Pesticide Fate in Soil and Plants

Travis W. Gannon, Ph.D

What We'll Talk About

- Why is pesticide fate important?
  - Pesticide behavior in soil
  - Systemic nature of pesticides

Pesticide Fate

Why is it important???

Preserve tools (pesticides) today, while providing information required for the implementation of best application practices in the future

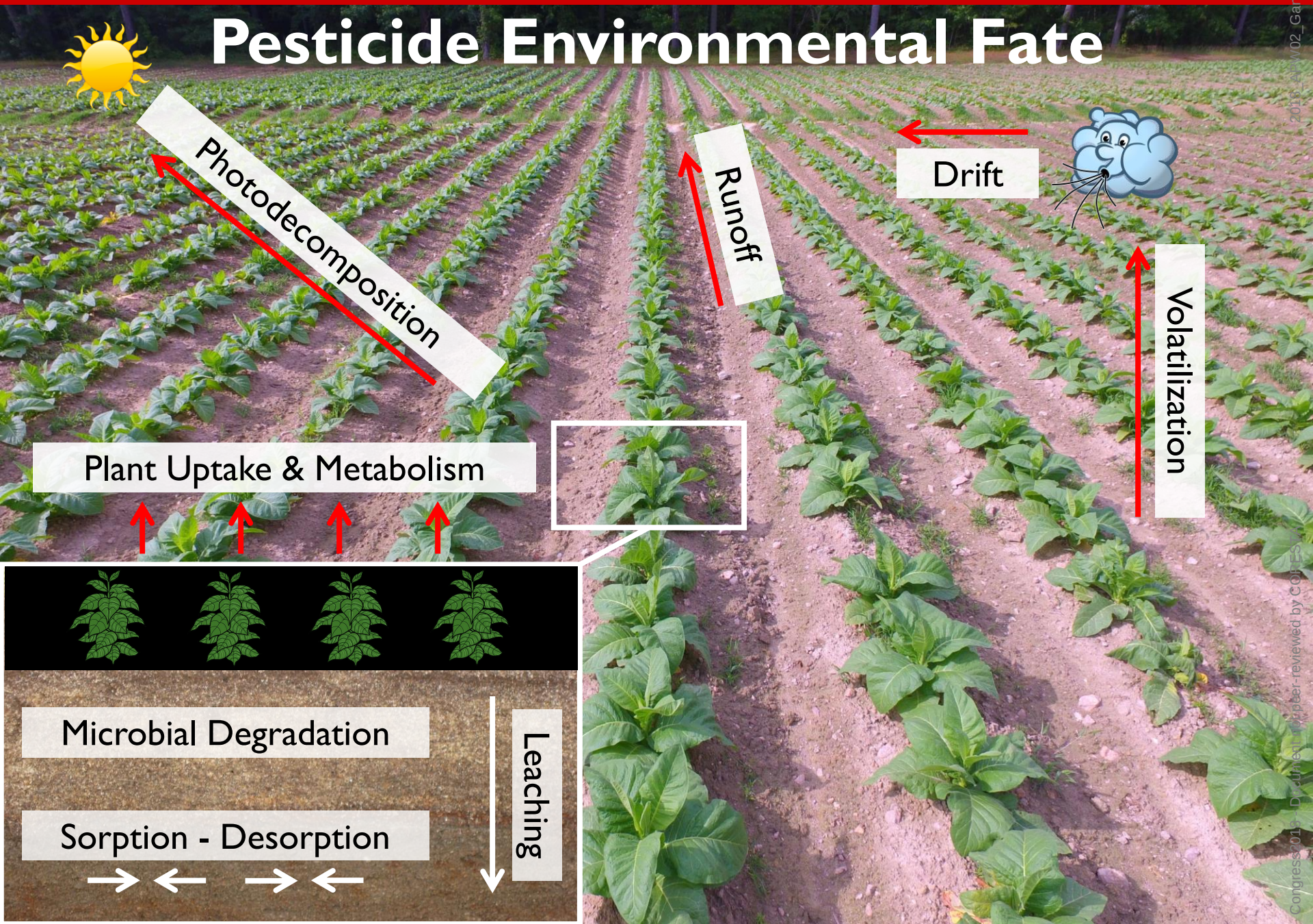
Pesticide Fate

Why is it important???

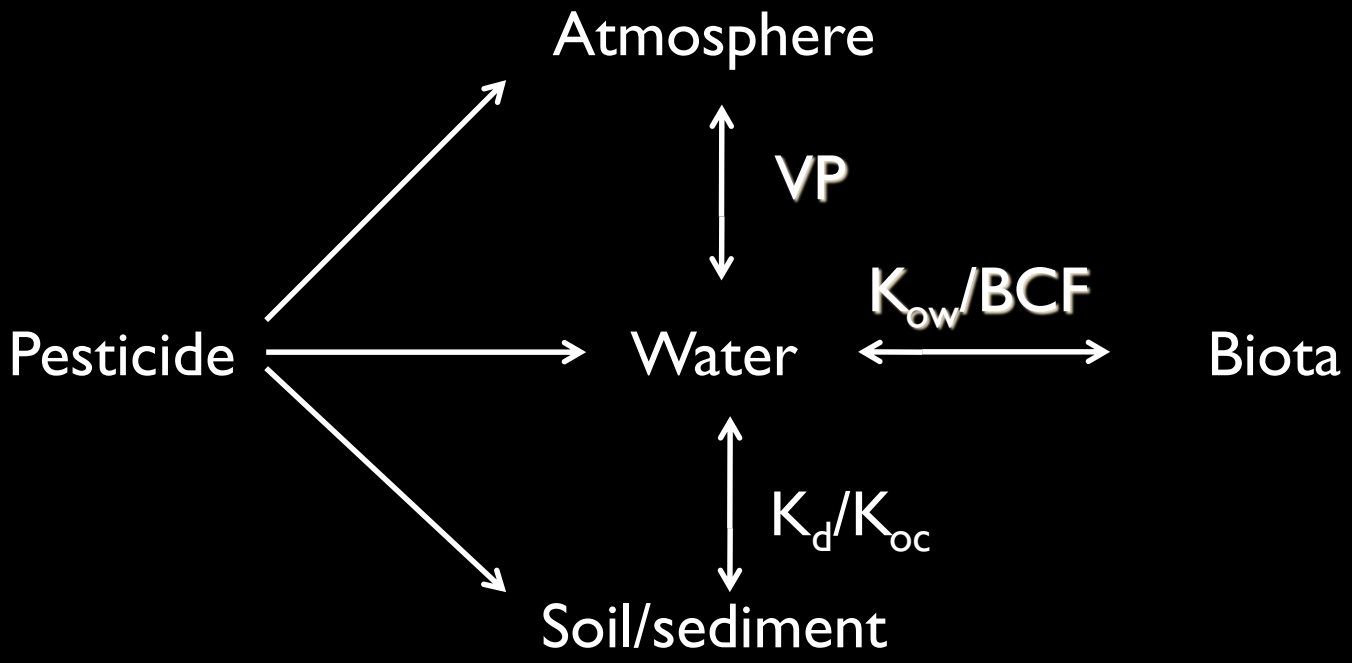
- Keep the right pesticides on the market
- Residue management
- Improve comprehensive IPM plans
- Reduce potential for adverse effects on off-target areas or species

  off-target movement = angry neighbors or health issues

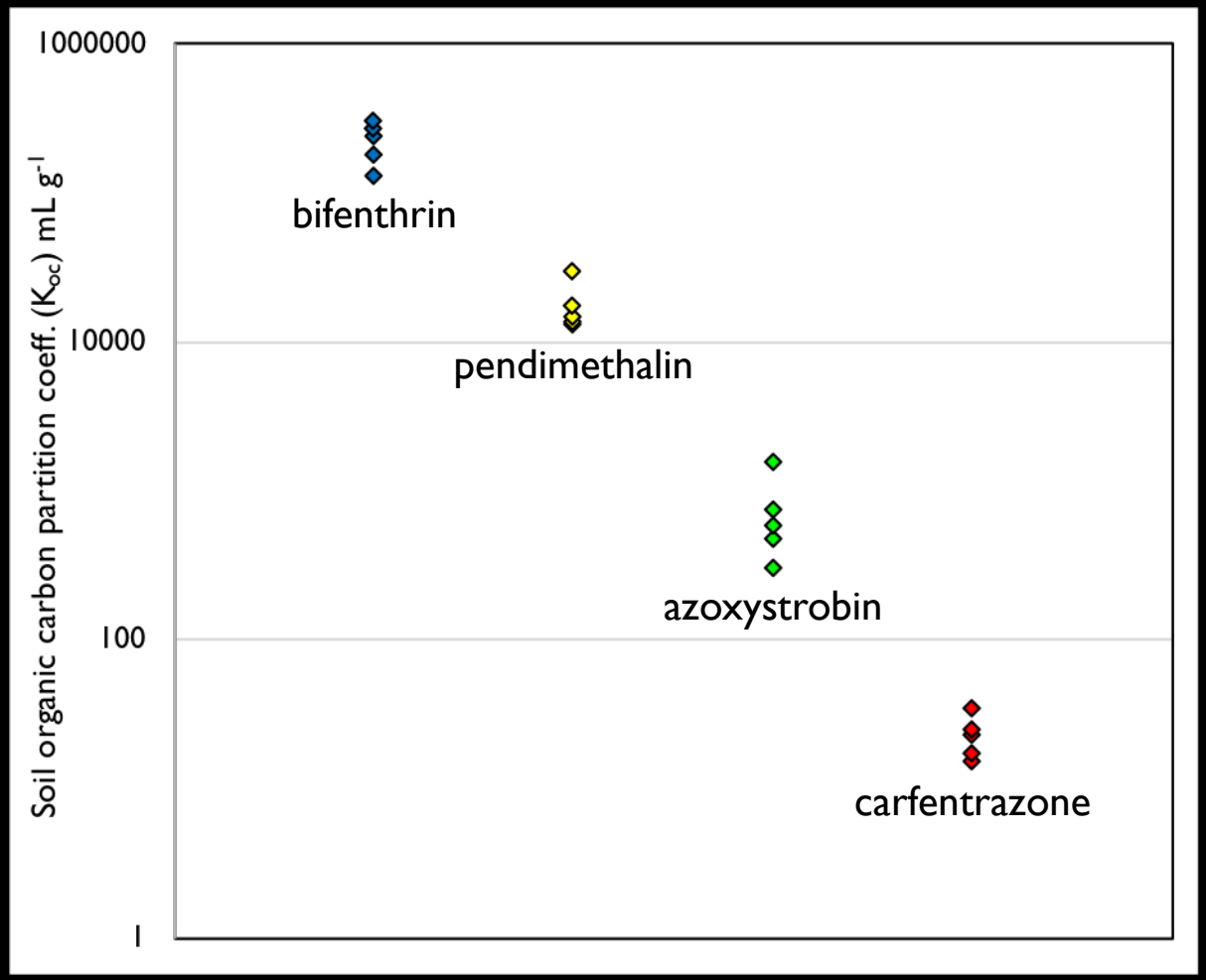
Pesticide Environmental Fate

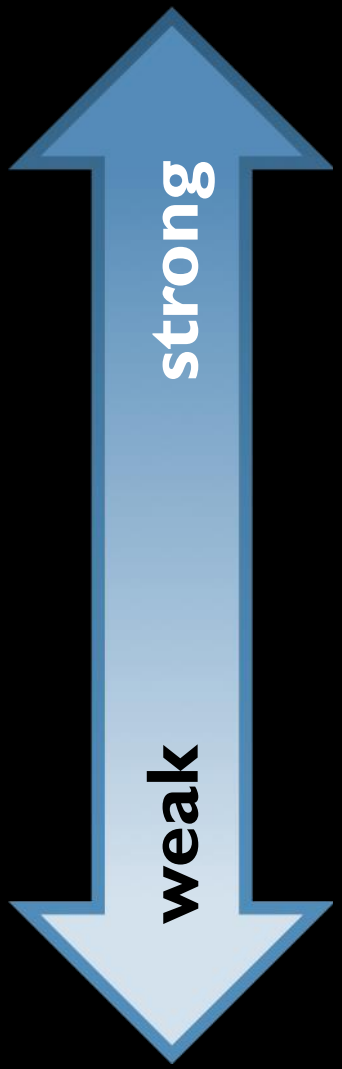


What Happens After Pesticide Application



Soil Adsorption





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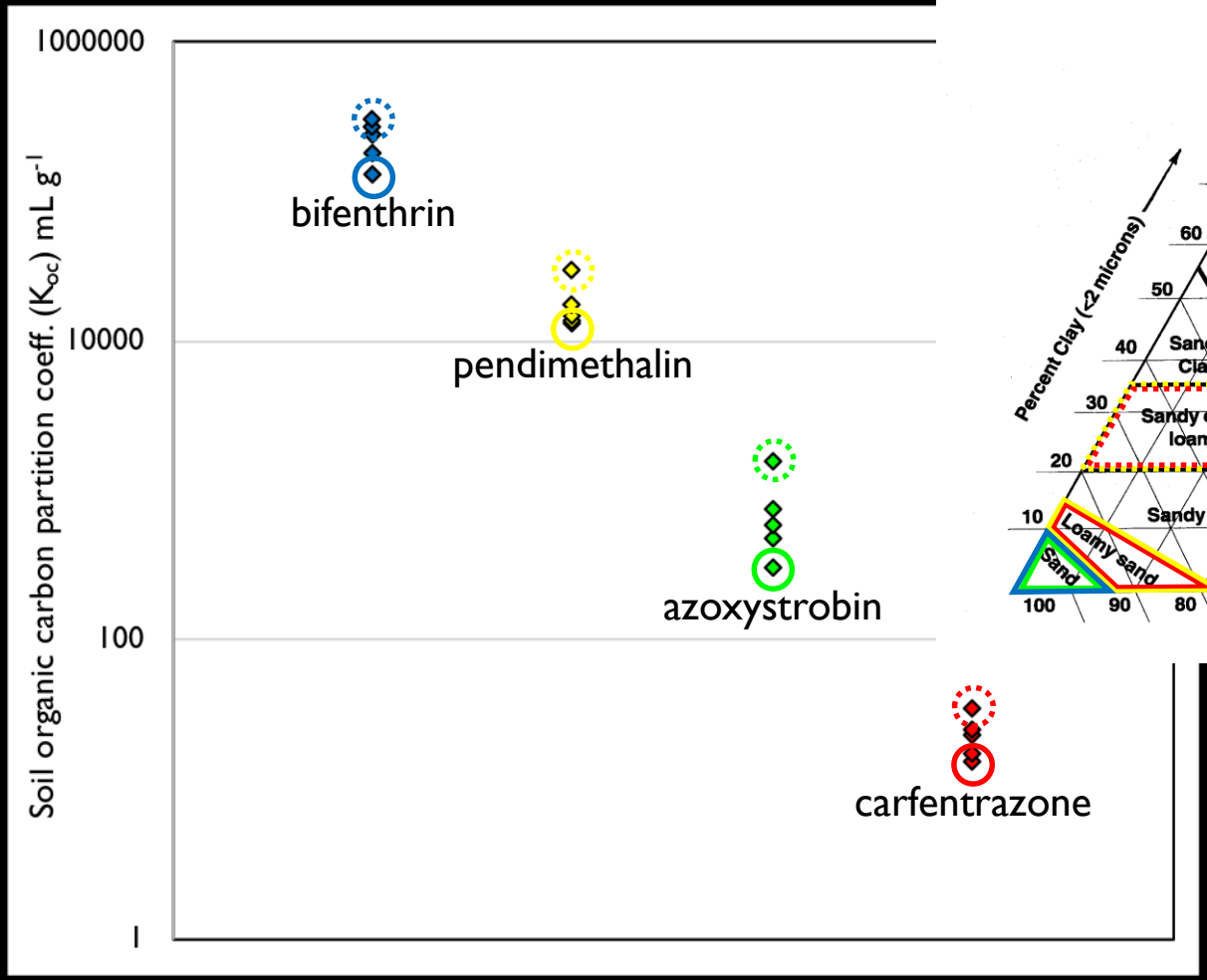
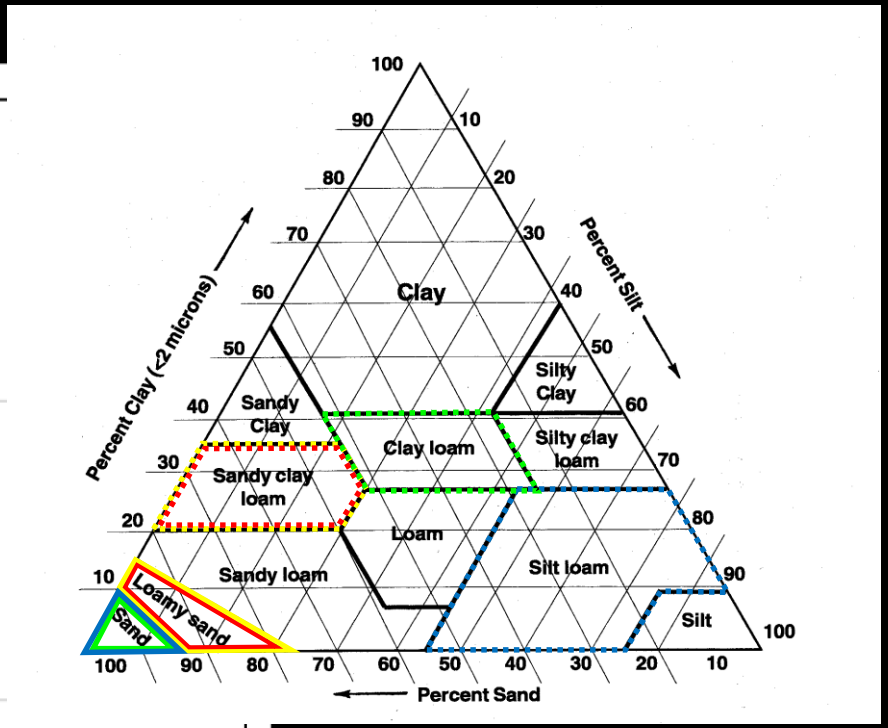
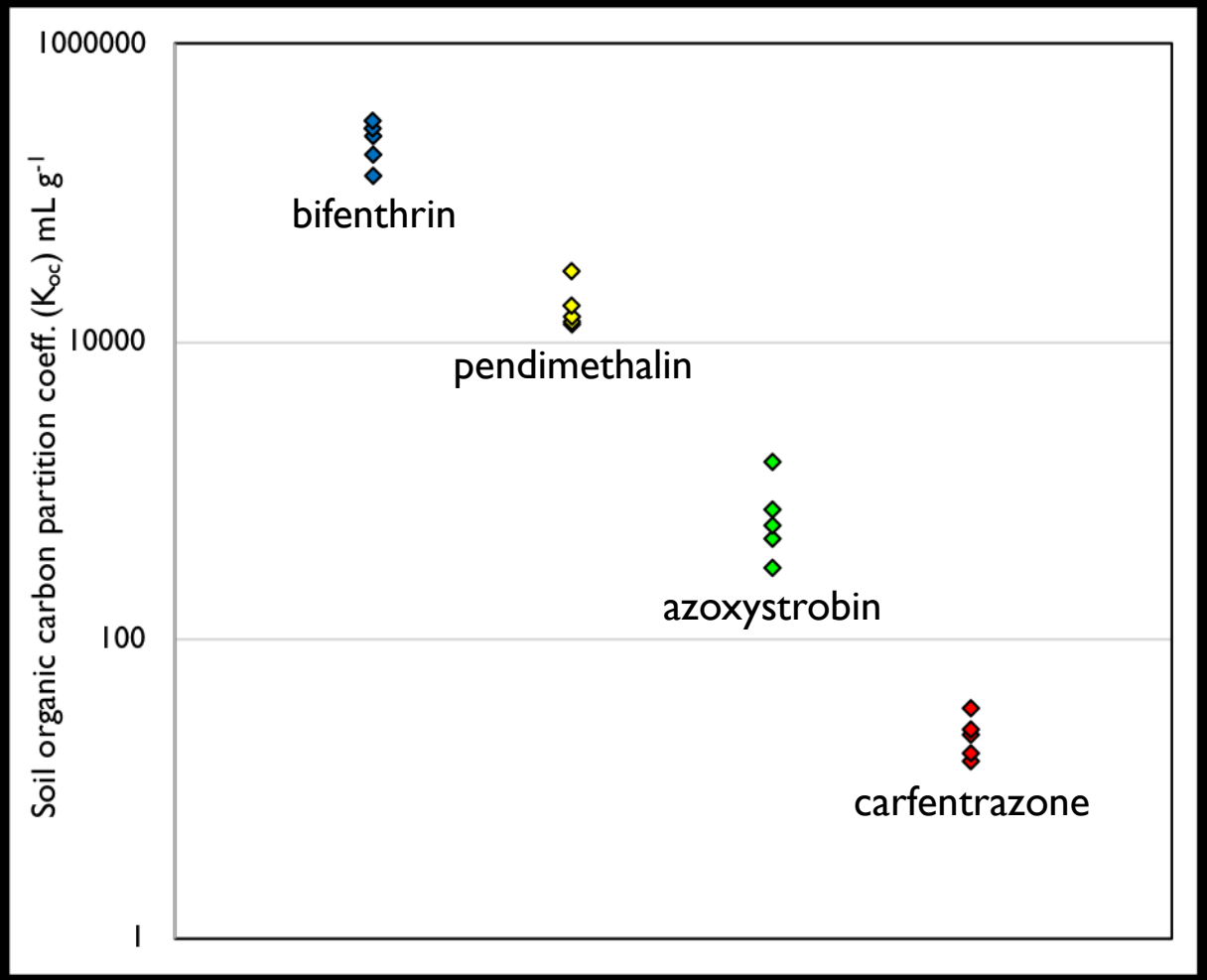




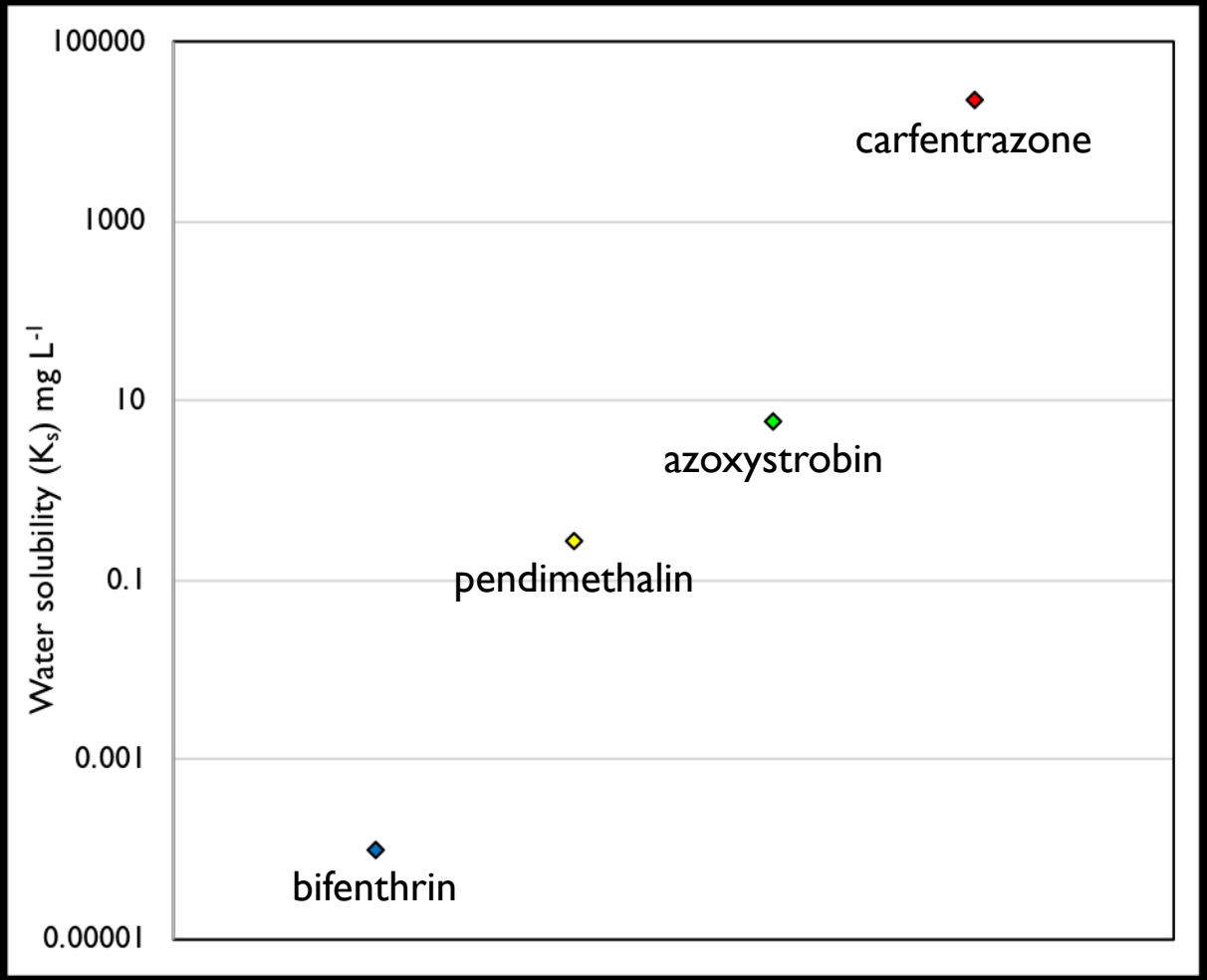
K_{oc} values will vary depending on soil texture evaluated

Soil Adsorption



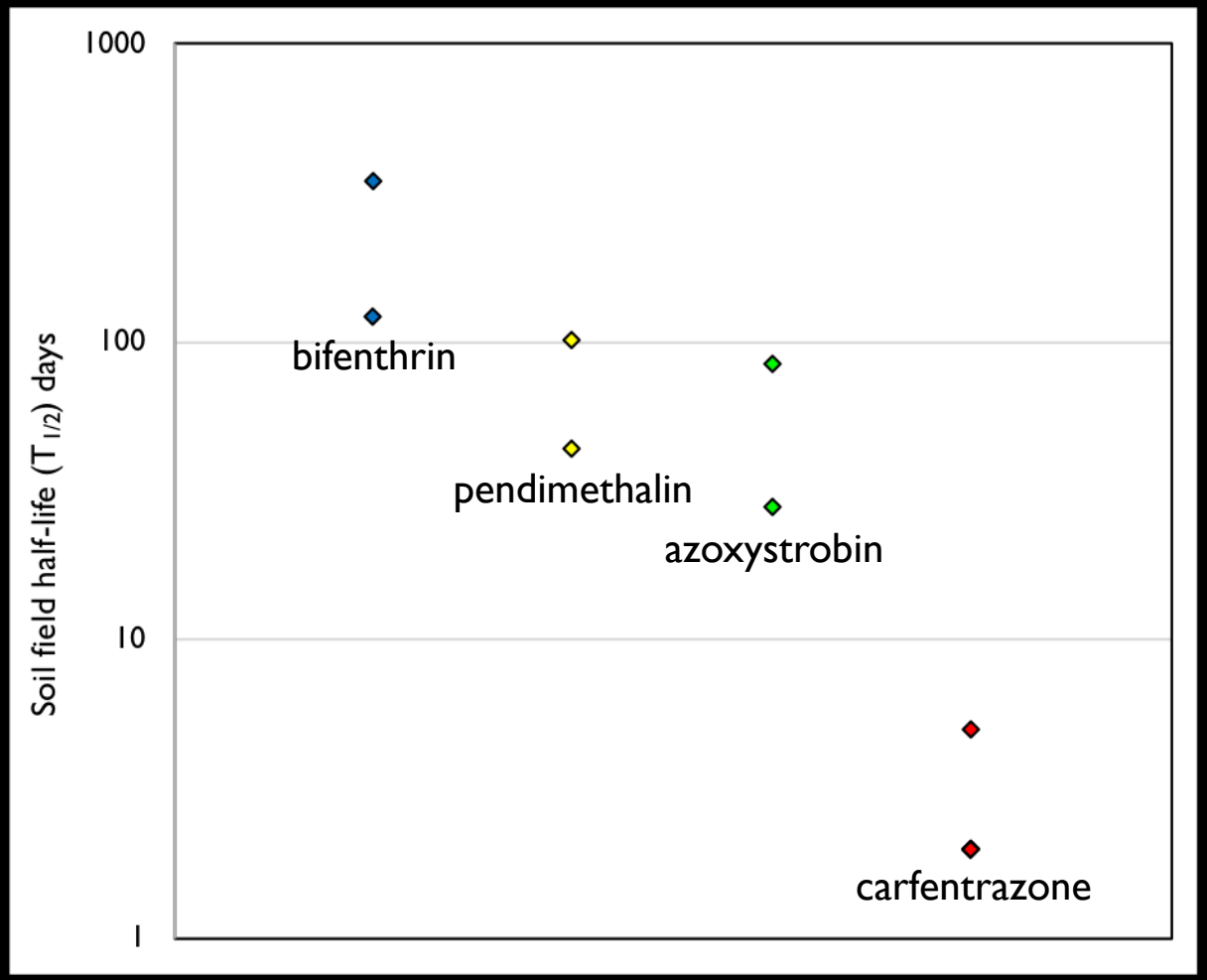
K_{oc} (mL/g)	Solubility class
>5000	Very Strong
2000 - 5000	Strong
500 - 2000	Moderate
50 - 500	Weak
<50	Very Weak

Water Solubility



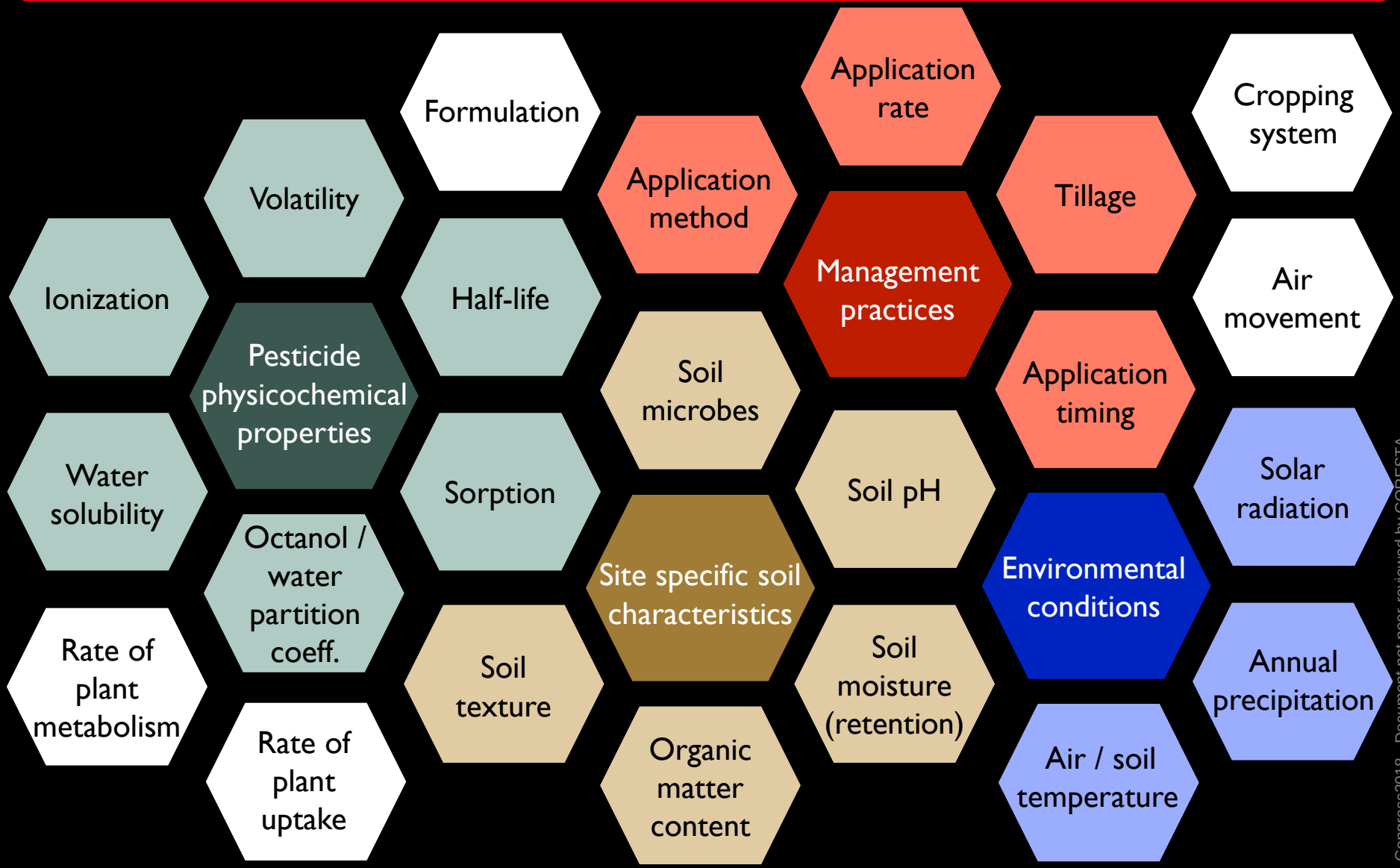
K_s (mg/L)	Solubility class
>5000	Very High
1000 - 5000	High
100 - 1000	Moderate
10 - 100	Low
<10	Very Low

Persistence



$T_{1/2}$ (days)	Persistence class
>150	Very Long
100 - 150	Long
30 - 100	Moderate
5 - 30	Short
<5	Very Short

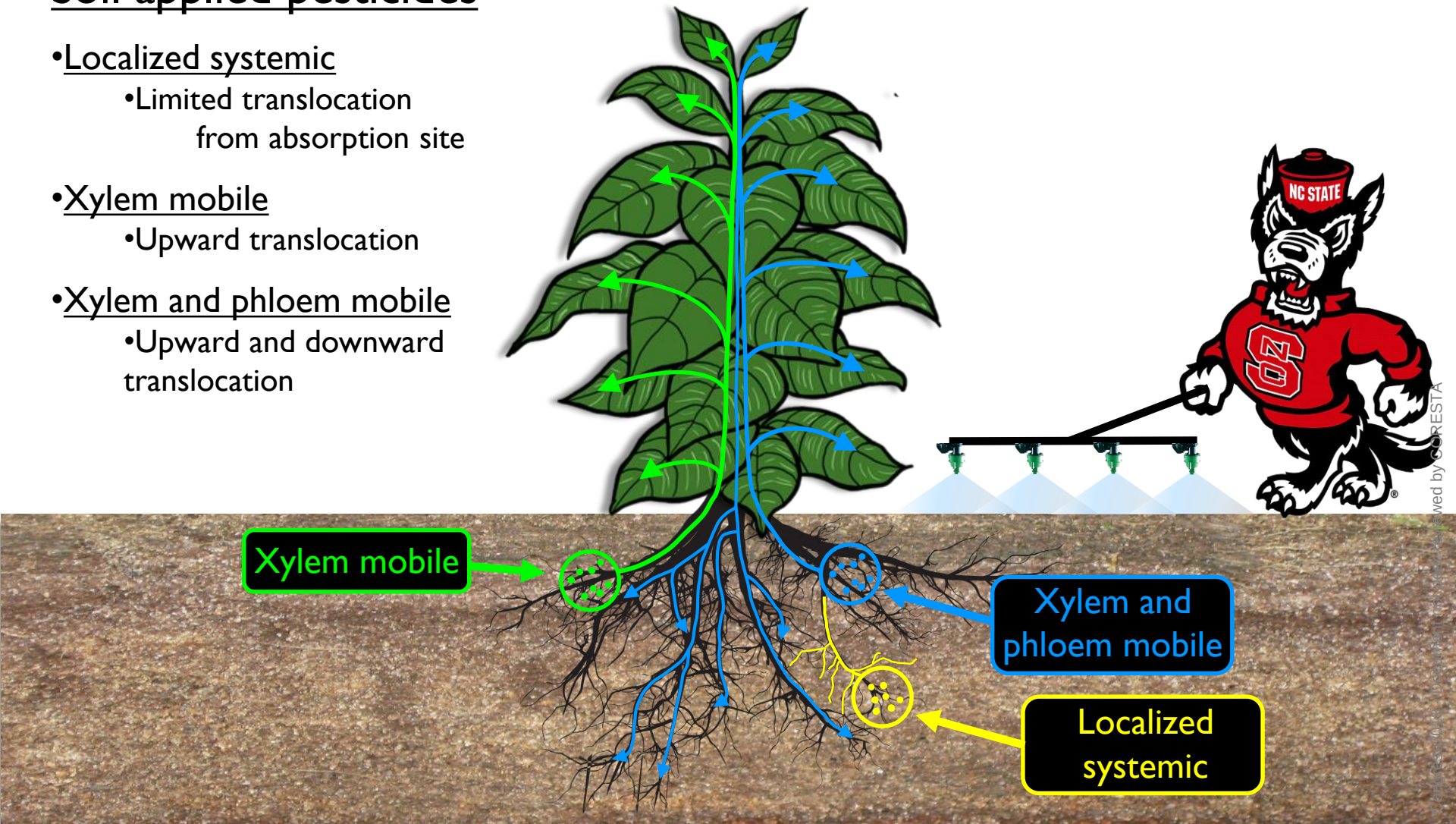
Factors Affecting Pesticide Fate



Root Uptake and Translocation

Soil applied pesticides

- Localized systemic
  - Limited translocation from absorption site
- Xylem mobile
  - Upward translocation
- Xylem and phloem mobile
  - Upward and downward translocation



Pesticide K_{ow}

$$K_{ow} = \frac{\text{concentration in octanol phase (}\textit{lipophilic}\text{)}}{\text{concentration in aqueous phase (}\textit{lipophobic}\text{)}}$$

Octanol and water are immiscible, therefore this measurement serves as a relatively good approximation of the partitioning between the cytosol and lipid membranes of living systems.

Pesticide K_{ow}

K_{ow} values can be used to predict pesticide:

- water solubility
- sorption affinity
- propensity to bioaccumulate
- plant uptake and subsequent translocation

"K_{ow}" is often presented as "log K_{ow}" with values ranging from -3 to 7

Pesticide	Log K_{ow}	Water solubility (mg/L)	K_d Soil sorption (mL/g)
Acephate	- 0.9	790,0000	0.9
Imidacloprid	0.6	610	132 to 310
Clomazone	2.5	1,110	150 to 562
Pendimethlin	5.3	0.275	17,200
Bifenthrin	6.0	0.001	131,000 to 302,000

Effect of log K_{ow} on Absorption

Briggs et. al. 1982 investigated the relationship between lipophilicity and root uptake and translocation of nonionizable pesticides in barley.

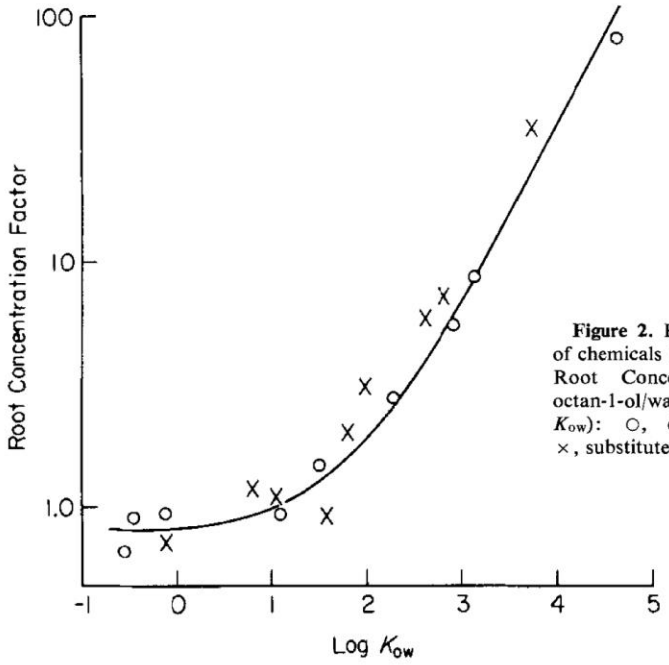


Figure 2. Relationship between the uptake of chemicals by barley roots (expressed as the Root Concentration Factor), and their octan-1-ol/water partition coefficients (as log K_{ow}): ○, *O*-methylcarbamoyloximes; and ×, substituted phenylureas.

Root uptake of lipophilic chemicals is dominated by physical sorption.

Briggs et. al. 1982

Effect of log K_{ow} on Translocation

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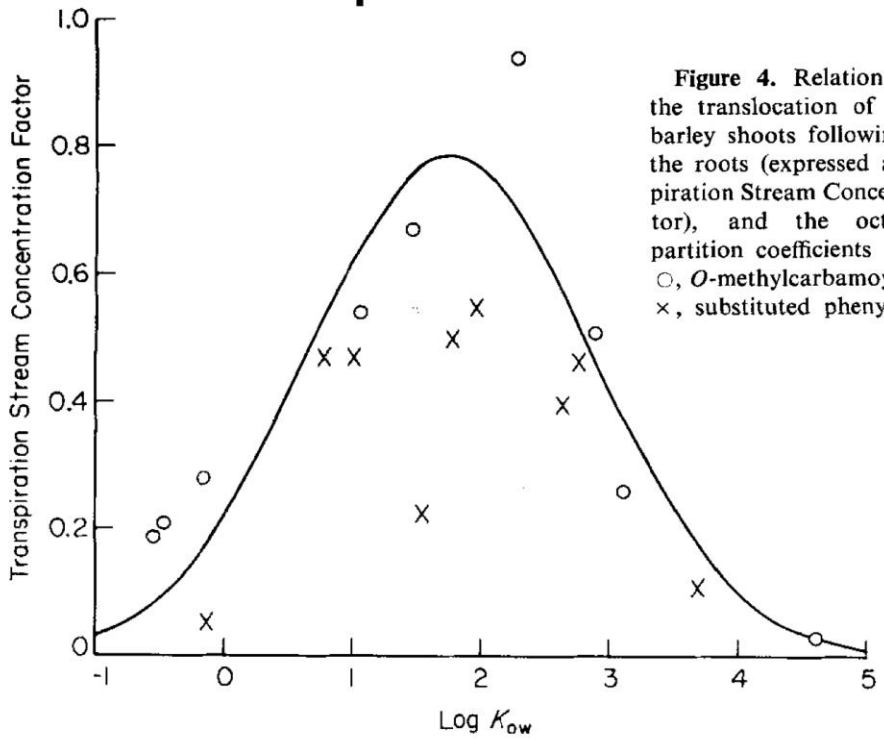

Figure 4. Relationship between the translocation of chemicals to barley shoots following uptake by the roots (expressed as the Transpiration Stream Concentration Factor), and the octan-1-ol/water partition coefficients (as log K_{ow}): ○, *O*-methylcarbamoyloximes; and ×, substituted phenylureas.

Transpiration stream concentration factor is estimated by determining the amount of the compound accumulating in the shoot per volume of water translocated.

Briggs et. al. 1982

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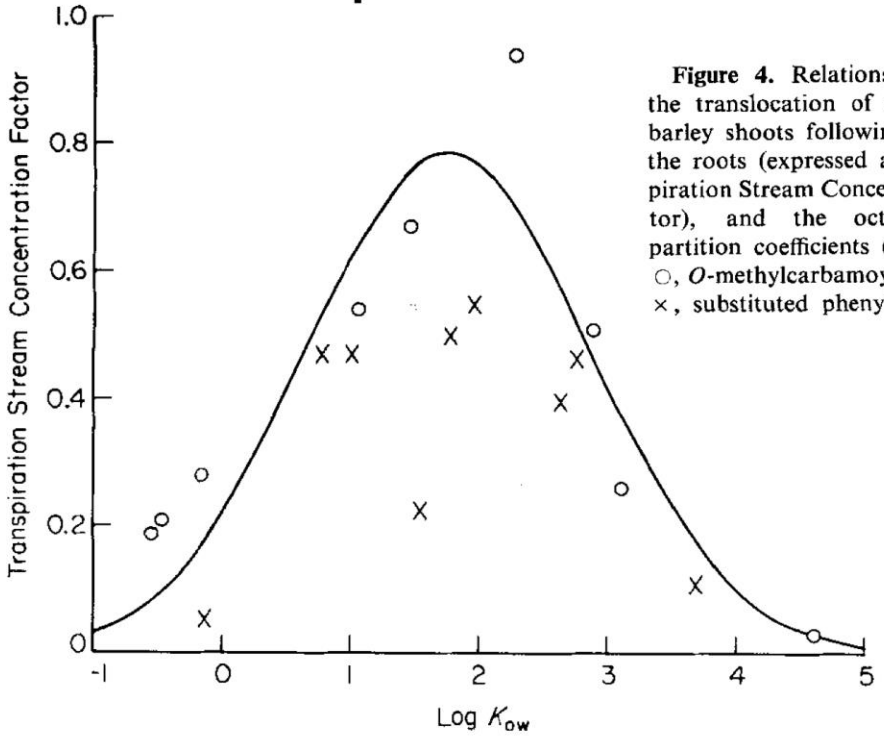

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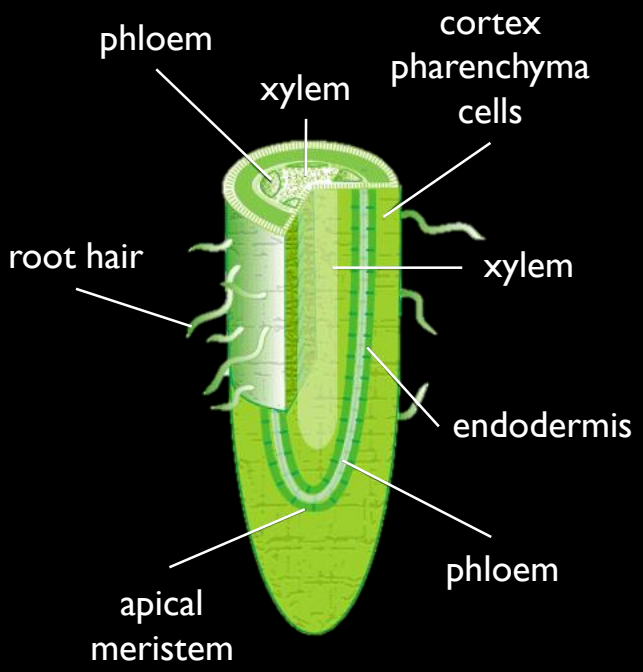
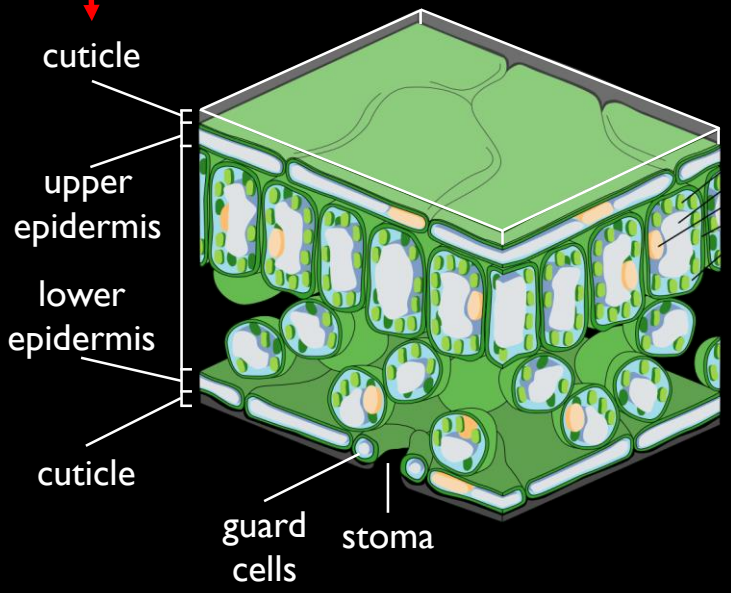
Optimum log K_{ow} for translocation is -0.5 to 3.5 (hydroponic culture).

Briggs et. al. 1982

Root vs. Leaf Morphology



Embedded with waxes (*give plants glossy appearance*)



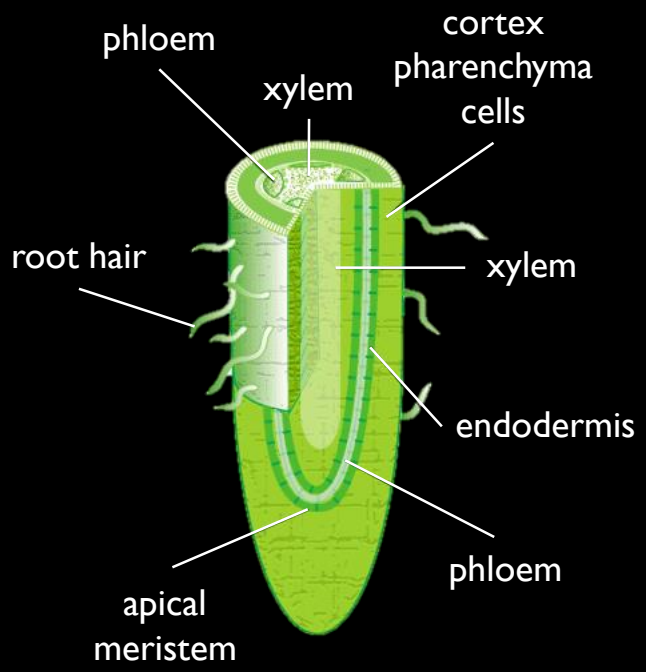
Root

- Absorb and translocate water and minerals to stem
- Store food

Leaf

- Primary photosynthetic organ
- Prevent water loss
- Allow gas exchange

Root vs. Leaf Morphology



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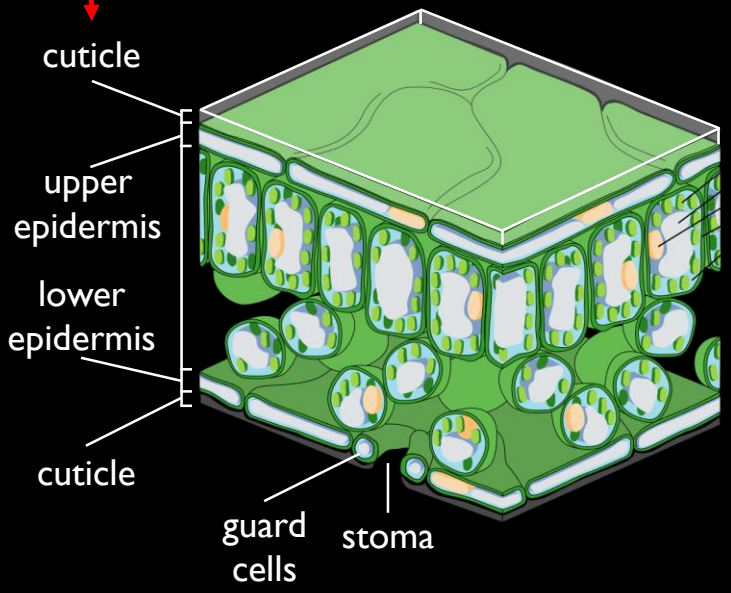

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Foliar Absorption and Translocation

Foliar applied pesticides

- Contact
  - No translocation
- Localized systemic
  - Limited translocation from absorption site
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  - Upward translocation
- Xylem and phloem mobile
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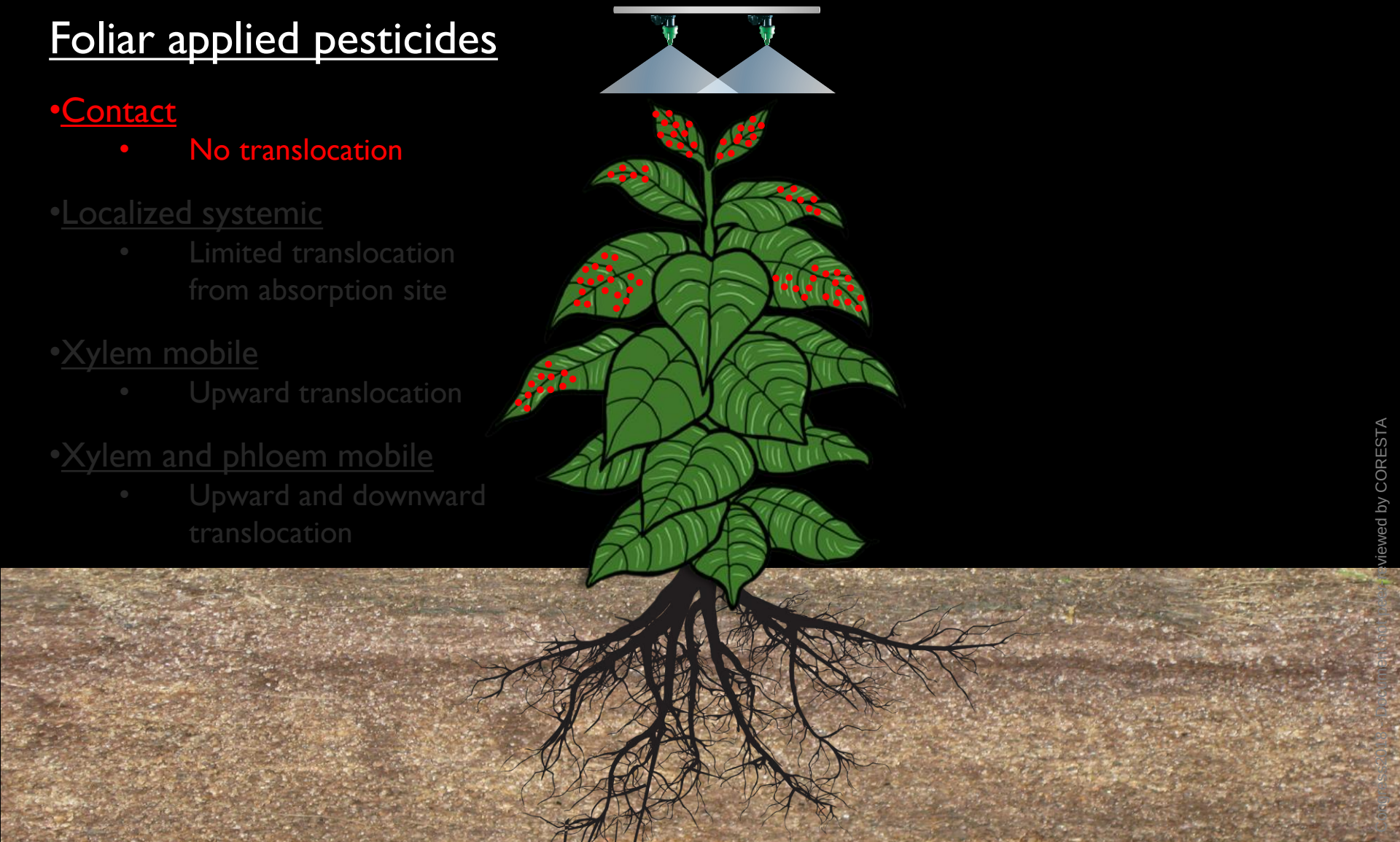

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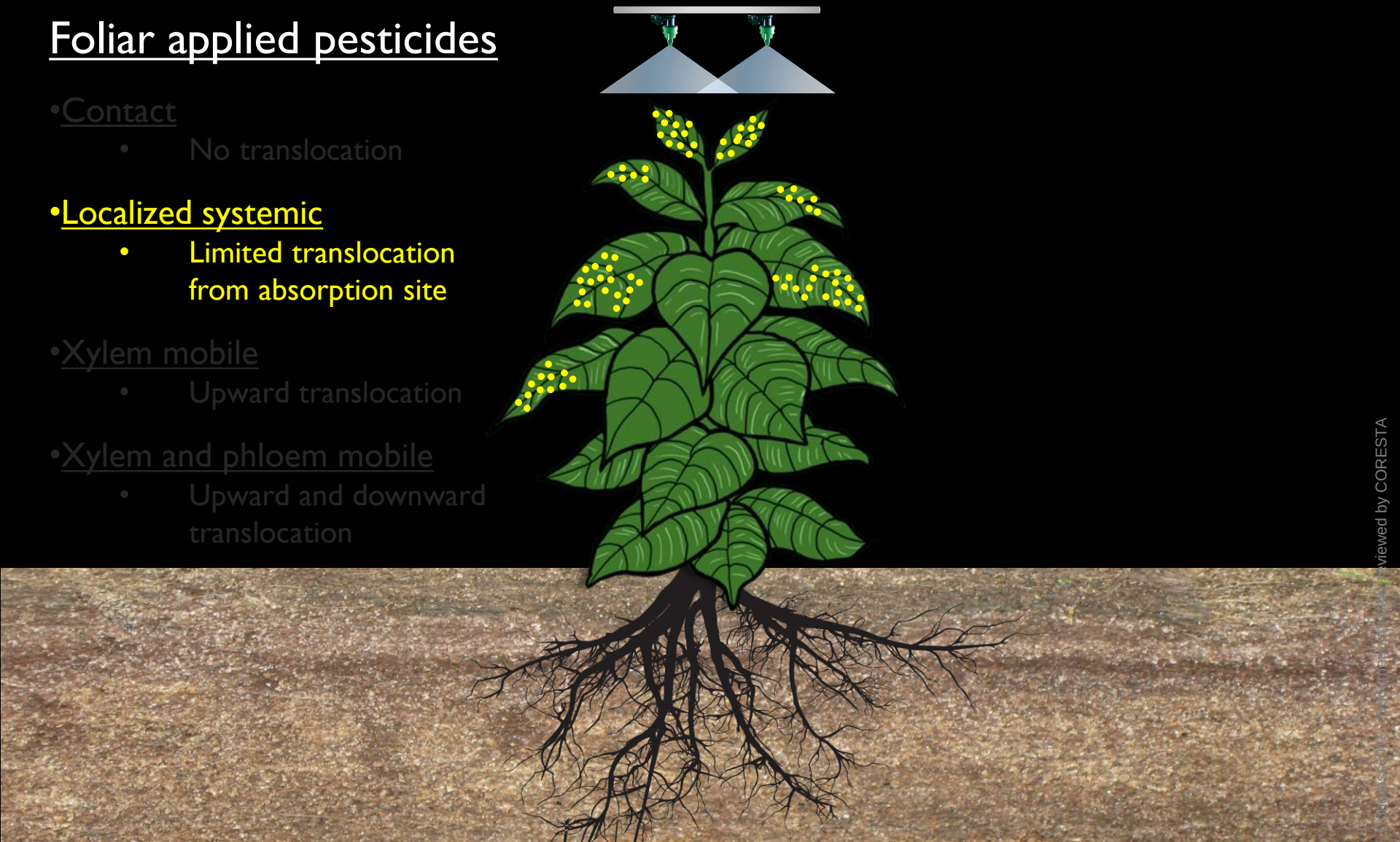

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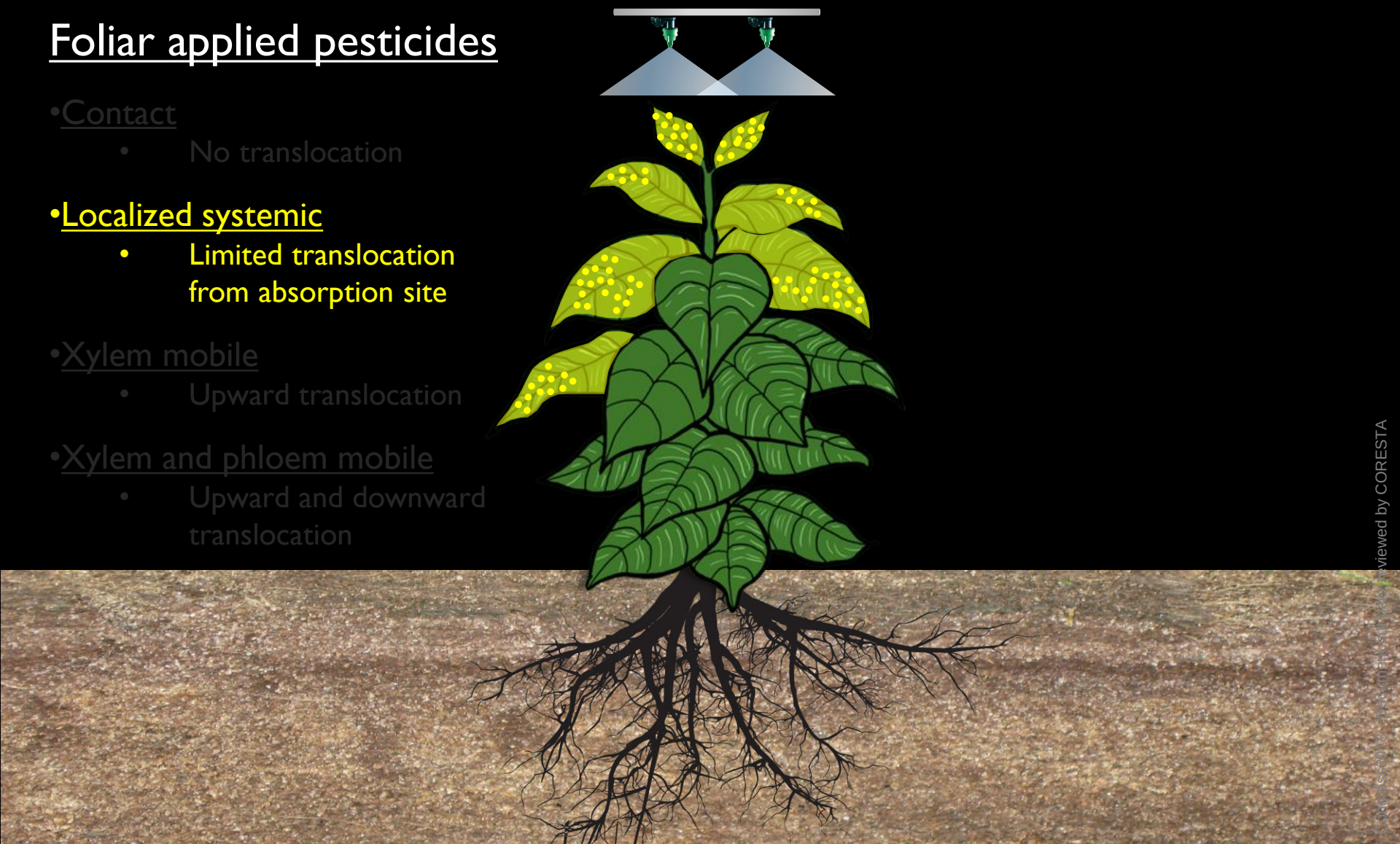

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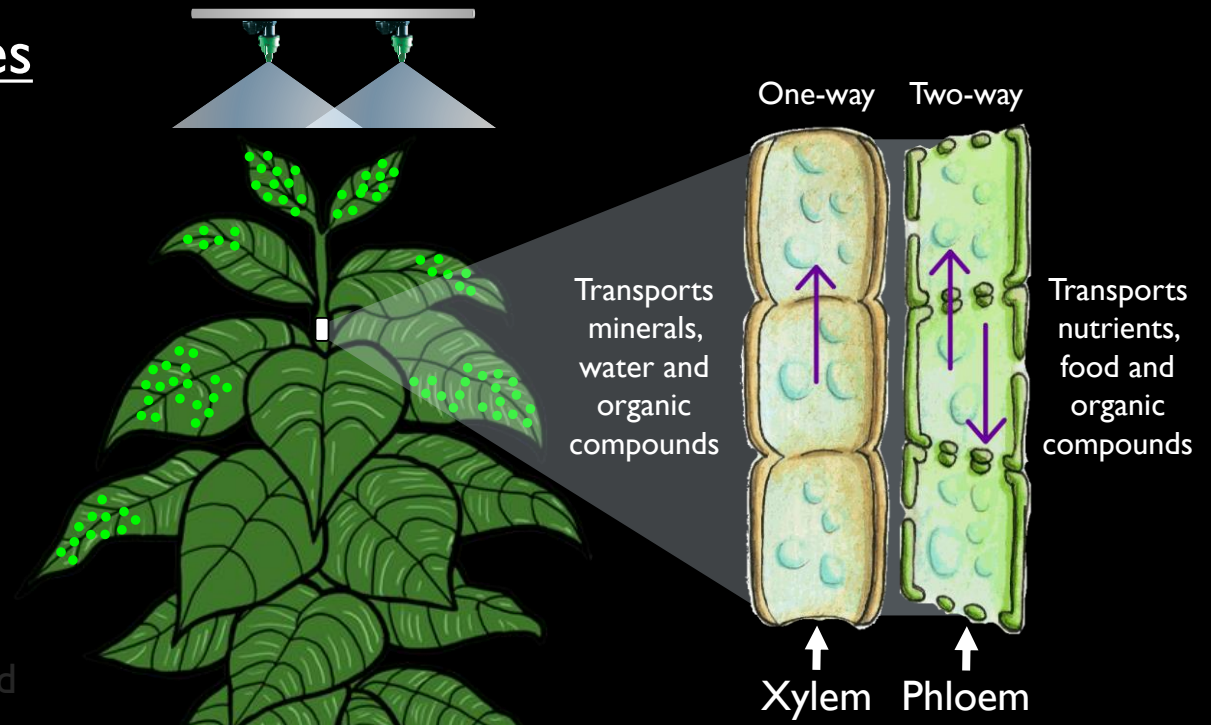

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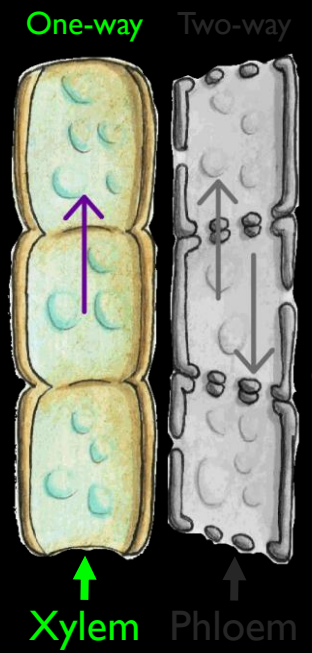

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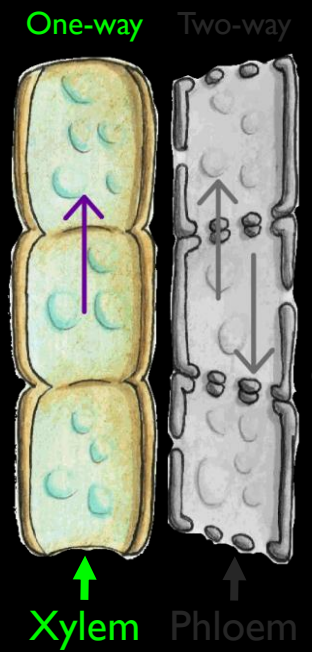

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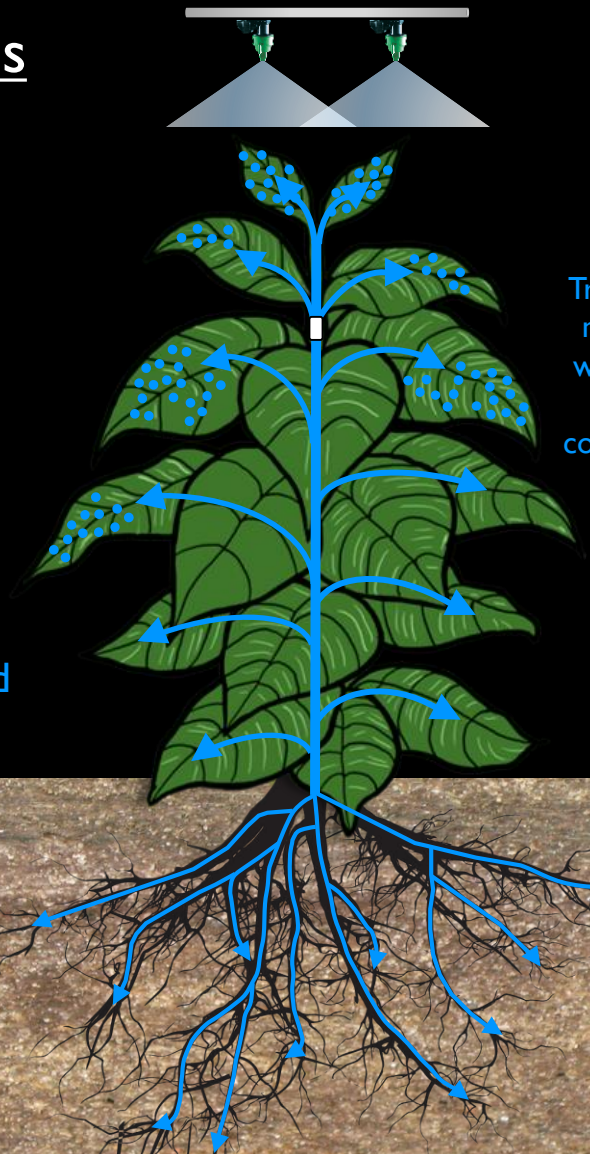

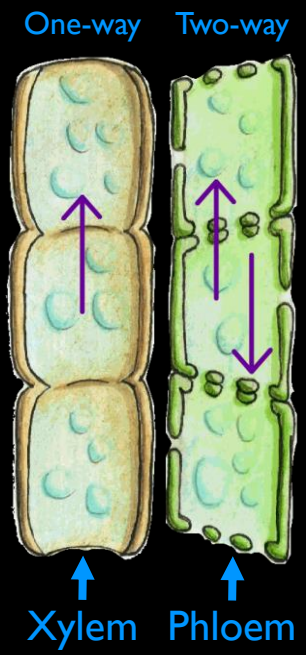

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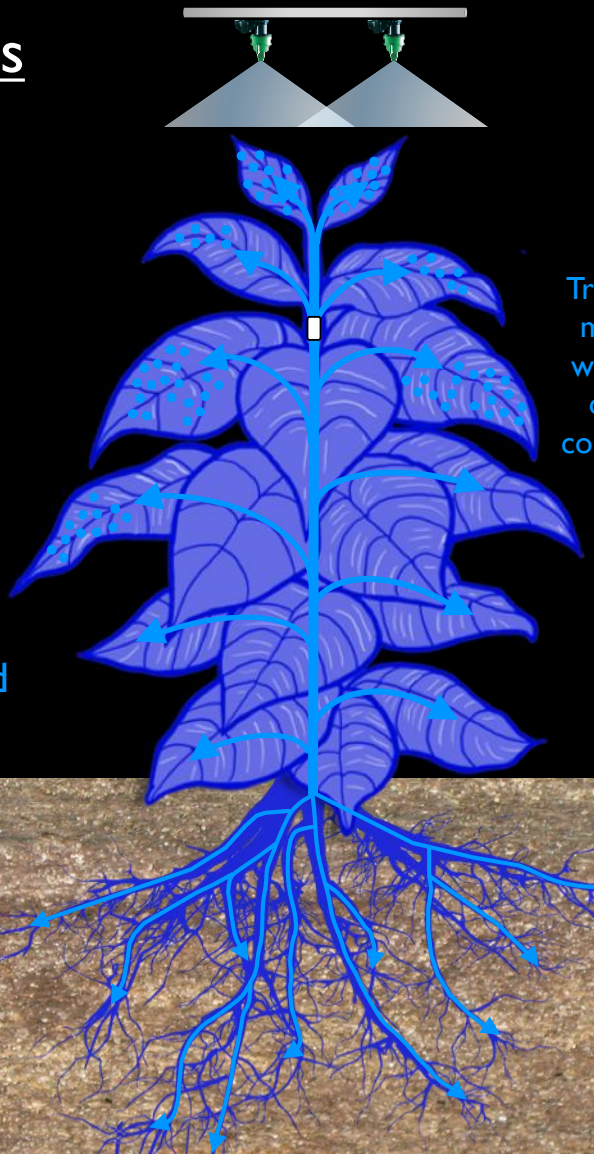

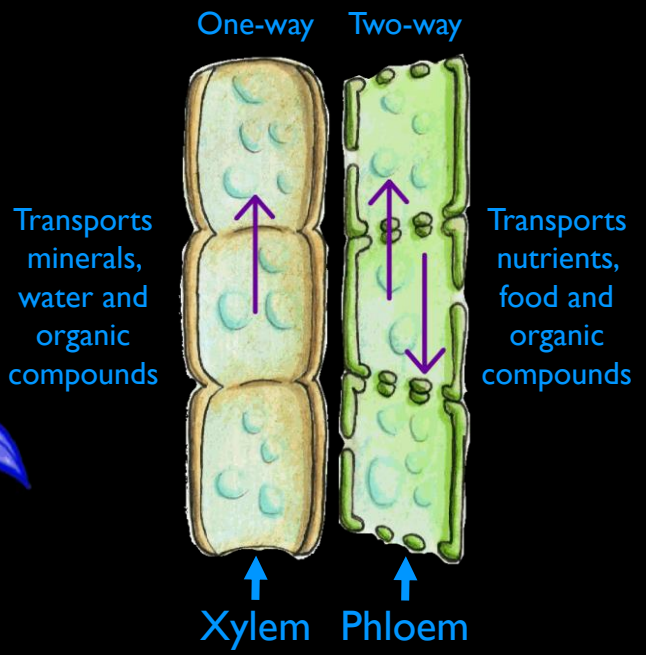

Pesticide Persistence in Foliage Affected by…

- Many factors including but not limited to:
  - Physicochemical properties of pesticide
    - Volatility, solubility, etc.
  - Environmental factors
    - Temperature, precipitation, humidity, air movement, etc.
  - Application timing
    - Rate of growth

Herbicide Properties

Herbicide	Soil sorption K_{oc} (mL/g)	Persistence soil field $T_{1/2}$ (days)	Translocated via:	Water solubility K_s (mg/L)
Carfentrazone	15 to 25	2.4 hours	Limited	12,000
Clomazone	150 to 562	5 to 60	Limited	1,100
Maleic hydrazide	23 to 250	2 to 7	Xylem and phloem	300,000
Napropamide	600	70	Xylem	73
Pebulate	430	36 to 60	Xylem	60
Pendimethalin	17,200	44	Limited	0.275
Sethoxydim	100	5	Xylem and phloem	1,040
Sulfentrazone	43	121 to 302	Limited	110 to 1,600

Insecticide Properties

Insecticide	Soil sorption K_{oc} (mL/g)	Persistence soil field $T_{1/2}$ (days)	Translocated via:	Water solubility K_s (mg/L)
Acephate	0.9	2 to 7	Limited	790,000
Acetamiprid	71 to 313	8.2	Xylem and phloem	2,950
Azadirachtin	21 to 875	2 to 25	Xylem	260
Bifenthrin	236,750	122 to 345	Limited	0.001
Chlorantraniliprole	328,000	1130	Xylem and phloem	1.0
Cyantraniliprole	128 to 266	32.3	Xylem and phloem	14.2
Imidacloprid	132 to 310	27 to 229	Xylem and phloem	610
Lambda-cyhalothrin	180,000	28 to 84	Xylem	0.0042
Pymetrozine	2,245	14	Xylem and phloem	290
Spinosad	4,237	9 to 17	Localized systemic	235

Fungicide Properties

Fungicide	Soil sorption K_{oc} (mL/g)	Persistence soil field $T_{1/2}$ (days)	Translocated via:	Water Solubility K_s (mg/L)
Acibenzolar	1,394	20	Xylem and phloem	7.7
Azoxystrobin	210 to 580	28 to 85	Xylem	6.7
Dimethomorph	290 to 566	35 to 53	Xylem (localized)	49.2
Fluopicolide	25,000	107	Xylem	2.8
Fosetyl-Al	0.1	1 hour	Xylem and phloem	111,300
Mancozeb	998	1 to 7	Limited	6.2
Mandipropamid	847	75 to 101	Localized systemic	4.2
Mefenoxam	20 to 790	42	Xylem	26,000

Pesticide Properties - Review

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Clomazone	150 to 562	5 to 60	Limited	1,100
Pendimethalin	17,200	44	Limited	0.275
Sethoxydim	100	5	Xylem and phloem	1,040
Sulfentrazone	43	121 to 302	Limited	110 to 1,600 (pH)

Summary

- Pesticide fate and residue will become increasingly more important

- Pesticide fate depends on various factors
  - Pesticide physicochemical properties
  - Site specific soil characteristics
  - Management practices
  - Environmental conditions, among others

- Important to understand systemic nature of pesticides
  - Efficacy
  - Residue

Thank you!

NC State University
Pesticide Environmental Fate Lab

Travis Gannon