# EFFECT OF SOIL MICROBIAL ACTIVITY ON THE DEGRADATION OF SOIL RESIDUAL HERBICIDES IN COVER CROPPING SYSTEMS

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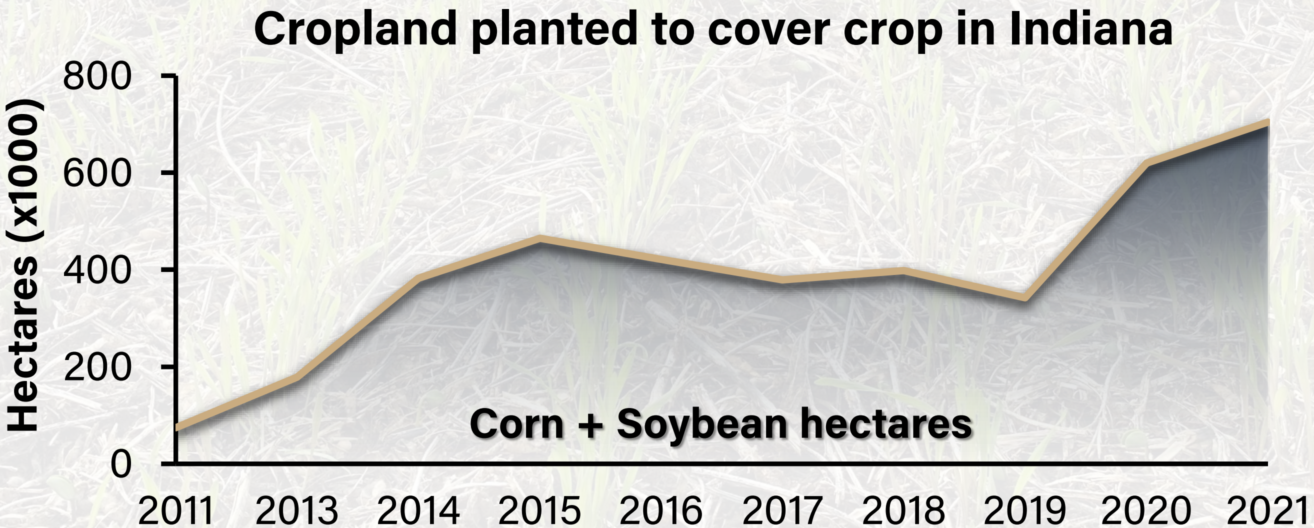
# Introduction

***Why use cover crops?***

- Protect against erosion
- Increase soil organic matter
- Improve soil water holding capacity
- Nitrogen scavenging
- Aid on weed suppression



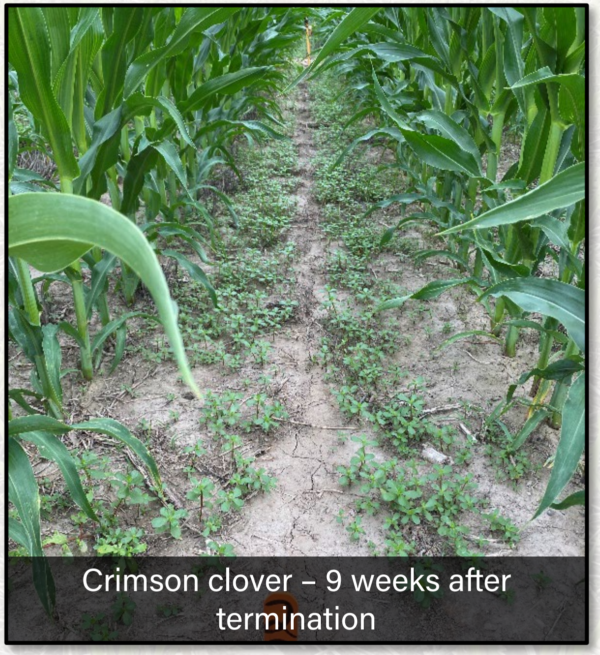

**704,000 ha**
**Greatest percentage of cover crop area in the US**

# Introduction

**Mechanisms of weed suppression in cover crops[1]**

- Competition for:
  - Light
  - Water
  - Nutrients
- Allelochemicals
- Physical barrier

Cereal rye – 9 weeks after termination



Crimson clover – 9 weeks after termination

1 Teasdale (1996)

# Introduction

**Soil residual herbicides**

- Extended period of weed control
- Reduced competition during the critical weed-free period
- Herbicide resistance management

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**Soil residual herbicides**

- Extended period of weed control
- Reduced competition during the critical weed-free period
- Herbicide resistance management
- **Supplement weed suppression from cover crops**

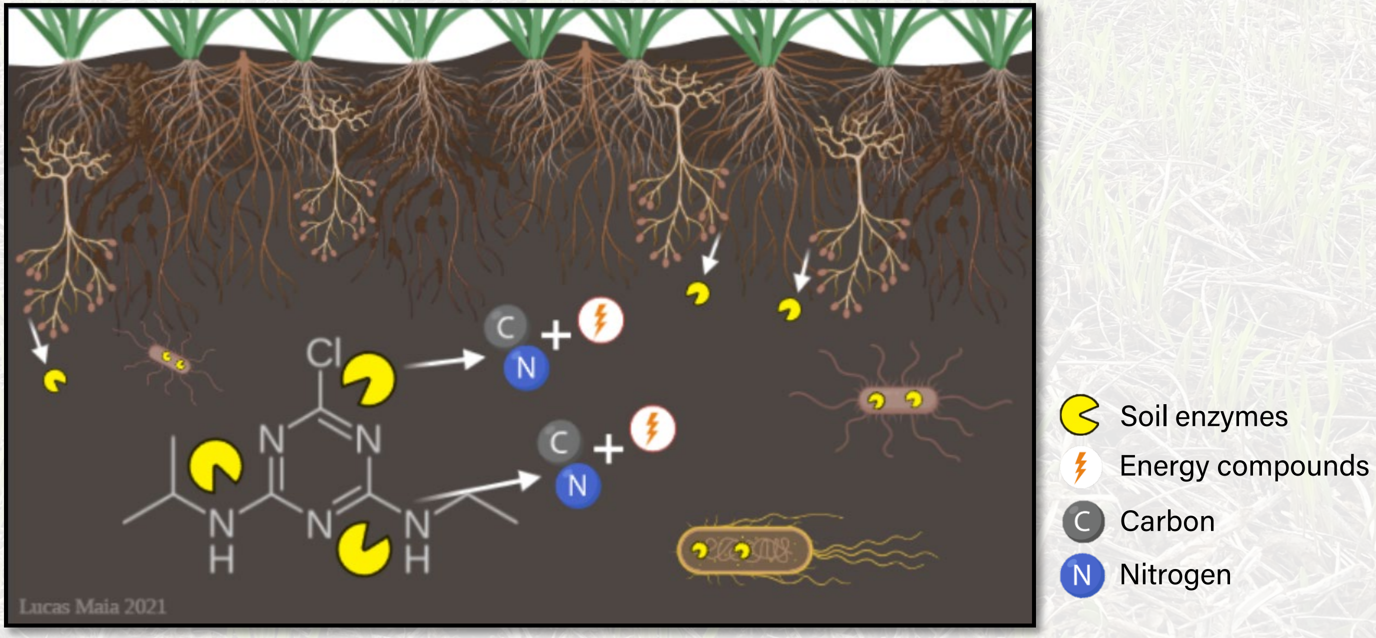
| Cover crop and tillage treatments | No residual | Residual PP[b] |
|---|---|---|
| | Overall weed co | |
| | —————————————%— | |
| Tillage | 20 n | 71 b–h |
| No tillage | 26 l–n | 72 b–g |
| Italian ryegrass | 48 i–k | 85 a–d |
| Austrian winter pea | 26 l–n | 74 a–g |
| Cereal rye | 33 k–n | 76 a–g |
| Cereal rye/winter vetch mix | 26 l–n | 85 a–d |
| Winter vetch | 21 mn | 72 b–g |
| Oat | 38 j–m | 80 a–e |
| Winter wheat | 38 j–m | 78 a–f |

Adapted from: Whalen et al. (2020)

# Introduction

## Microbial degradation

- Mediated by soil enzymes (intra or extracellular)
- Source of carbon, nitrogen and energy[1]
- Dehydrogenase – oxidation and dehalogenation of herbicides[2, 3]




1 Qiu et al. (2009)
2 Beller et al. (1996)
3 Waarrde et al. (1993)

# Introduction

## Interaction between cover crops and soil residual herbicides

1. Cover crops can increase soil microbial activity when environmental conditions are favorable and there is carbon input[1, 2, 3]

↓↑ **INTERACTION** ↓↑

2. Biodegradation is main pathway of degradation for most residual herbicides

***Will the long-term use of cover crops increase residual herbicide degradation in the soil?***

1 Tyler (2020)
2 Kim et al. (2020)
3 Brennan and Acosta-Martinez (2019)

# Hypothesis and Objective

### Hypothesis

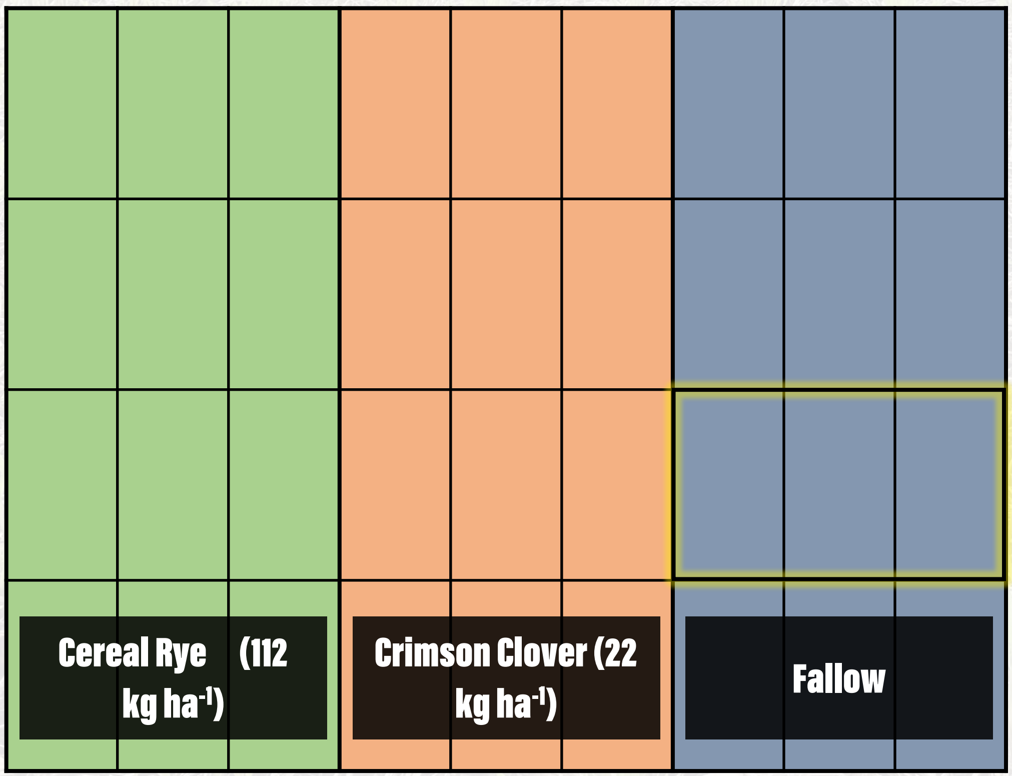
*The long-term use of cover crop will increase soil microbial activity and therefore increase the degradation of soil residual herbicides.*

### Objective

*Investigate the influence of cereal rye and crimson clover cover crops on soil microbial activity and degradation of soil residual herbicides.*

# Materials and Methods

- Field trials established at Pinney and Throckmorton (TPAC) Purdue Agricultural Centers in the Fall of 2019
- Experimental design: split-plot with 4 replications




| No Residual | Medium Residual | Heavy Residual |
| --- | --- | --- |
| Glyphosate<br>Glufosinate | Glyphosate<br>**Atrazine**<br>***S*-metolachlor** | Glyphosate<br>**Atrazine**<br>***S*-metolachlor**<br>**Mesotrione** |

# Materials and Methods

**Soil chemical and physical properties from PPAC and TPAC**

| Site | Organic matter (%) | Classification |
|---|---|---|
| Pinney | 1.8 | sandy loam |
| TPAC | 3.0 | silt loam |


**Herbicide programs used at cover crop termination and rates for TPAC and Pinney**

| Herbicide programs | Herbicide | Rate (g ae ai ha$^{-1}$) |
|---|---|---|
| No residual | Glyphosate | 1750 |
| | Glufosinate | 737 |
| Medium residual | Atrazine | 2241 (TPAC)<br>1681 (Pinney) |
| | *S*-metolachlor | 1790 (TPAC)<br>1420 (Pinney) |
| | Glyphosate | 1750 |
| Heavy residual | Atrazine | 2241 (TPAC)<br>1681 (Pinney) |
| | *S*-metolachlor | 1790 (TPAC)<br>1420 (Pinney) |
| | Mesotrione | 104 |
| | Glyphosate | 1750 |

| 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|
| Corn | Soybean | **Corn** | Soybean |

- Cover crop termination: 2 weeks before corn planting
- All herbicides within each treatment were applied in tank-mix and at cover crop termination
- 2 POST applications at 4 and 8 WAP
  - ➢ Same as no residual treatment

# Materials and Methods

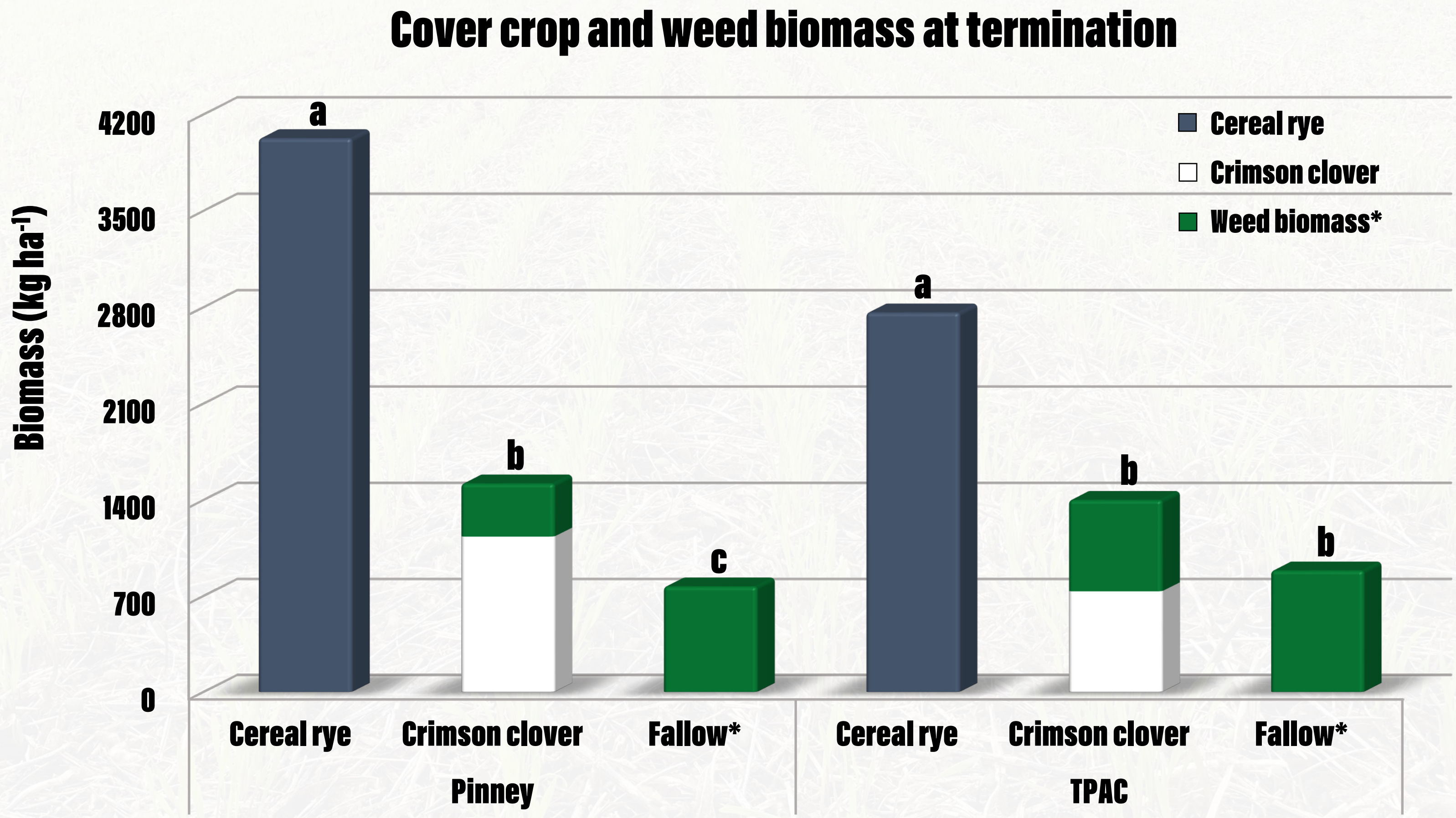
**Data collection**

1. Cover crop biomass assessed the day before termination (0.25 $m^2$)
2. Weed biomass at 4 weeks after corn planting (WAP) – prior to 1st POST
3. Soil samples taken at: -5 , 0, 10, 14, 28, 56, 84, and 112 days after termination (DAT)
   - 0 to 5 cm depth
   - Soil microbial activity: β-glucosidase and dehydrogenase activities
   - Herbicide concentration (samples from 0 to 112 DAT)
     - QuEChERS method - Ultra-performance liquid chromatography

**Statistical analysis**

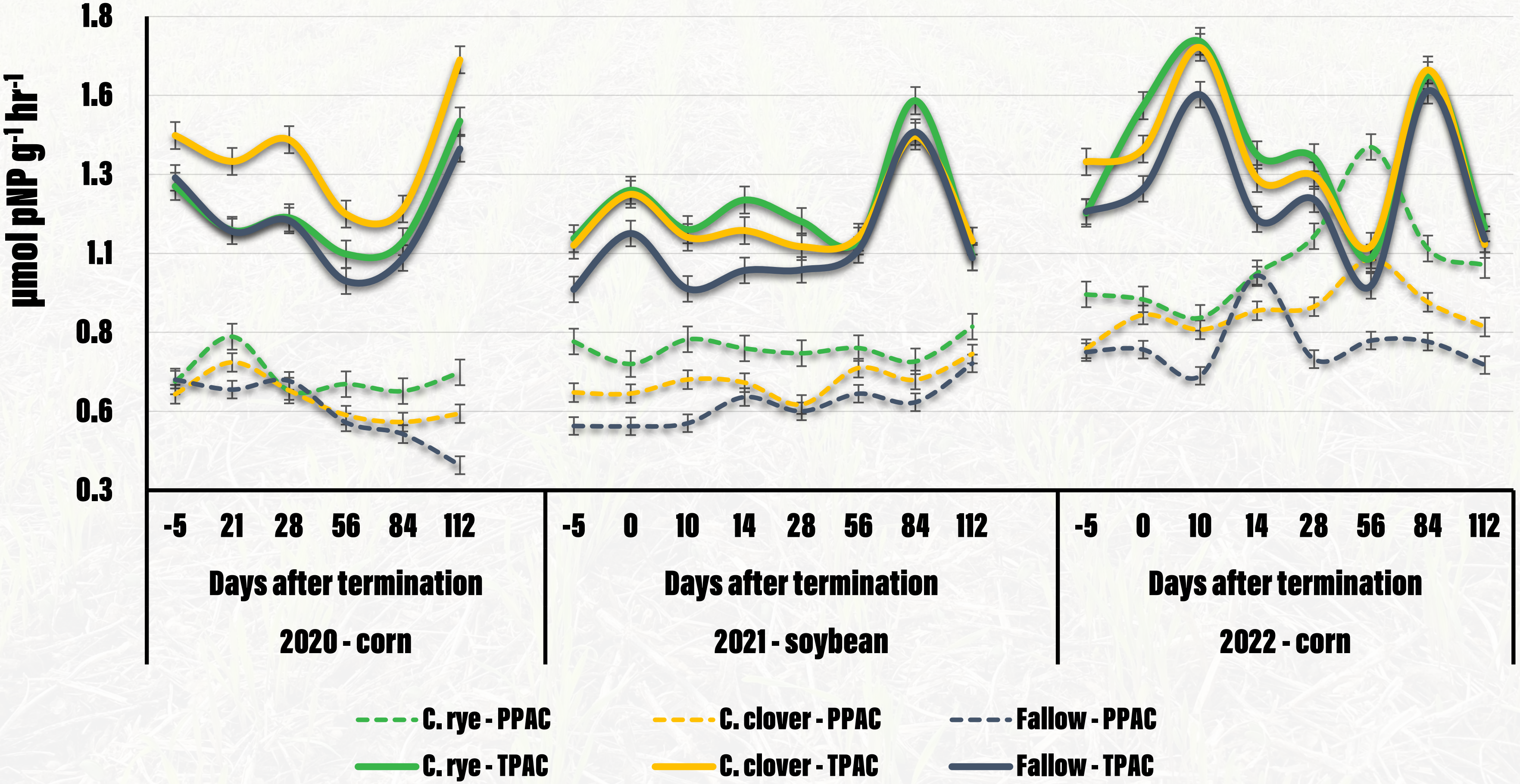
- Proc GLIMMIX in SAS – mean separation using Tukey's HSD ($P \leq 0.05$)
- Data was transformed as appropriate

# Results and Discussion



# Results and Discussion

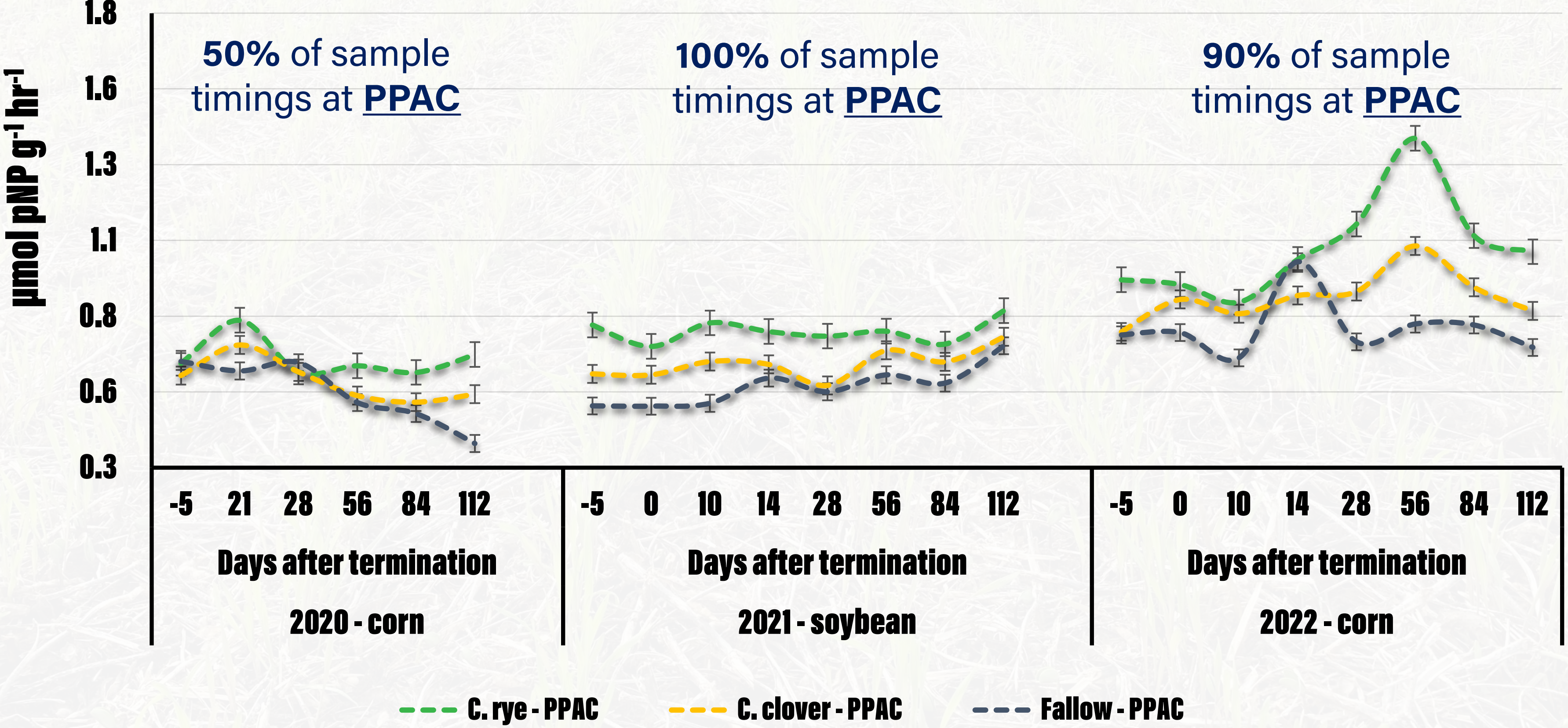
## β-glucosidase activity



# Results and Discussion

## β-glucosidase activity

**Use of cover crops resulted in greater β-glucosidase activity compared to the fallow control**



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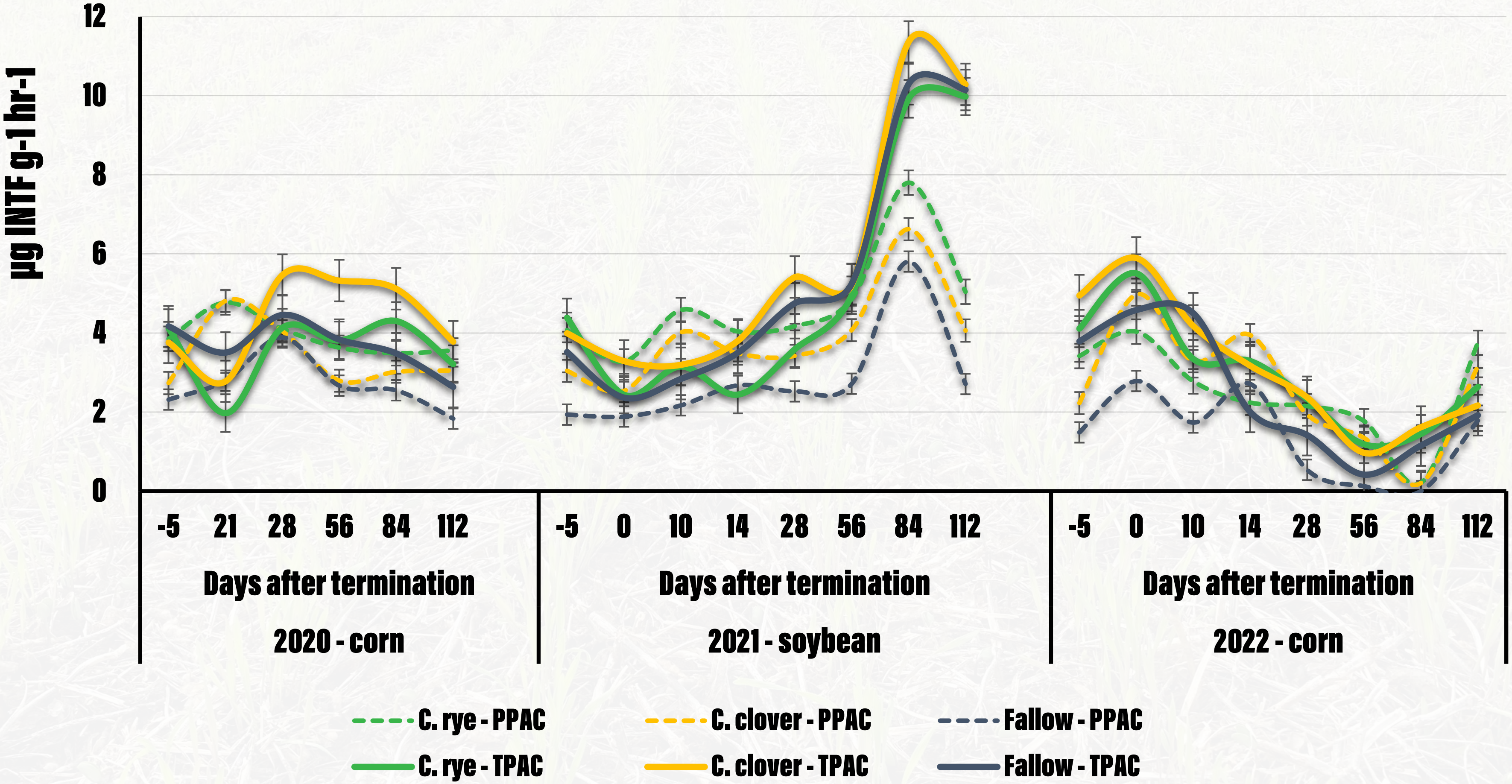
## Dehydrogenase activity

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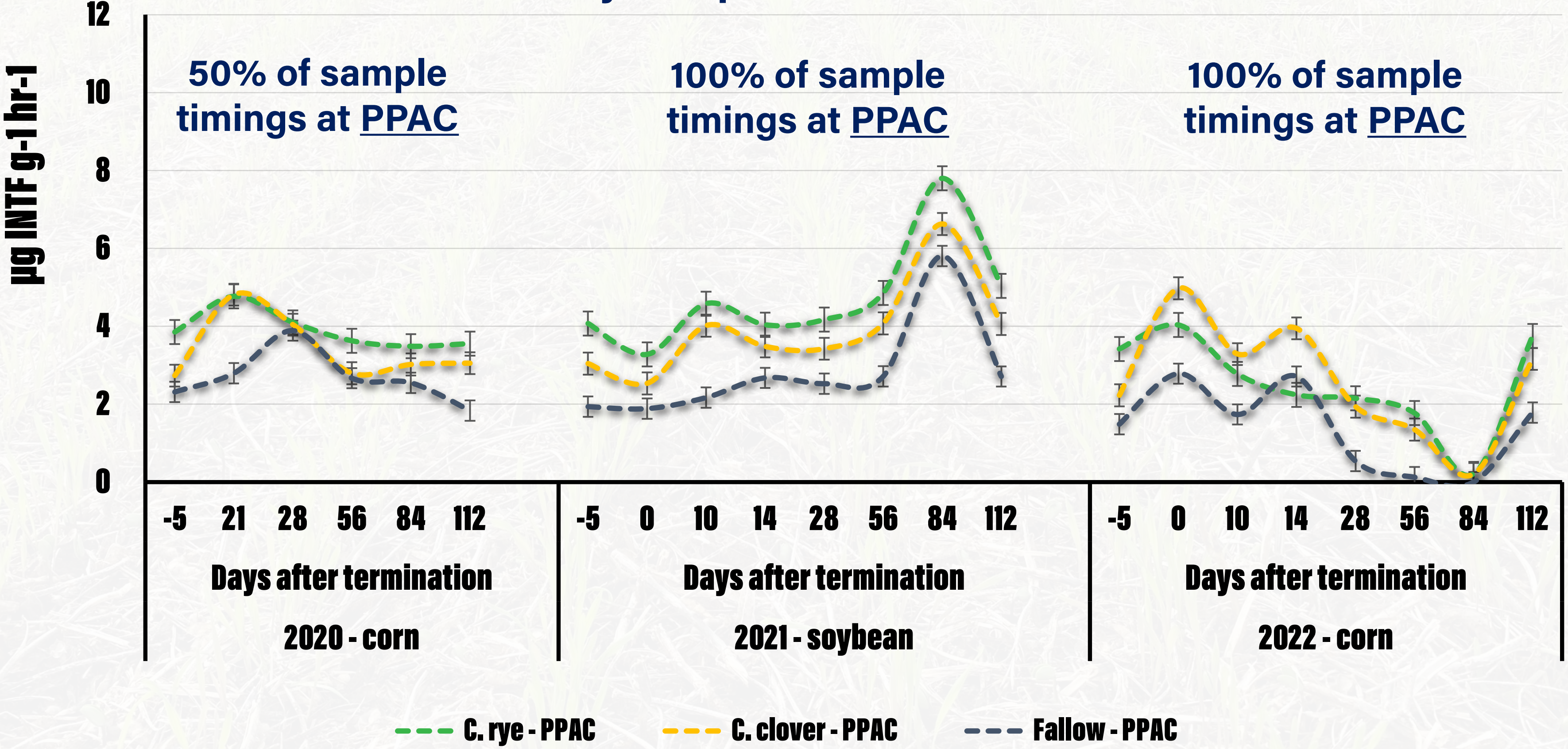
# Results and Discussion

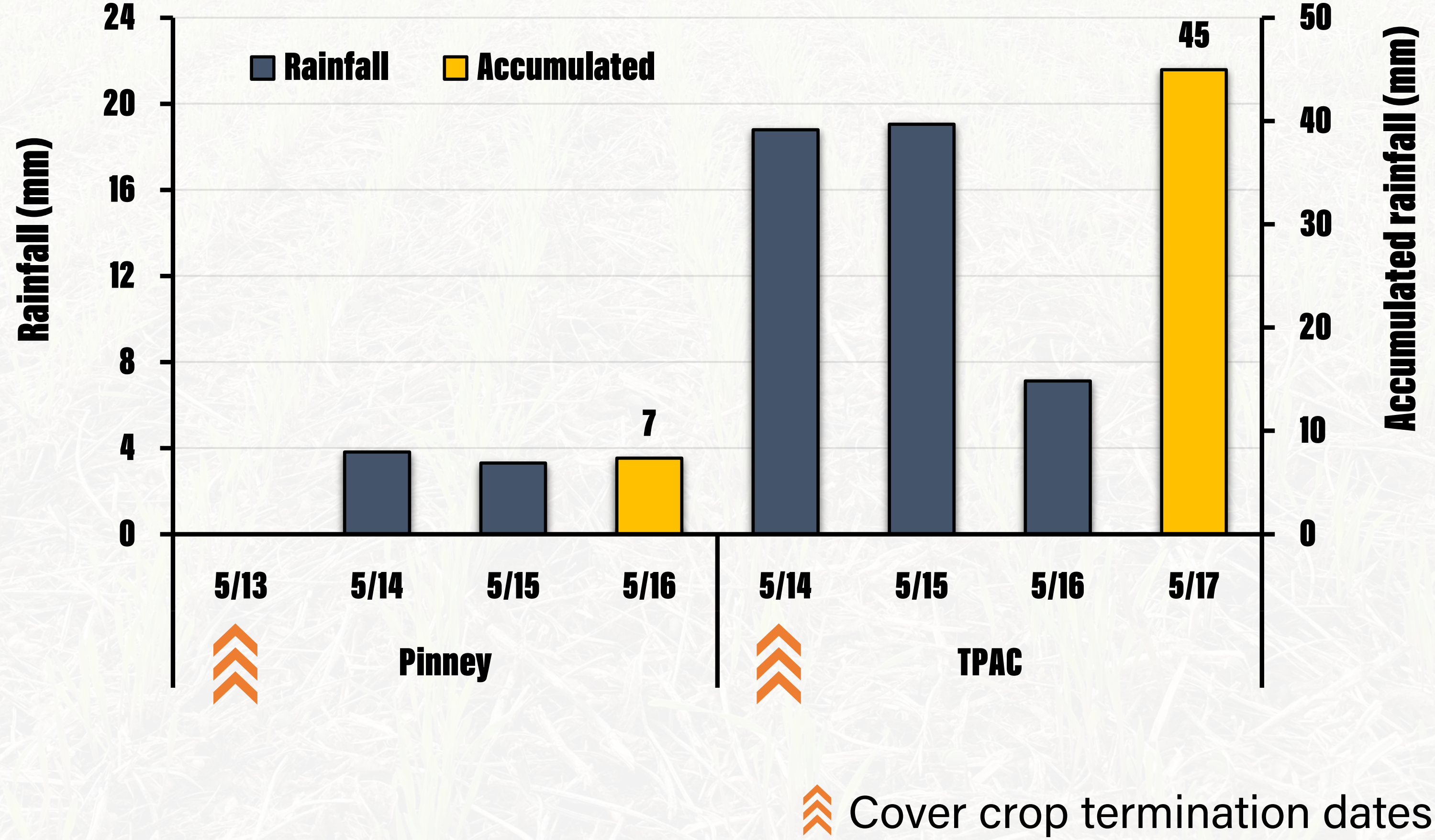
## Dehydrogenase activity

**Use of cover crops resulted in greater dehydrogenase activity compared to the fallow control**



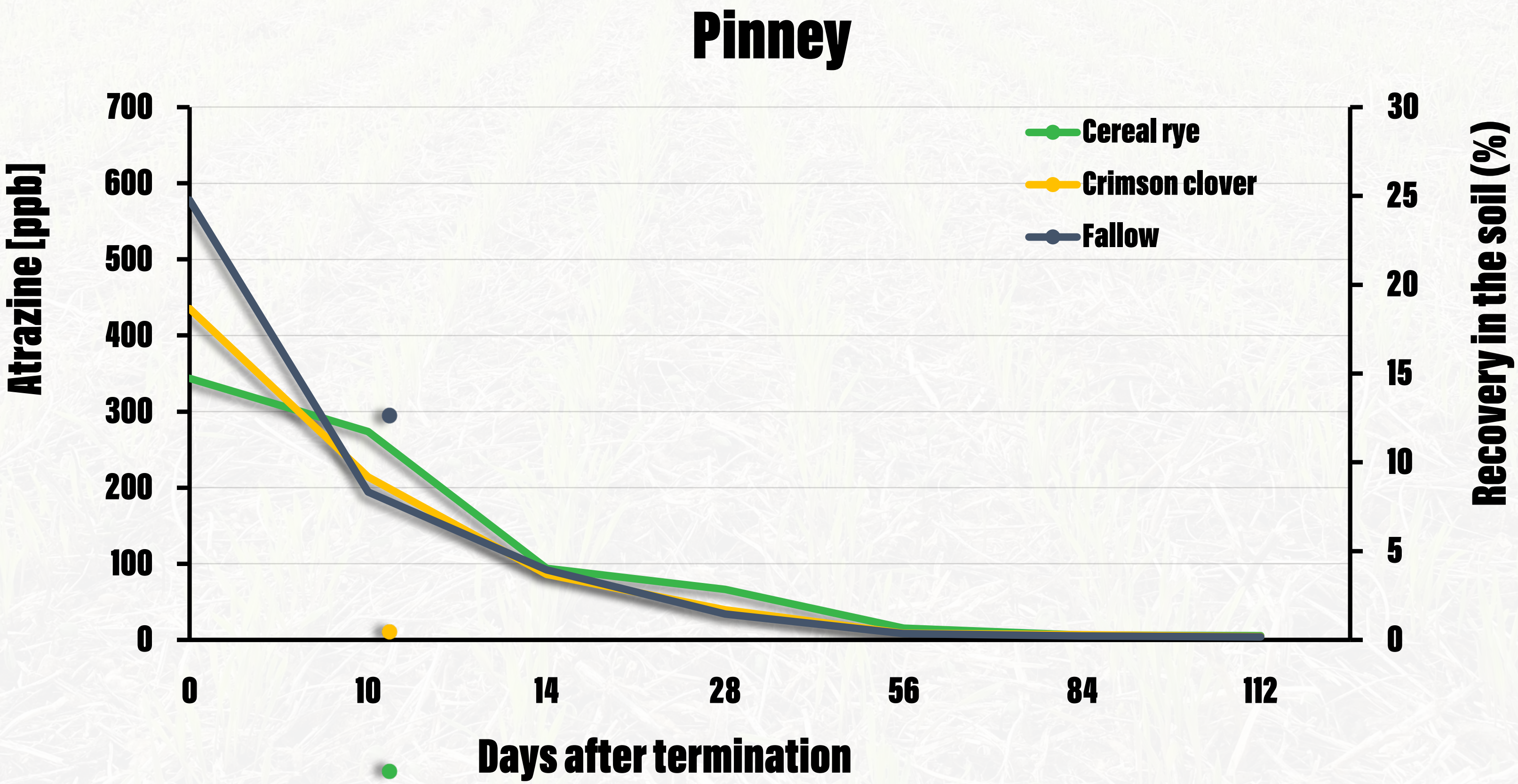
# Results and Discussion

## Rainfall data up to 72 hours after herbicide application



# Results and Discussion

## Atrazine concentration in the soil



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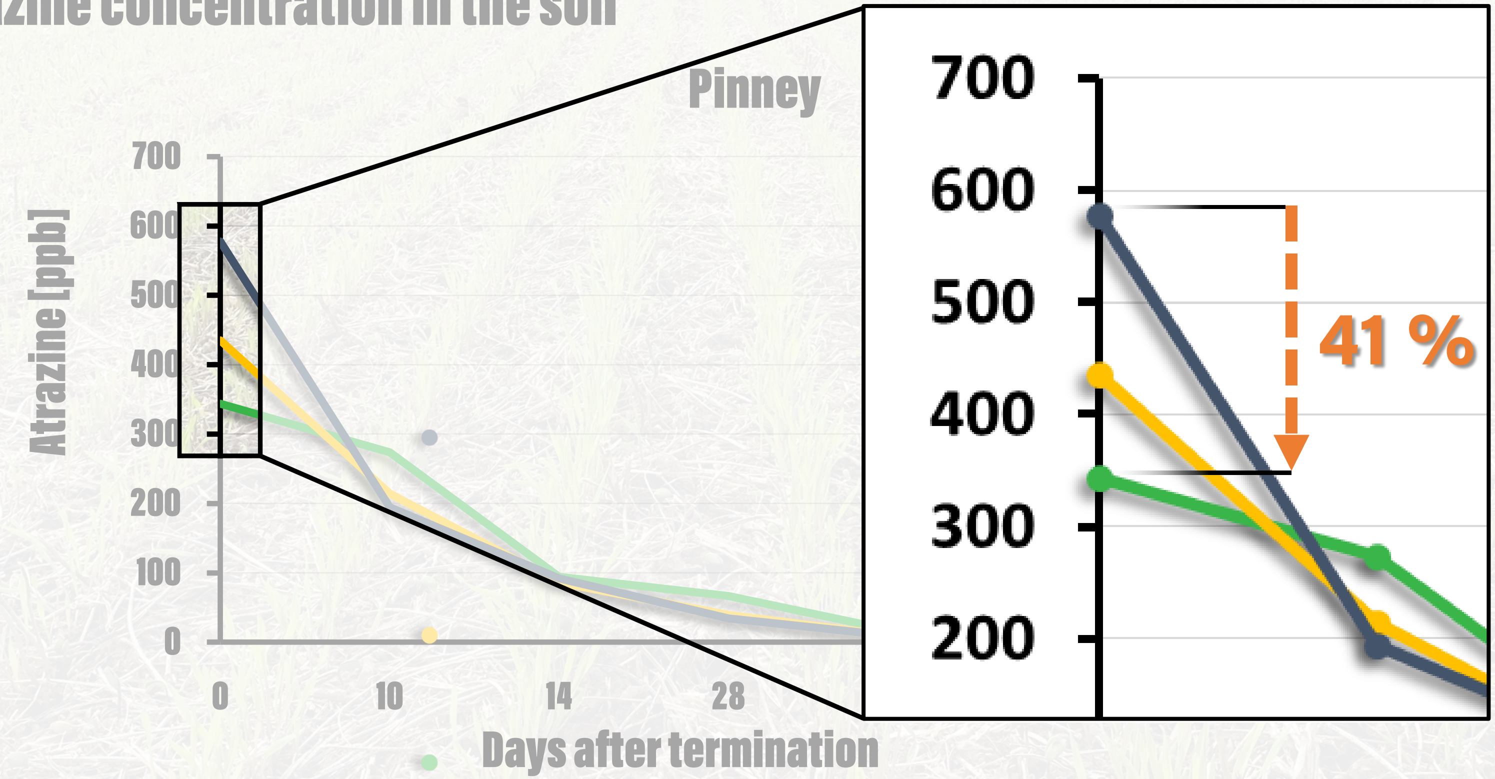

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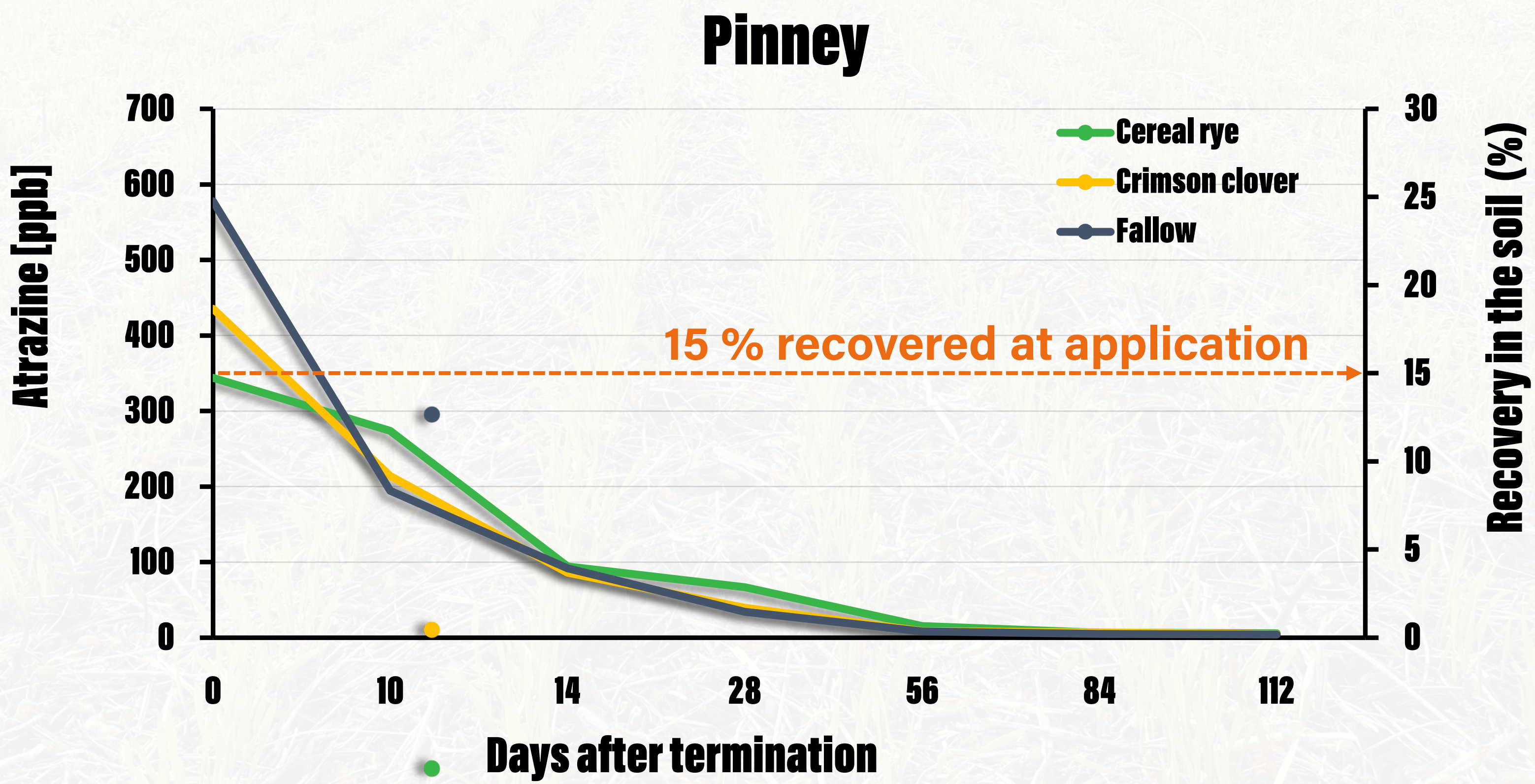


Recovery data is relative to the theoretical initial concentration of atrazine (2251 ppb) at the 0 to 5 cm layer of soil.

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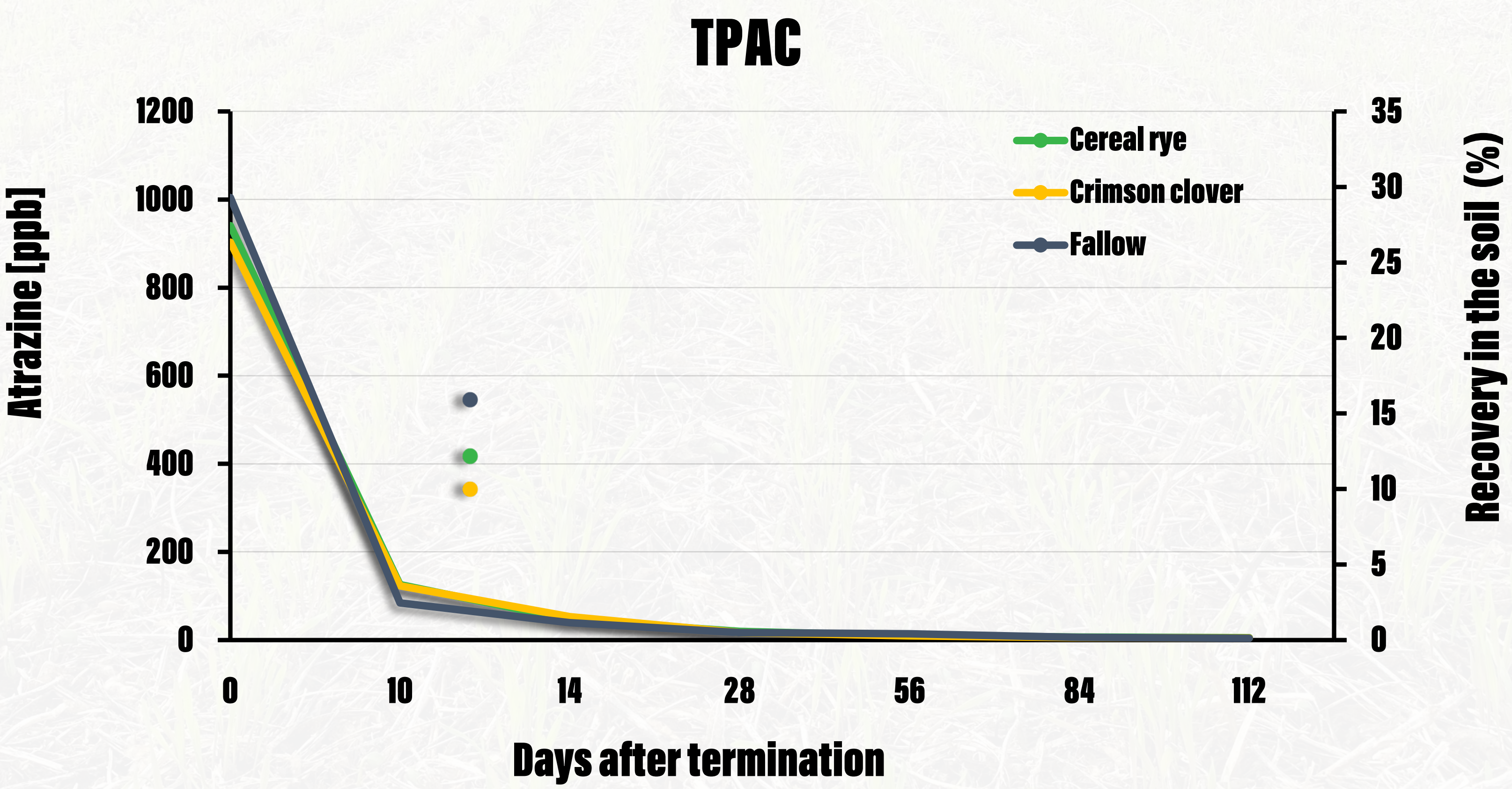
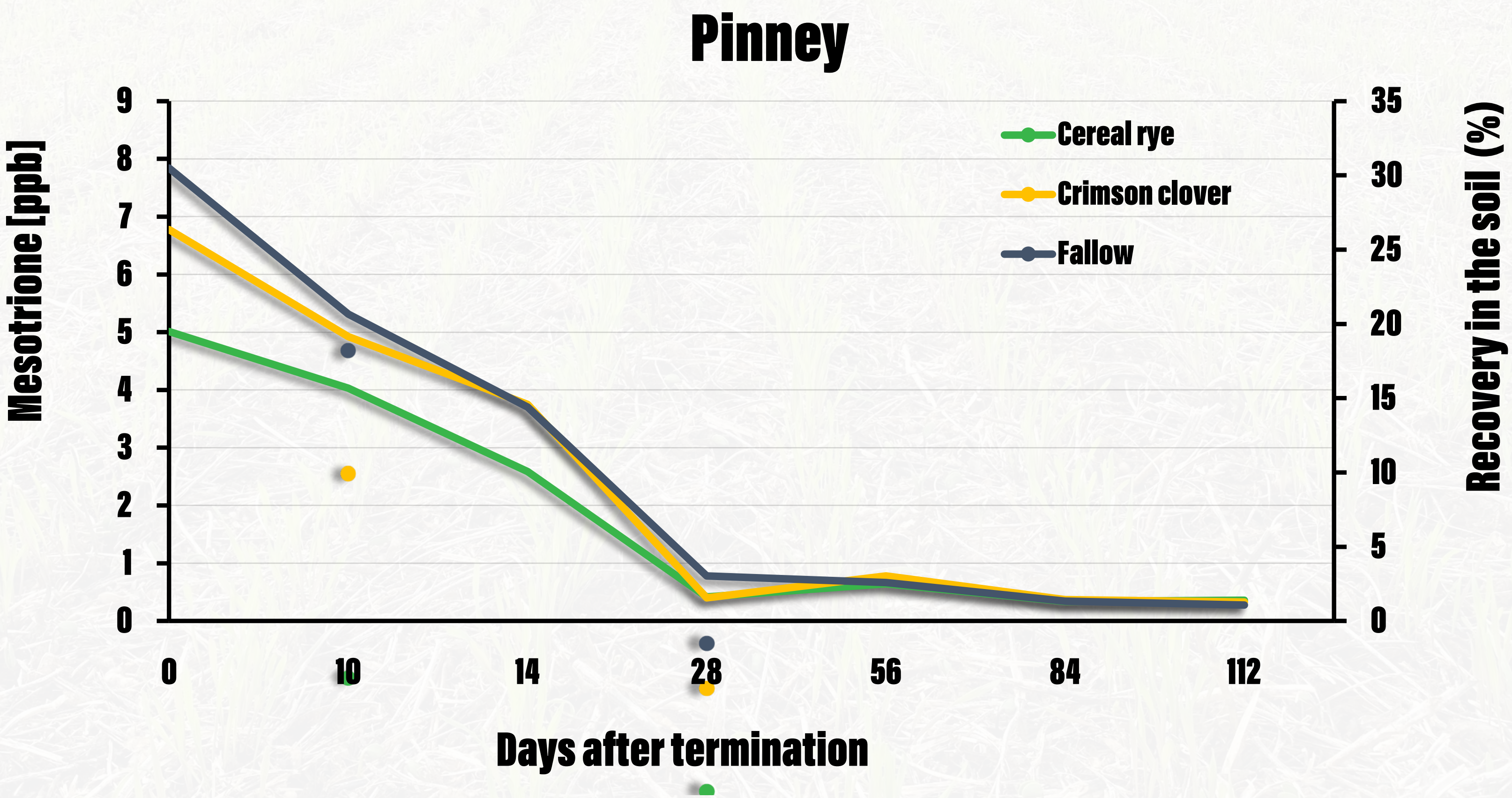


# Results and Discussion

## Mesotrione concentration in the soil



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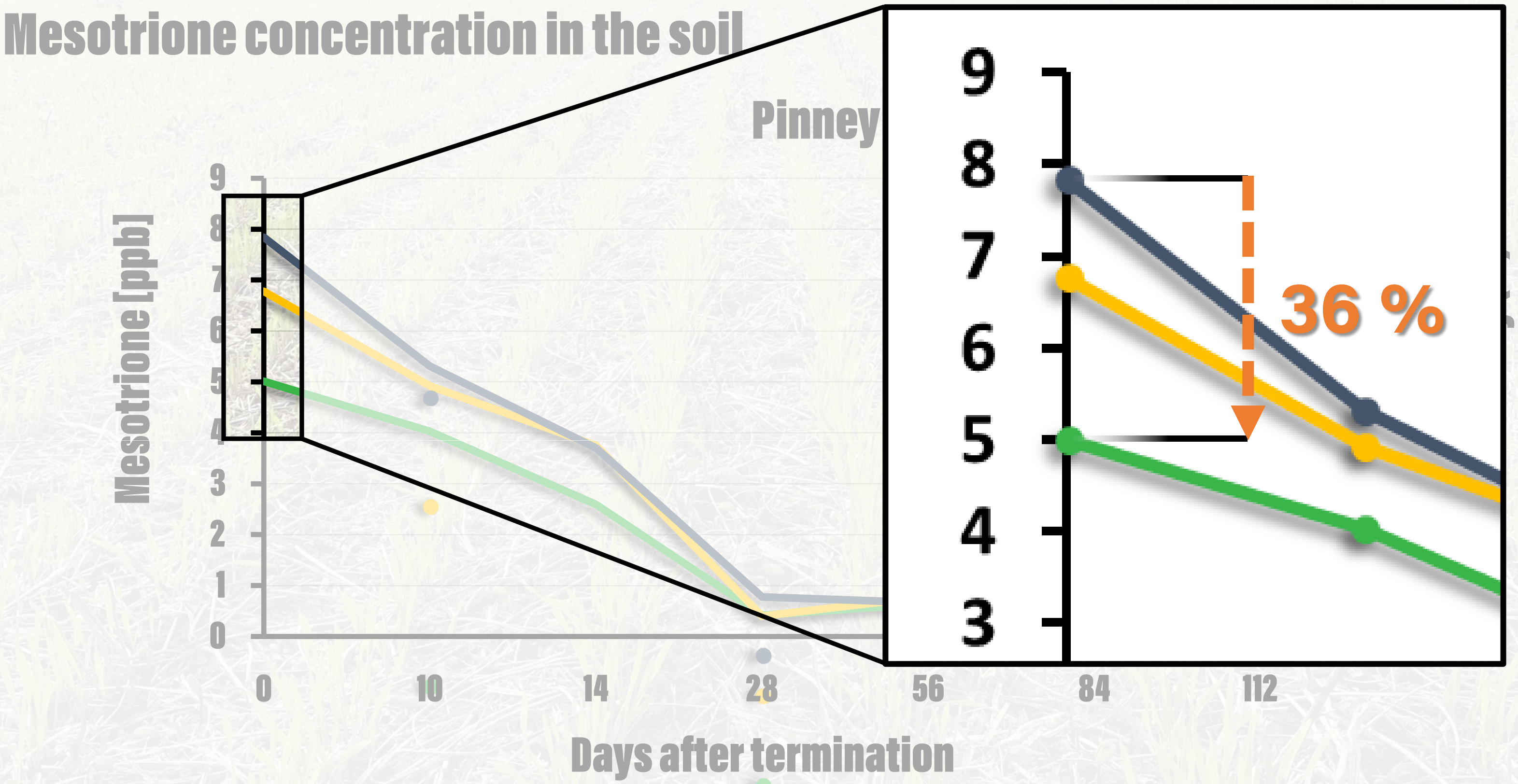

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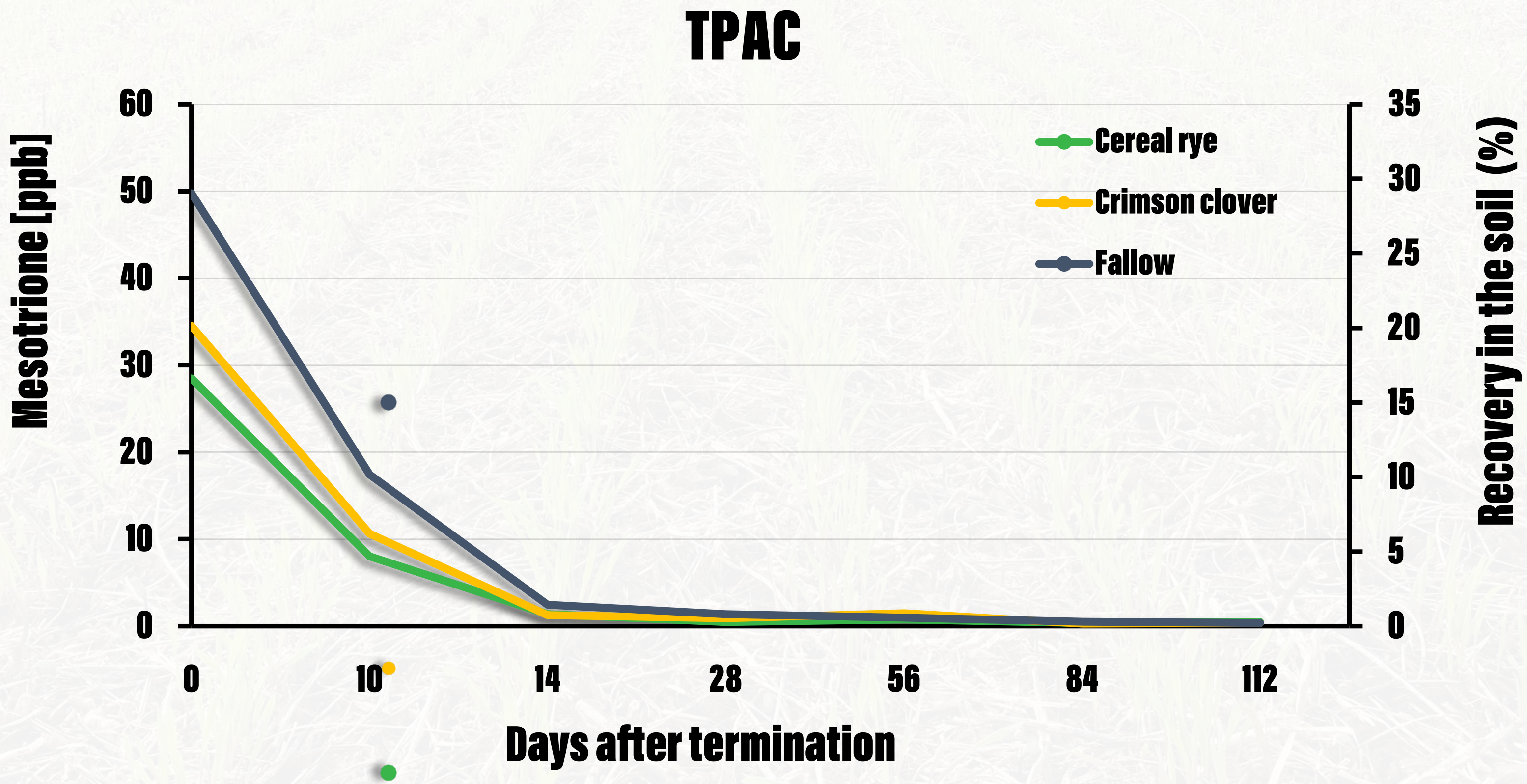
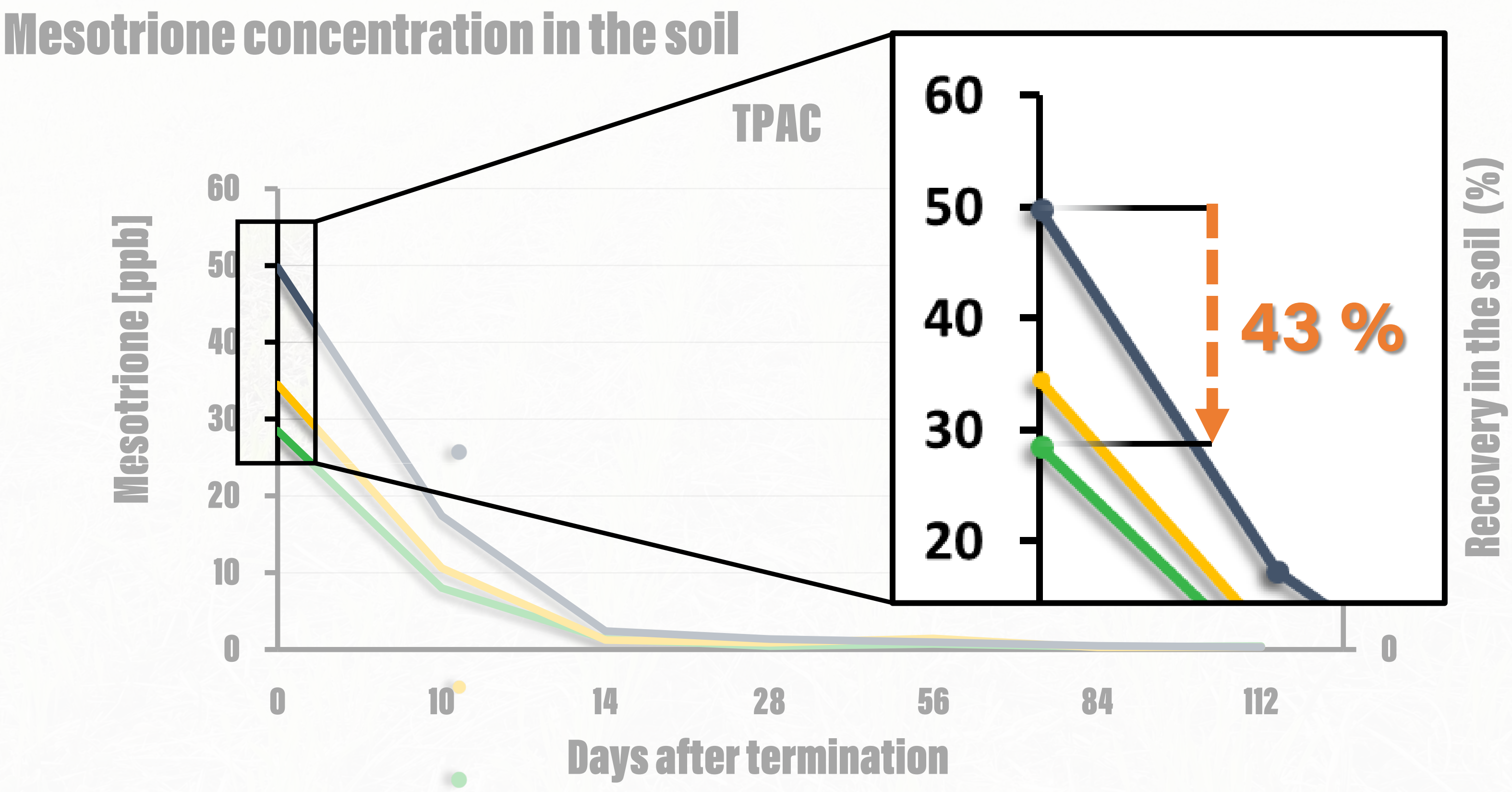
## Mesotrione concentration in the soil




Recovery data is relative to the theoretical initial concentration of mesotrione (155 ppb) at the 0 to 5 cm layer of soil.

# Results and Discussion



# Results and Discussion

## Correlation between herbicide concentration and microbial activity

### Pinney

Pearson Correlation Coefficients

| | Atrazine | BG | DHA |
|---|---|---|---|
| Atrazine | 1.0000 | -0.1561 | 0.4458 |
| BG | -0.1561 | 1.0000 | 0.1526 |
| DHA | 0.4458 | 0.1526 | 1.0000 |

Pearson Correlation Coefficients

| | Mesotrione | BG | DHA |
|---|---|---|---|
| Mesotrione | 1.0000 | -0.227 | 0.4383 |
| BG | -0.2277 | 1.0000 | 0.1094 |
| DHA | 0.4383 | 0.1094 | 1.0000 |

### TPAC

Pearson Correlation Coefficients

| | Atrazine | BG | DHA |
|---|---|---|---|
| Atrazine | 1.0000 | 0.0664 | 0.5689 |
| BG | 0.0664 | 1.0000 | 0.3834 |
| DHA | 0.5689 | 0.3834 | 1.0000 |

Pearson Correlation Coefficients

| | Mesotrione | BG | DHA |
|---|---|---|---|
| Mesotrione | 1.0000 | 0.1265 | 0.4846 |
| BG | 0.1265 | 1.0000 | 0.4114 |
| DHA | 0.4846 | 0.4114 | 1.0000 |

**BG: β-glucosidase; DHA: Dehydrogenase**

# Results and Discussion

## Correlation between herbicide concentration and microbial activity

**Pinney**

Pearson Correlation Coefficients

| | Atrazine | BG | DHA |
|---|---|---|---|
| Atrazine | 1.0000 | -0.1561 | 0.4458 |
| BG | [illegible] | [illegible] | [illegible] |
| DHA | [illegible] | [illegible] | [illegible] |

Pearson Correlation Coefficients

| | Mesotrione | BG | DHA |
|---|---|---|---|
| Mesotrione | 1.0000 | -0.227 | 0.4383 |
| BG | [illegible] | [illegible] | [illegible] |
| DHA | [illegible] | [illegible] | [illegible] |

**Atrazine and mesotrione did not inhibit β-glucosidase and dehydrogenase activities**

**TPAC**

| | Atrazine | BG | DHA |
|---|---|---|---|
| Atrazine | 1.0000 | 0.0664 | 0.5689 |
| BG | 0.0664 | 1.0000 | 0.3834 |
| DHA | 0.5689 | 0.3834 | 1.0000 |

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BG: β-glucosidase; DHA: Dehydrogenase

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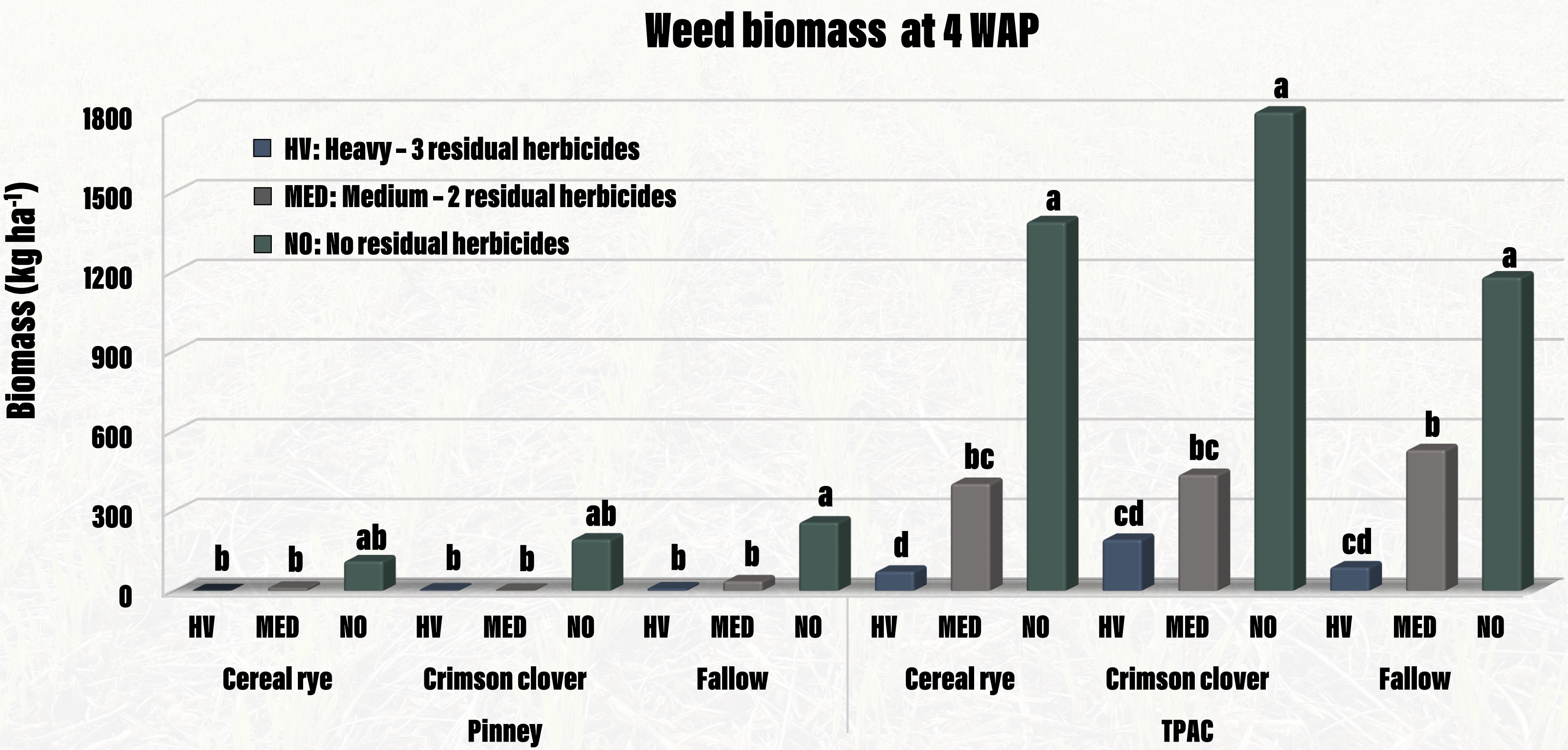


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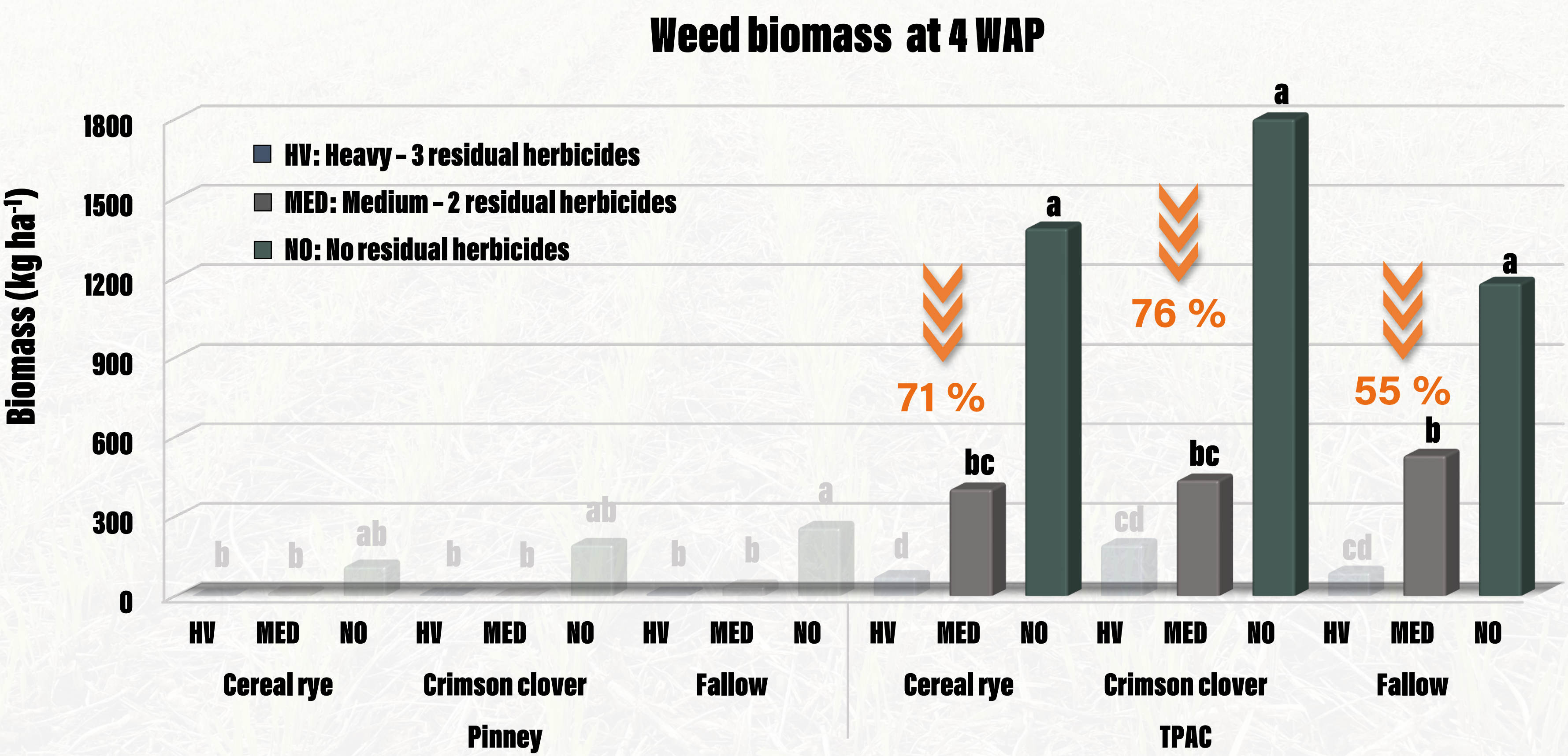
# Results and Discussion



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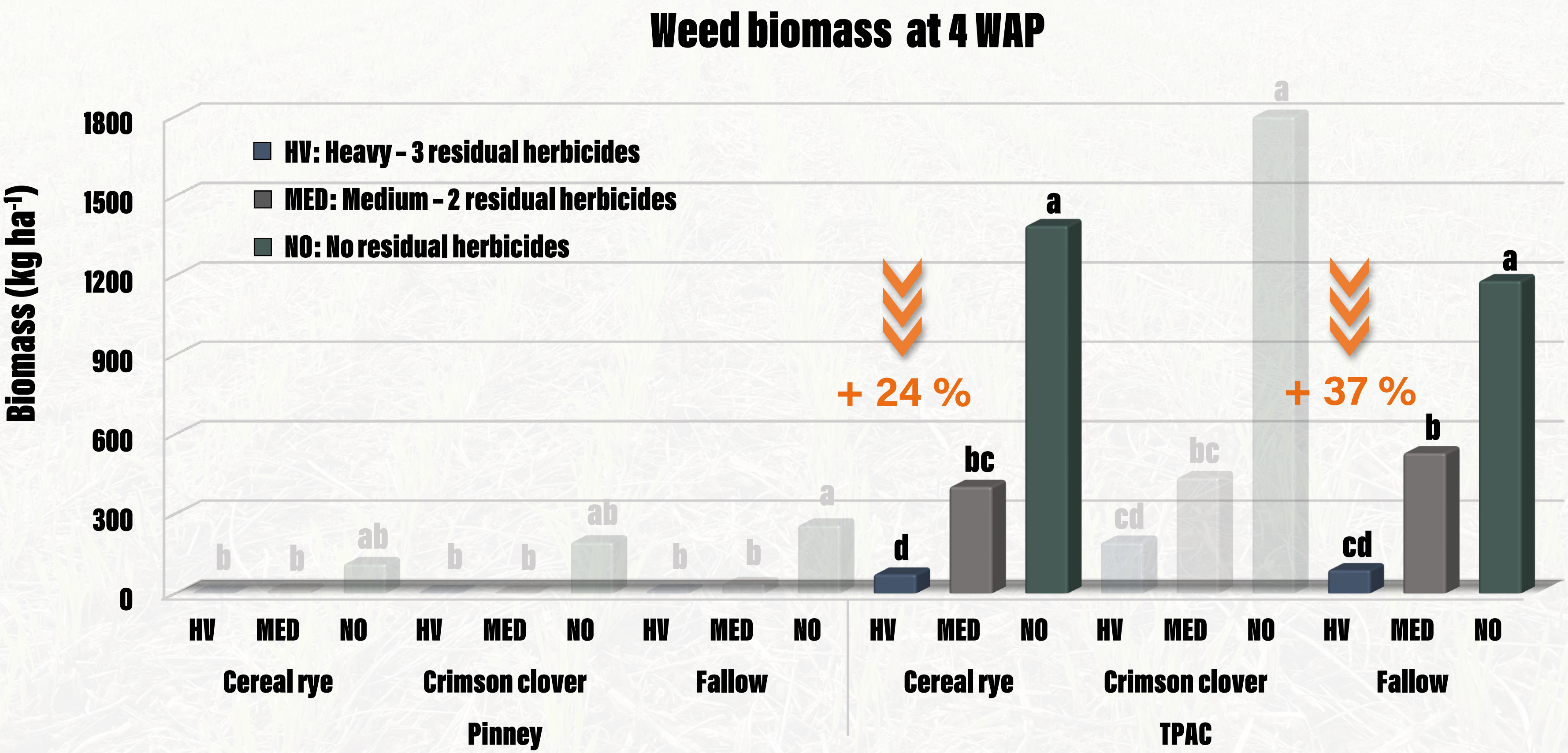

# Conclusions

**Soil enzymatic activity** → **support the hypothesis**

- The use of cereal rye for three years increased β-glucosidase and dehydrogenase activities by an average of 23 and 76%, respectively, compared to the fallow control

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- The use of cereal rye for three years increased β-glucosidase and dehydrogenase activities by an average of 23 and 76%, respectively, compared to the fallow control

**Herbicide concentration in the soil → do not support the hypothesis**

- The increase in soil microbial activity as result of cereal rye use did not increase atrazine or mesotrione degradation
- The presence of 4027 kg $ha^{-1}$ of cereal rye biomass at Pinney reduced the initial concentrations of atrazine and mesotrione in the soil by 41 and 36%, respectively, compared to the fallow control

# Conclusions

**Weed control**

- The application of 3 residual herbicides at cover crop termination provided up to 83 and 95% reduction in weed biomass compared to the termination with two or no residual herbicides, respectively.

# Implications

1. **Despite significant interception, soil residual herbicides should still be applied at cover crop termination**
   - **ALWAYS → <u>Full label rates</u>**

2. **Cover crops should be terminated prior to a rainfall event when soil residual herbicides are included in the herbicide tank mix**

# Future Research

- Data collection on this study will continue until 2024
- Additional field trials are being conducted to investigate:

1. Influence of rainfall on residual herbicide wash off from cover crop residue onto the soil
2. Influence of cover crop orientation on residual herbicide concentration in the soil

# Acknowledgements


- Financial support to this project was provided by the Indiana Corn Marketing Council
- Purdue weed science team


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Marketing Council

# THANK YOU

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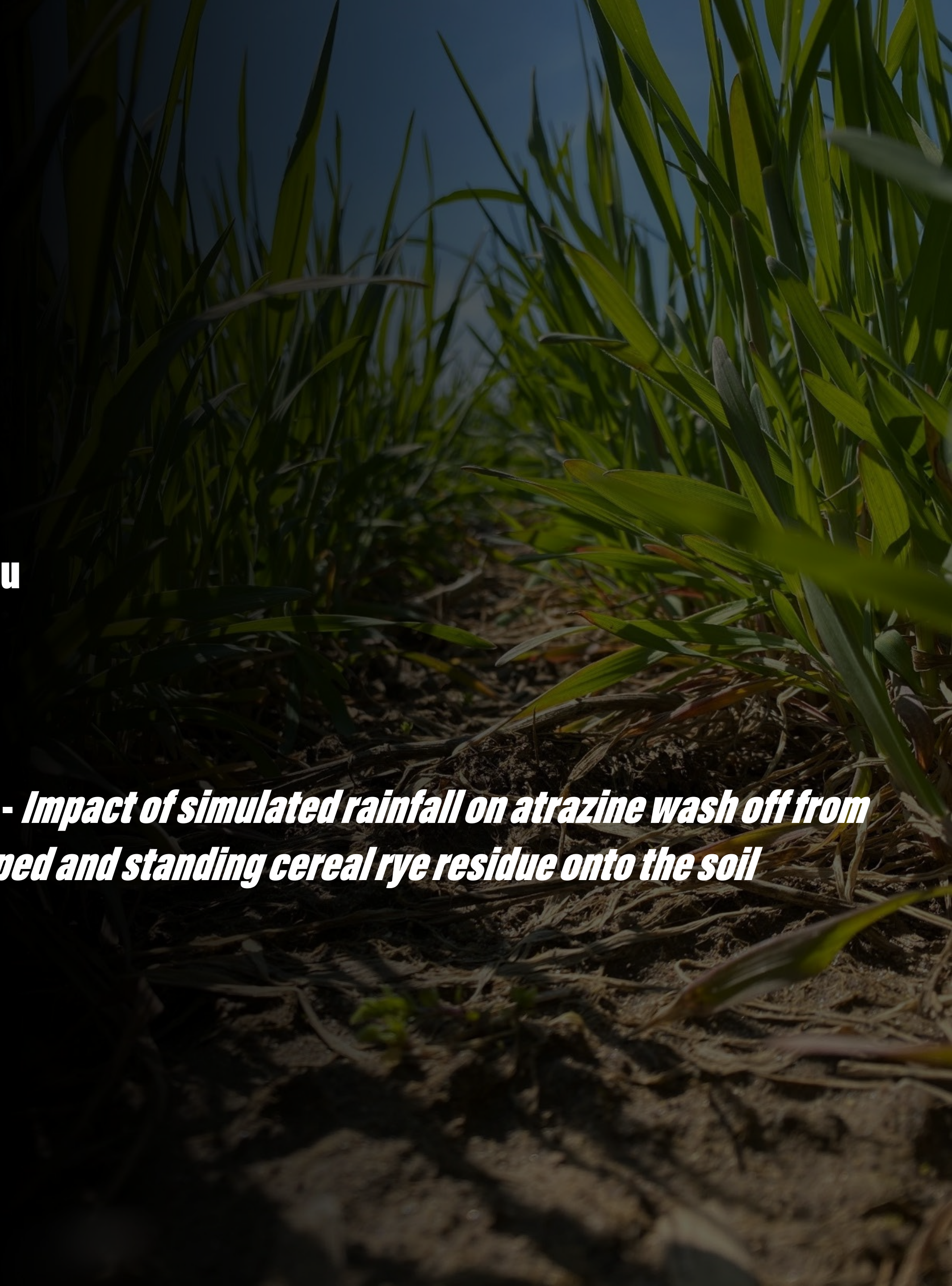
**Poster # 85 -** ***Impact of simulated rainfall on atrazine wash off from roller crimped and standing cereal rye residue onto the soil***



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