Mechanism of Action and Resistance to Plant Growth Regulators

(Synthetic Auxins)

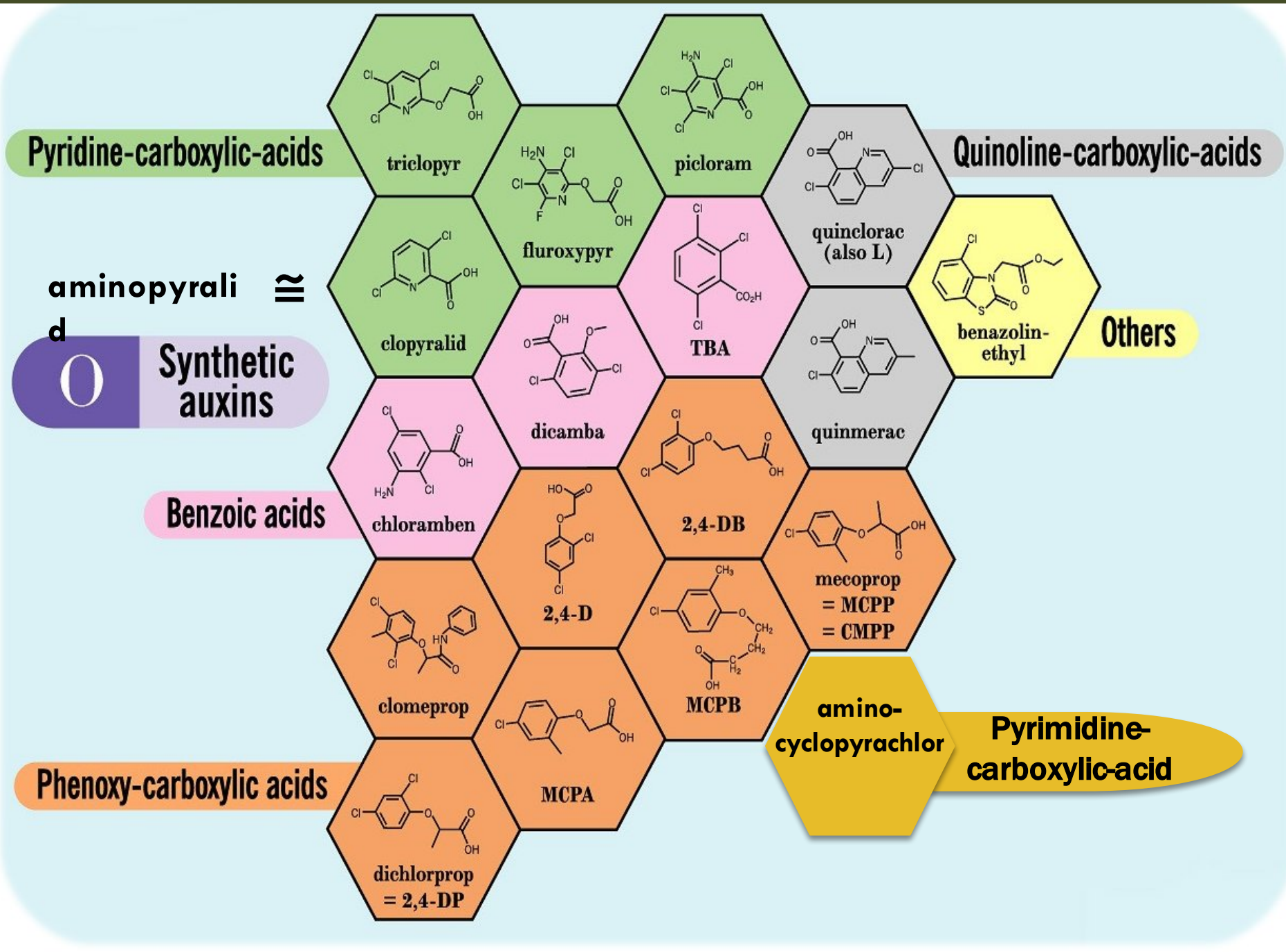
Dr. Scott Nissen, Professor
Colorado State University, Fort Collins, CO

Assistance from: Drs. Greg Kruger, Mithila Jugulam

Colorado State University

Outline

- Overview of current active ingredients and basic modes of action
- Current status of PGR herbicides
- Known mechanisms of resistance
- Implications for production agriculture


Pyridine-carboxylic-acids
triclopyr
fluroxypyr
picloram
Quinoline-carboxylic-acids
quinclorac (also L)
aminopyralid ≅
clopyralid
TBA
benazolin-ethyl
Others
Synthetic auxins
dicamba
quinmerac
Benzoic acids
chloramben
2,4-DB
2,4-D
mecoprop = MCPP = CMPP
clomeprop
MCPB
amino-cyclopyrachlor
Pyrimidine-carboxylic-acid
MCPA
Phenoxy-carboxylic acids
dichlorprop = 2,4-DP

Herbicides that Mimic Natural Plant Hormone (PGR)

- Natural plant hormones control
  - growth, development
  - tissue differentiation
  - RNA and DNA synthesis
- Herbicides with this mode of action can do the same things at low concentrations
- At high concentrations these compounds are herbicides

PGR Mode of Action

- Symptoms
  - abnormal growth resulting in twisted stems
  - stem swelling due to rapid and uncontrolled cell division
  - differentiated cells changing to immature cells

Mechanism of Selectivity

- Hypothesis #1
  - Differential metabolism, grasses form amino acid conjugates, while broadleaves form sugar conjugates
- Hypothesis #2
  - Auxin receptors in grasses do not recognize these synthetic auxins so the cascade effect is never initiated.

PGR Mode of Action

- Mode of action
  - we understand symptoms
  - we don't completely understand why grasses are resistant and broadleaf plants are susceptible
  - lack of ethylene response
  - differences in metabolism?

Effects of Picloram on *Centaurea solstitalis*

PGR symptoms on *Centaurea diffusa*

Aminopyralid
0.4 L/ha

Picloram L/ha

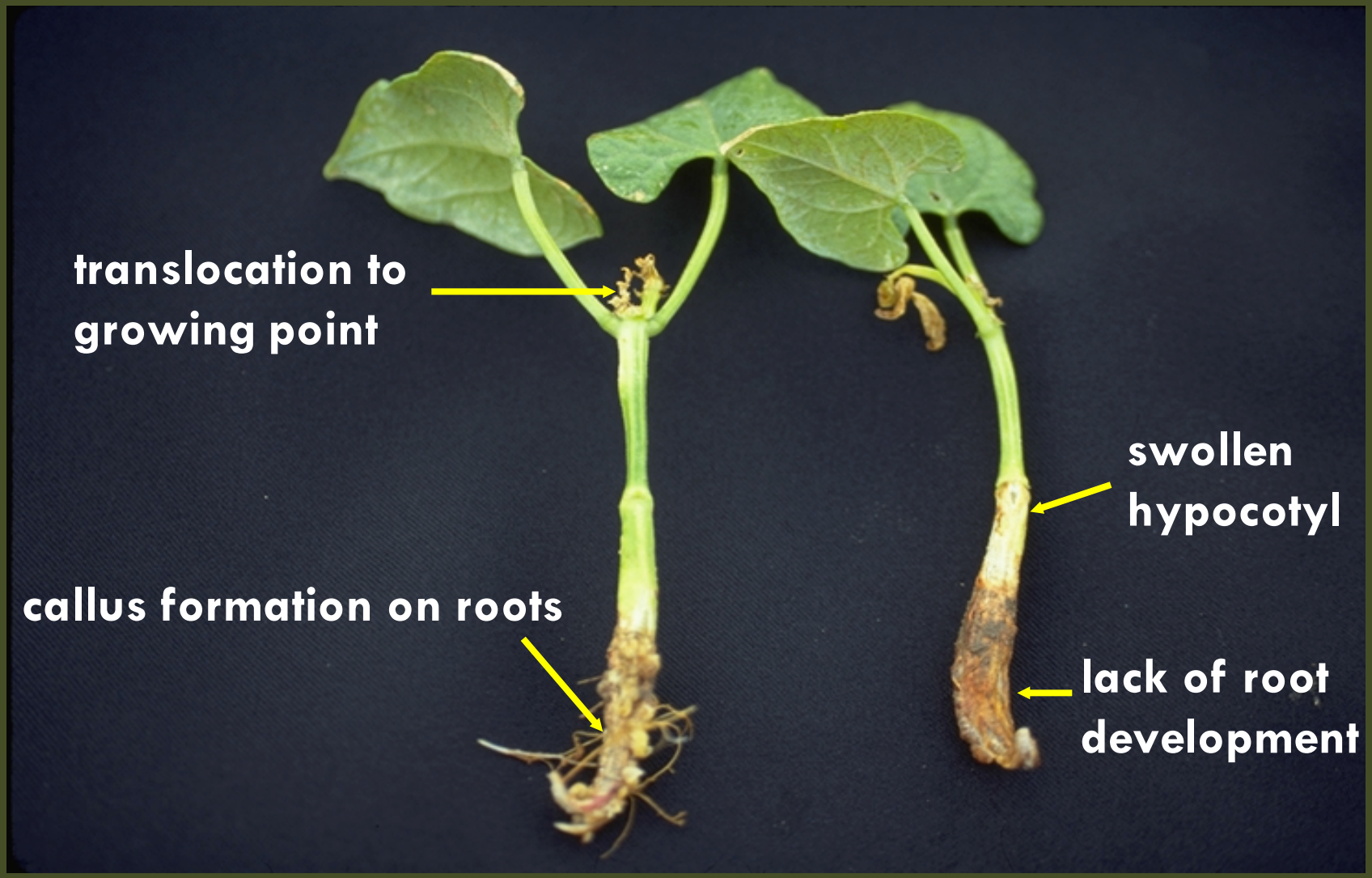
Cirsium arvense response to aminopyralid 7 DAT

Cirsium arvense response to aminopyralid 14 DAT

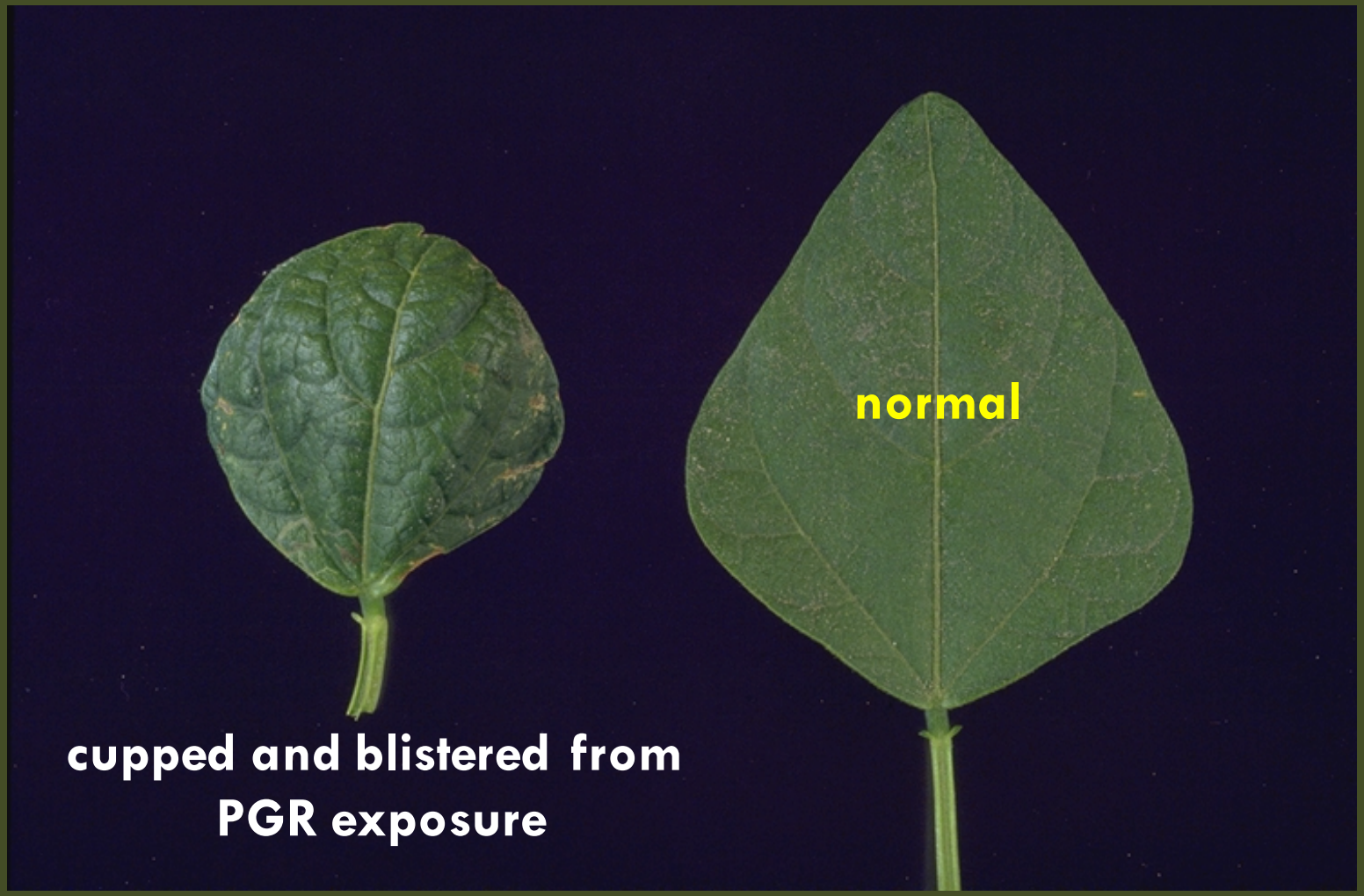
Figure 1. Injury symptoms in dry bean field following corn.

Figure 2. Closer look at dry bean injury scattered throughout the field.

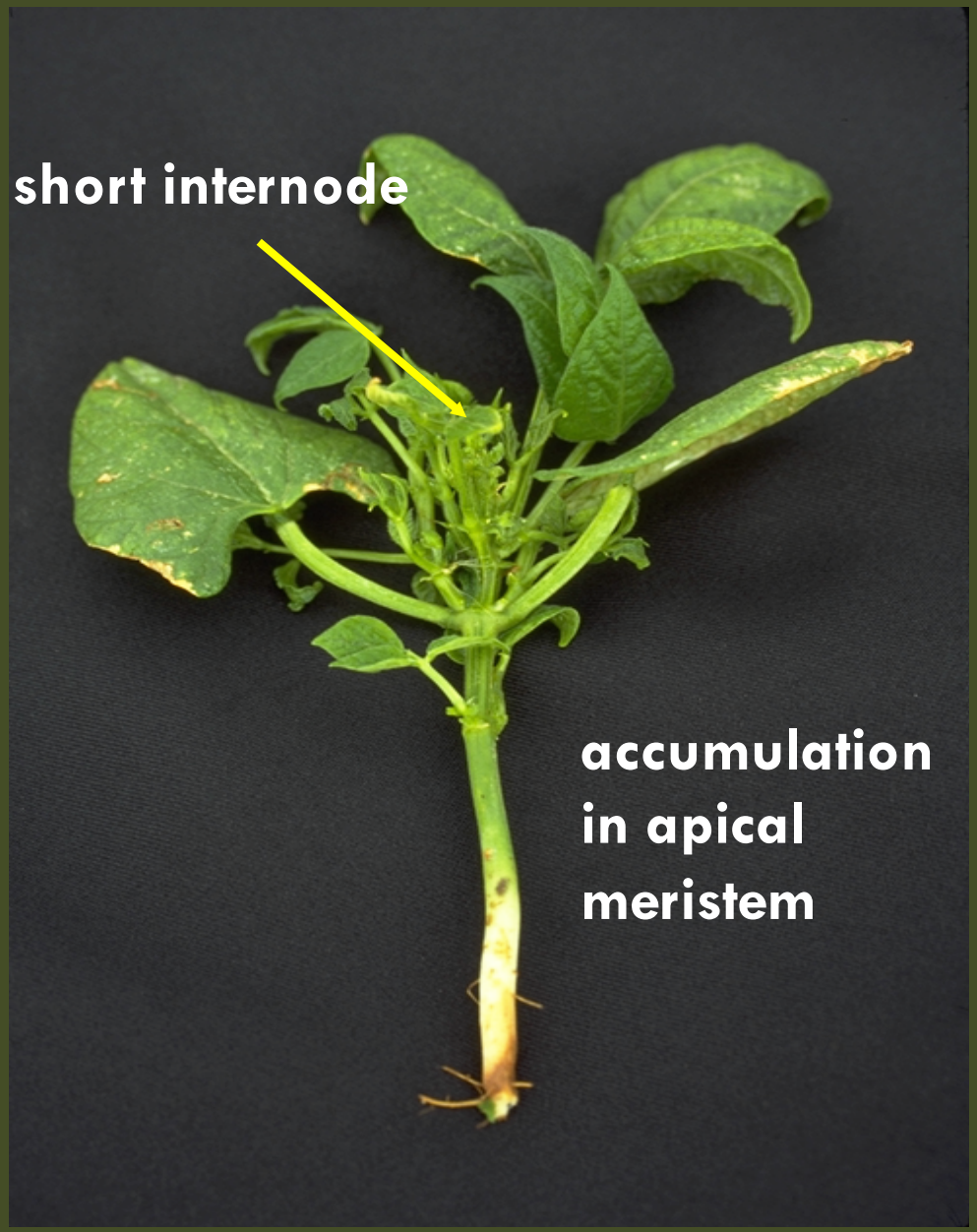
Root Absorption of PGR Herbicides



Common Leaf Symptoms from PGR Exposure



Foliar PGR Simulated Drift




2,4-D on Tomato
Postemergence

Enhanced Burndown Study

Glyphosate (1 L/ha) + saflufenacil (0.07 L/ha) + Merge (1.0% v/v)

Glyphosate (1 L/ha) + 2,4-D (1 L/ha)

Dicamba Tolerant (DT) Soybean

Weedy check

Glyphosate

Glyphosate + dicamba

Characteristics of PGR Herbicides

- Clopyralid
  - The most selective PGR herbicide
  - Trees, corn, grass seed, range, pasture, cane berries, sugar beets, rape
  - Annual weeds: wild buckwheat, cocklebur, jimsonweed, ragweeds
  - Perennial weeds: Canada thistle, knapweeds, biannual thistles, composites species in general

Characteristics of PGR Herbicides

- Triclopyr
  - Specialized brush product and one of the best all around aquatic herbicides
  - Conifer release, non-crop, cut stump, basal bark applications, utilities,
  - Annual weeds: black medic, dandelions, ivy, burdock, plantian spp.
  - Perennial weeds: many tree and brush species

Characteristics of PGR Herbicides

- 2,4-D
  - First selective herbicide
  - Small grains, corn, turf, non-crop, butyl ester can be used in alfalfa, aquatic uses
  - Annual weeds: horseweed, dandelion, cocklebur, ragweeds, winter annuals, lambsquarters, pigweeds etc.
  - Perennial weeds: probably not the best generally only provides the in season control

Specific Characteristics of PGR Herbicides

Herbicide	Water Solubility	Translocation	Persistence
Clopyralid	Acid 1000 ppm Salt 300,000 ppm Weak acid pKa 2.3	Excellent absorption and translocation	Avg 40 days Range 12-70 days
Tricolpyr	Acid 430 ppm Salt 2,000,000 ppm Ester 23 ppm Weak acid pKa 2.7	Excellent absorption and translocation	Avg 30 days Range 10-46
2,4-D	Acid 900 ppm BEE 100 ppm Salt 796 Isooctyl ester 0.03 ppm Weak acid pKa 2.8	Excellent absorption and translocation	Avg 10 days Range 7-32

Status of Synthetic Auxin Resistance

- *Commelina diffusa*
- First reported in Hawaii in 1957
- Selected in sugarcane

- Worldwide there are 30 officially reported cases of auxin herbicide resistance (HRAC website).
- Seven of thirty reports from US
- Only two reported from Brazil

Examples of Auxin Resistant Weeds

Family	Species	Herbicides	Year/Location
Asteraceae	*Carduus nutans*	2,4-D	1981/New Zealand
	C. pycnocephalus	2,4-D	1979/New Zealand
	Cirsium arvense	MCPA	1979/Sweden
	Lactuca serriola	2,4-D, MCPA, dicamba	2007/USA
	Matricaria perforata	2,4-D	1975/France
Brassicaceae	*Raphanus raphanistrum*	2,4-D, MCPA	1999/Australia
	Sisymbrium orientale	2,4-D, MCPA	2005/Australia
	Sinapis arvense	2,4-D, MCPA, mecoprop, dicamba, picloram	1990/Canada
Poeace	*Digitaria ischaemum*	quinclorac	2002/USA
	Echinocloa crus-galli		1999/Brazil
	E. crus-pavonis		1999/Brazil
	E. colona		2000/Colombia

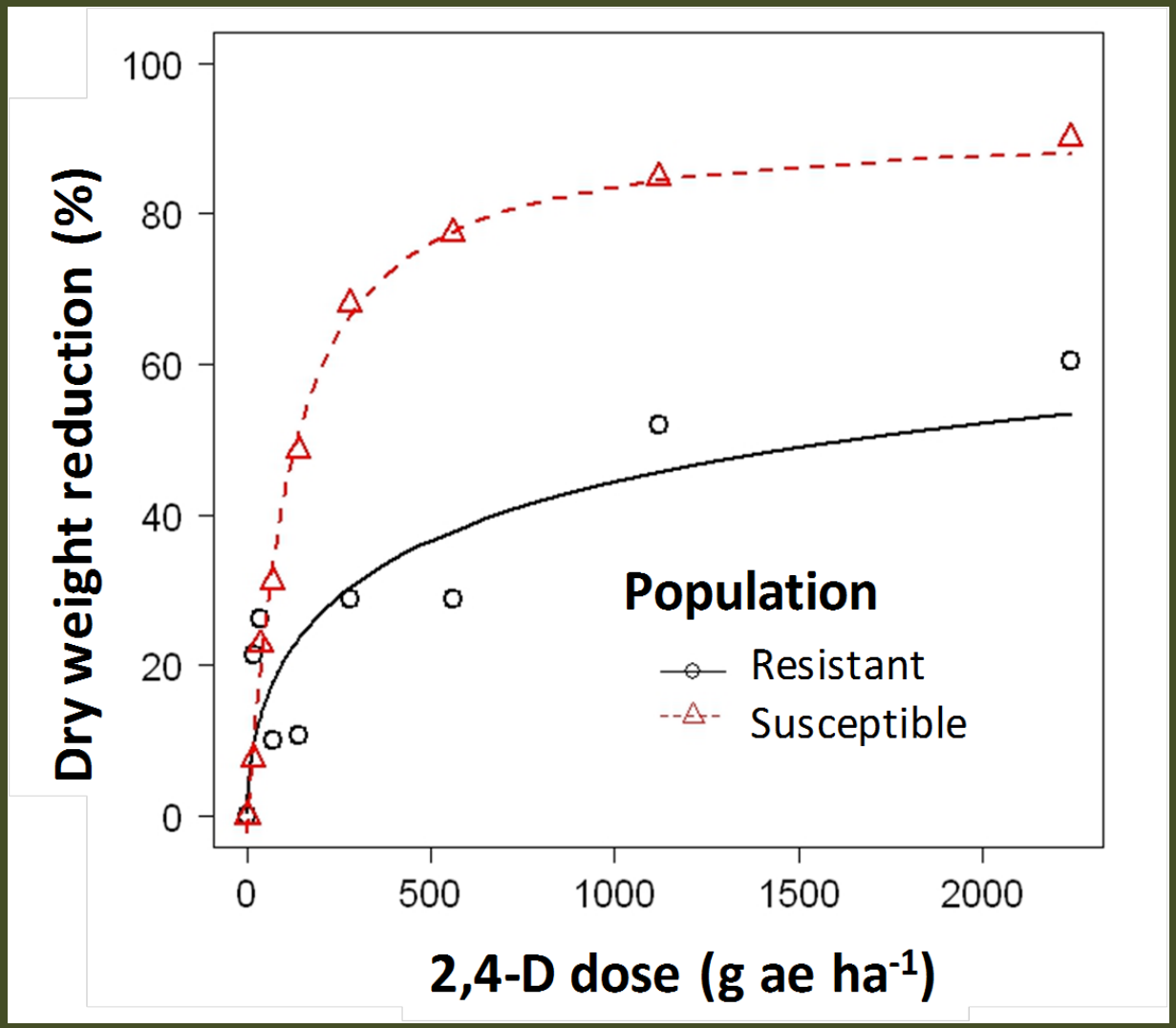
2,4-D Resistant *Amaranthus tuberculatus*

- High level of resistance reported in 2009 from a grass seed field in Western Nebraska, USA
- Herbicide use history was 12 years of 2,4-D use, sometimes multiple applications per year.
- Dr. Pat Tranel (U of I) has already identified *Amaranthus rudis* populations with resistance to 4 herbicide modes of action.
- Enlist™ (Dow Agro) stacked herbicide technology may provide only temporal solution

21 DAT

G. Kruger, UNL

Greenhouse Dose Response 21 DAT



ED50

R:S – 9.1

ED90

R:S – 111

G. Kruger, UNL

Field Evaluations 14 DAT

Untreated

280 g ha^{-1}

1,120 g ha^{-1}

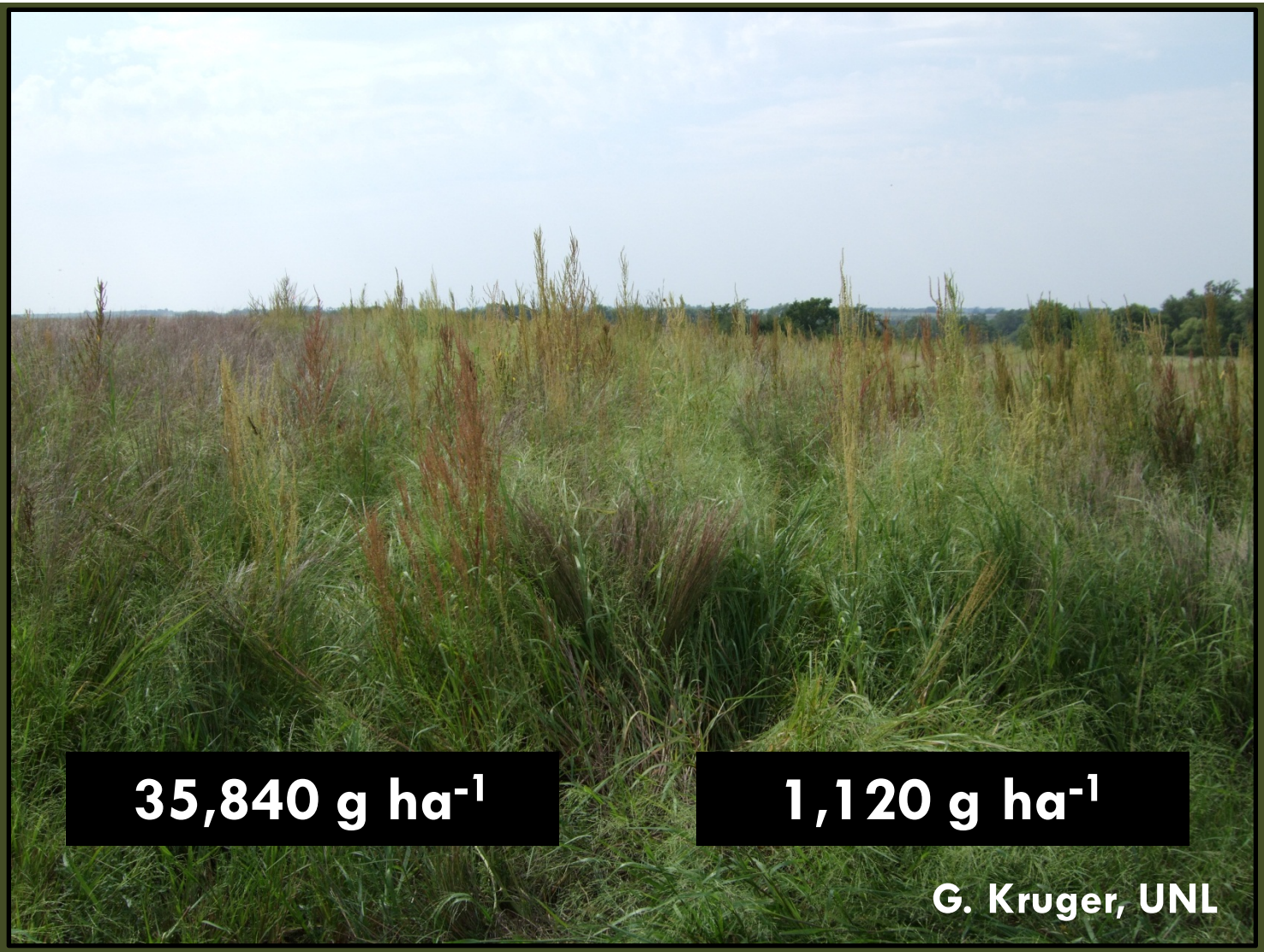
G. Kruger, UNL

Field Evaluations 14 DAT

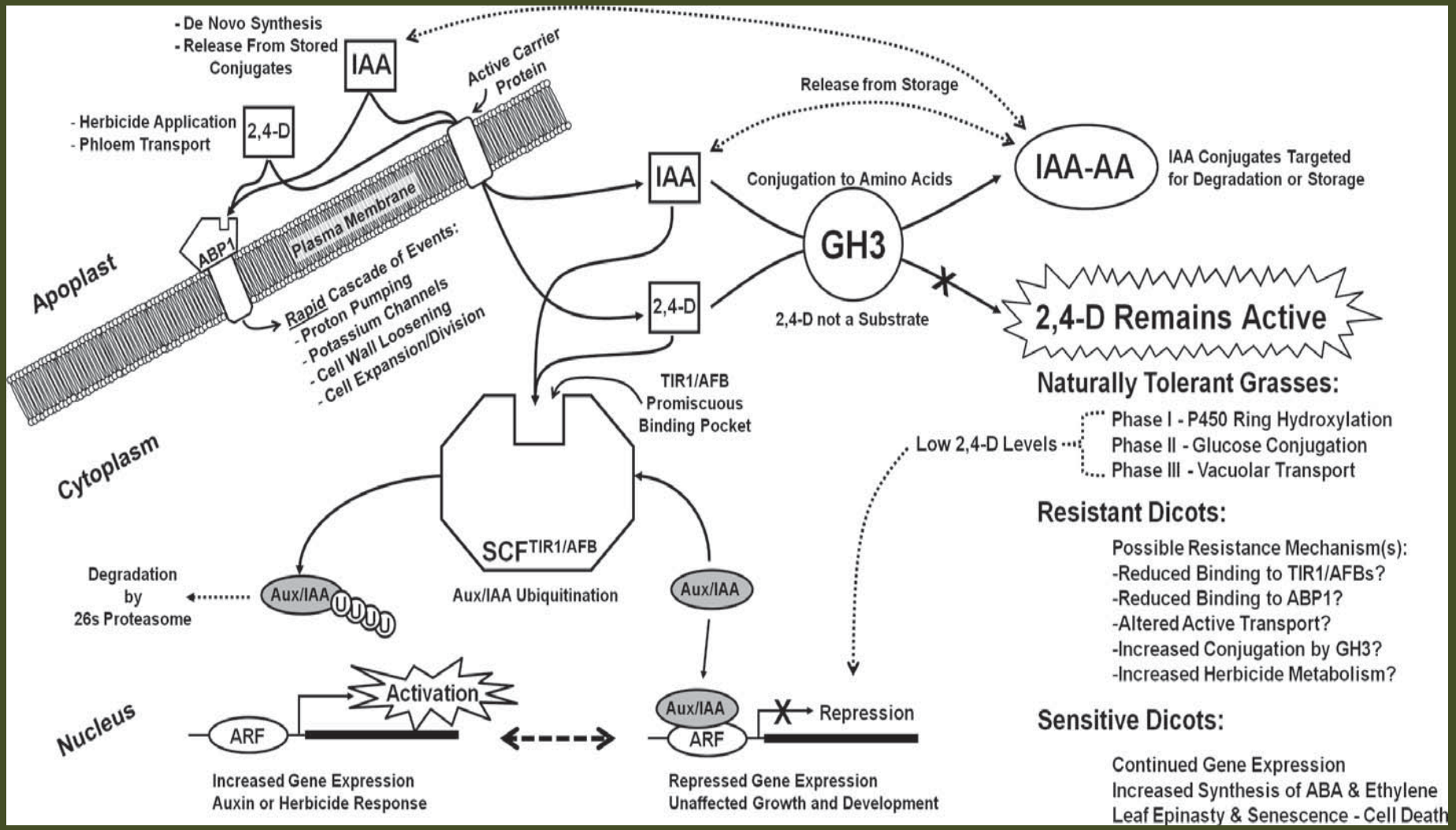
4,480 g ha^{-1} 8,960 g ha^{-1} 35,840 g ha^{-1}

G. Kruger, UNL

Recovery and Flowering 84 DAT



Proposed Resistance Mechanisms



Possible Mechanisms of Auxinic Herbicide Resistance

- Reduced binding to the ABP1
- Reduced binding to other receptors (TIR1, AFB)
- Altered active transport
- Increased conjugation
- Increased metabolism

Implications For USA

- *A. tuberculatus* could force significant changes in mid-west production systems. (Dr. Pat Tranel, UI)
- *A. tuberculatus* is native species, there is no genetic bottle neck, massive amounts of genetic variability to select from.
- Enlist™ (Dow Agro) stacked herbicide technology and Monsanto's dicamba resistant varieties will provide a temporary solution.
- Very high levels of 2,4-D resistance have been identified in Nebraska.
- HPPD herbicides were thought to provide a bridge until new modes of action could be discovered, we already have the first case of resistance.

Implications for Brazil

- Is there a *A. palmeri* or *A. tuberculatus* type plant lurking somewhere in Brazil or in surrounding country? (Blame it on Paraguay?)
- Brazil has the advantage of watching the US and hopefully preventing the same things from happening here.
- Coordination for resistance management efforts will be critical with university, industry and grower partnerships.

Acknowledgements

- Dr. Greg Kruger, University of Nebraska-Lincoln
- Dr. Mithila Jugulam, Kansas State University