewan

Integrated Crop Management

- Even a relatively uncompetitive crop like lentil can compete more effectively against weeds
- Conventional seed est. goal for lentils
  = 130 plants / sqm
- Organic seed est. goal for lentils
  = 230 plants / sqm





Baird, Shirtliffe, & Walley, U of S 2009

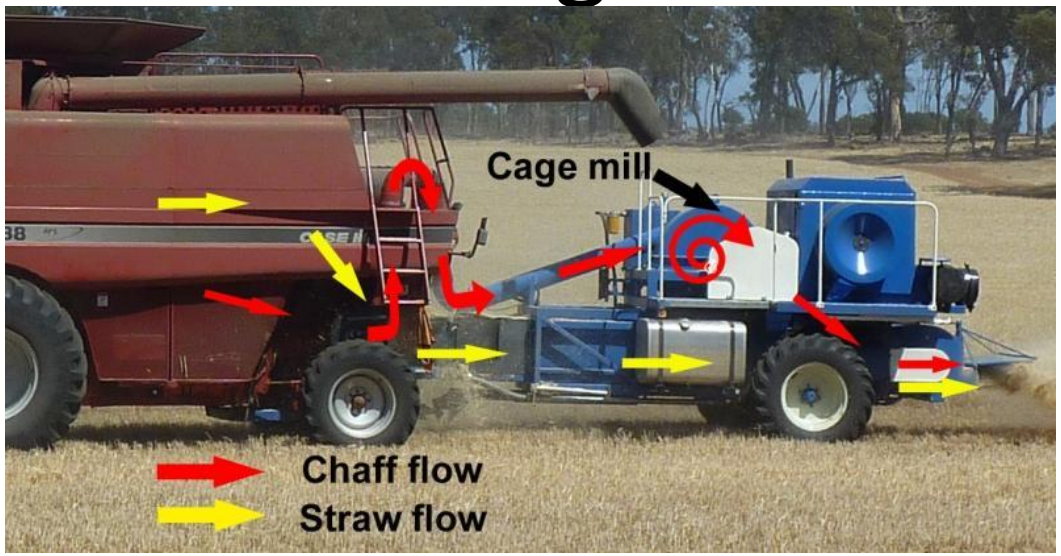
Integrated Crop Management

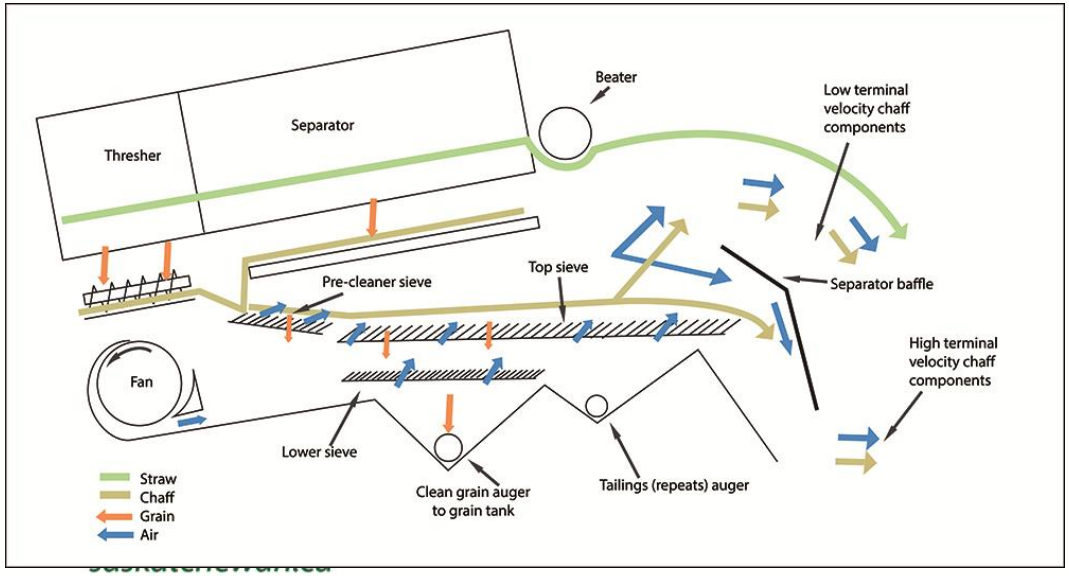
Harvest Weed Seed Managment

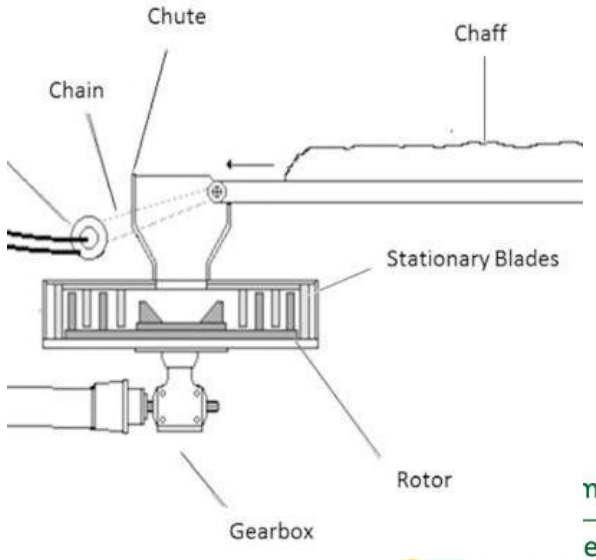
The Great Weed Spreader!

Harvest Weed Seed Management

- Cage mills for seed destruction
  - Harrington Seed Destructor
  - Seed Terminator







Harvest Weed Seed Management

- Harrington Seed Destructor

- Seed Terminator

Harvest Weed Seed Management

- Harrington Seed Destructor

Photo: Lucerne Australia

- Seed Terminator

Photos: Kondinin Group

Harvest Weed Seed Management

Harvest Weed Seed Management

- Challenges
- Weed seed actually has to get into the combine to be effective
- Highly shattering weeds like wild oat – only 60% of seed still on plant at harvest
- Clipping above crop (CTM Weed Surfer)

Challenges

- Commodity prices vs. costs of production are not balanced across cropping options
- Commodity organizations promoting increasing acres of their crop to achieve production goals at the expense of sound agronomy

Summary

- Integrated solutions should include short and long term goals
- Key to minimize risk of resistance is to reduce weed densities before herbicides are used
- Some cultural methods as good as (or better than) herbicides for reducing weed densities

Thank you!

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