A Novel Approach to Expand Our Understanding of Alfalfa Hay Spoilage and Improve the Efficacy of Hay Preservatives

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For our alfalfa hay line of research our goal is to develop a novel preservative that can preserve hay up to 30% moisture at a low cost

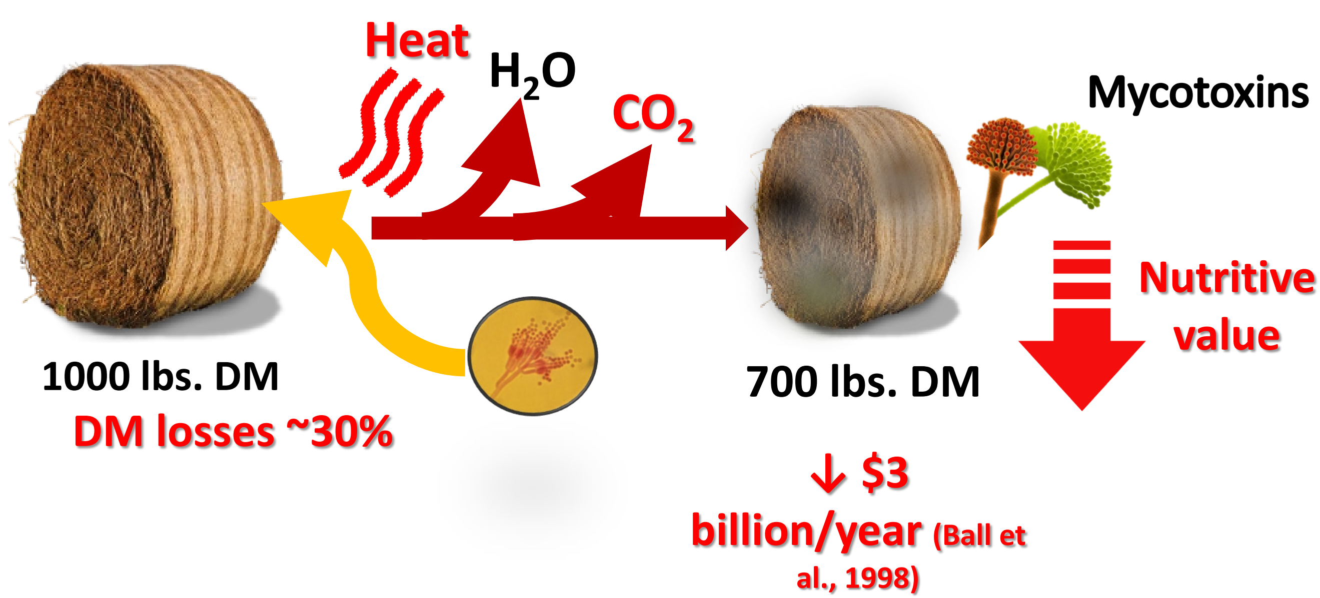
Curing is one of the biggest barriers for hay production in the eastern US

Hay has a superior marketability than silage

Limitations of haymaking

↑ moisture (>16-20%) → storage losses (↑ microbial spoilage)

↓ moisture (< 15%) → harvest losses (↑ leaf shatter)



Preservatives are needed when weather or logistical issues impede us from baling at recommended moisture levels

(Reyes et al., 2019)

Hay preservatives:

Anhydrous ammonia

Applied as gas:
- Special equipment and material required

Expensive

Hazardous

Organic acids

Corrosive

Hazardous

Antifungal compounds:
- Propionic acid
- Acetic acid
- Formic acid
- Etc.

Buffered organic acids

Less corrosive

Neutralized:
- Ammonium propionate
- Sodium diacetate
- Potassium sorbate

Less antifungal (in lab settings)

Field comparisons not documented

Urea

Broken down into ammonia by plant enzymes

Less hazardous

Microbial inoculants

Good bacteria:
- Produce antifungal compounds
- Compete with spoilage microbes

Effective?

How effective?

Inconsistent results / No quantitative review ever done

RESULTS

Chemical preservatives

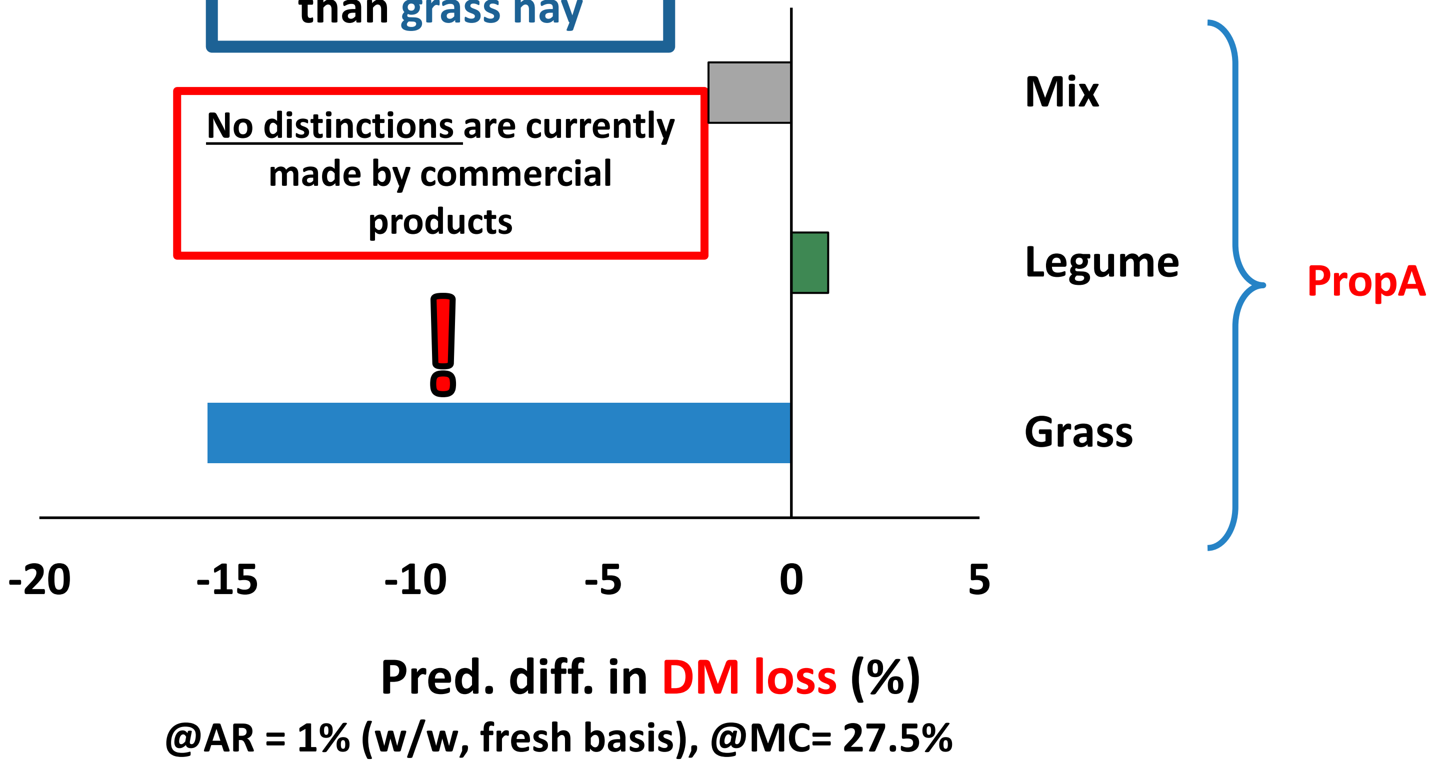
DM loss

Legume hay will require higher doses than grass hay

Untreated mean = **13.9%**

Overall effect = **-0.371% units**

More negative diferences = better!



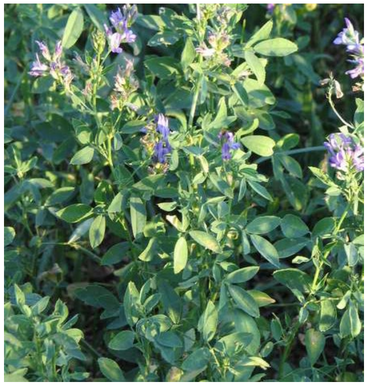
Forage Type × Preservative Class: *P* = 0.045

Pred. diff. = Treated– Untreated

(Killerby et al., 2022)

Propionic acid might be less effective on legume hay because more prone to spoilage

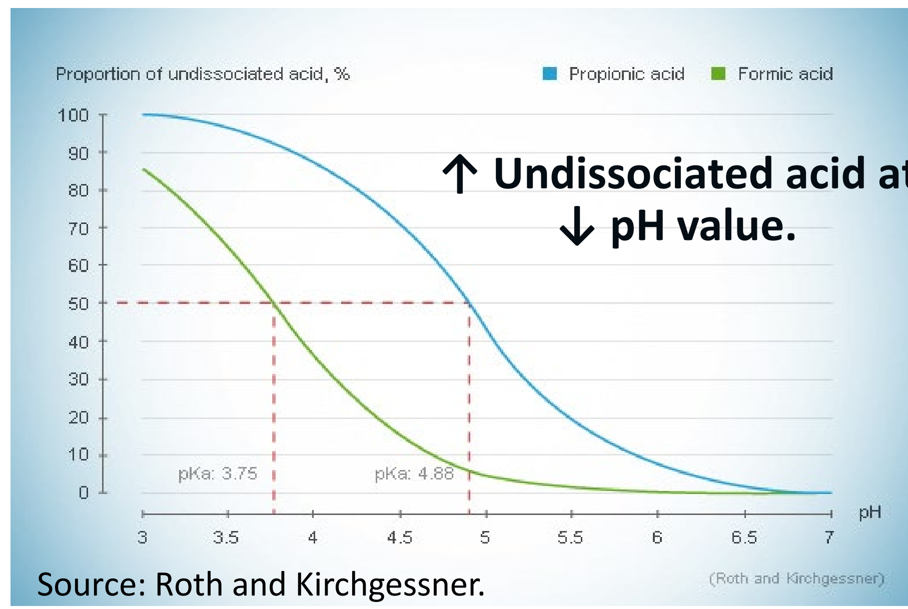
Legumes



Nutritive value

(protein, pectins and ash)

Buffering capacity = **Resist changes in pH!**



(Killerby et al., 2022)

Grasses

Nutritive value

Buffering capacity

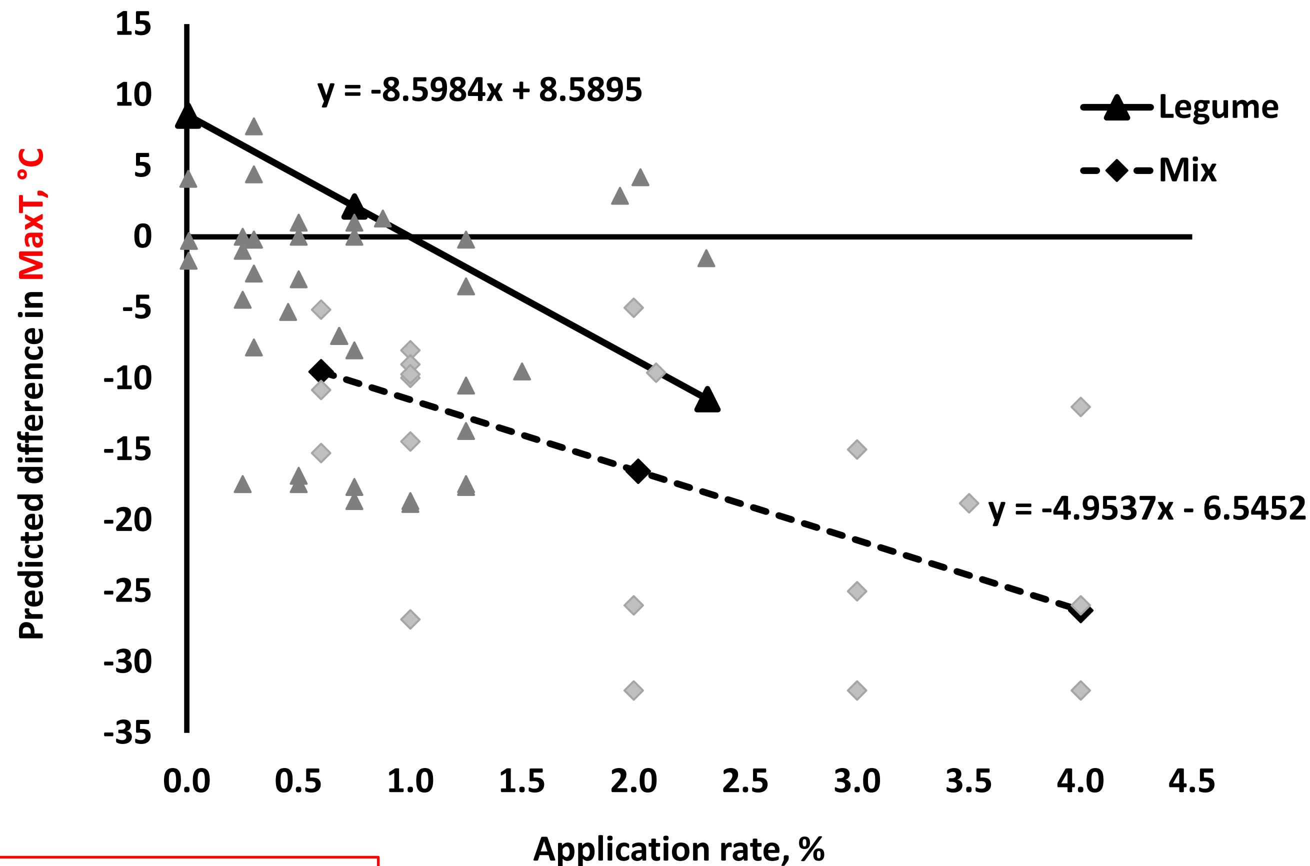
(Killerby et al., 2022)

Maximum temperature in the bale

@MC= 27.5%

Untreated mean = **45.1°C**

Overall effect = **-9.4°C**



More **negative** differences = better!

Forage Type × Application rate: *P* < 0.001

Pred. diff. = Treated– Untreated

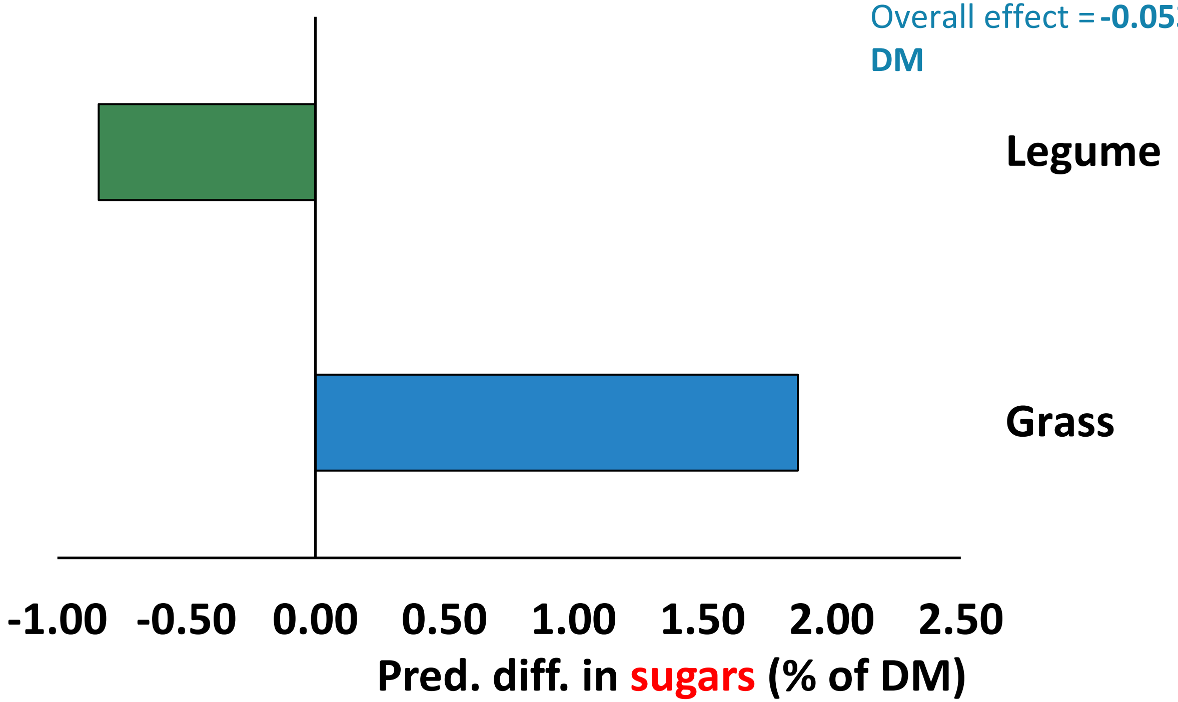
(Killerby et al., 2022)

Sugars

@AR= 1.1%
@MC= 27.5%

Untreated mean =
8.85% of DM

Overall effect = **-0.053% of DM**



More positive diferences = better!

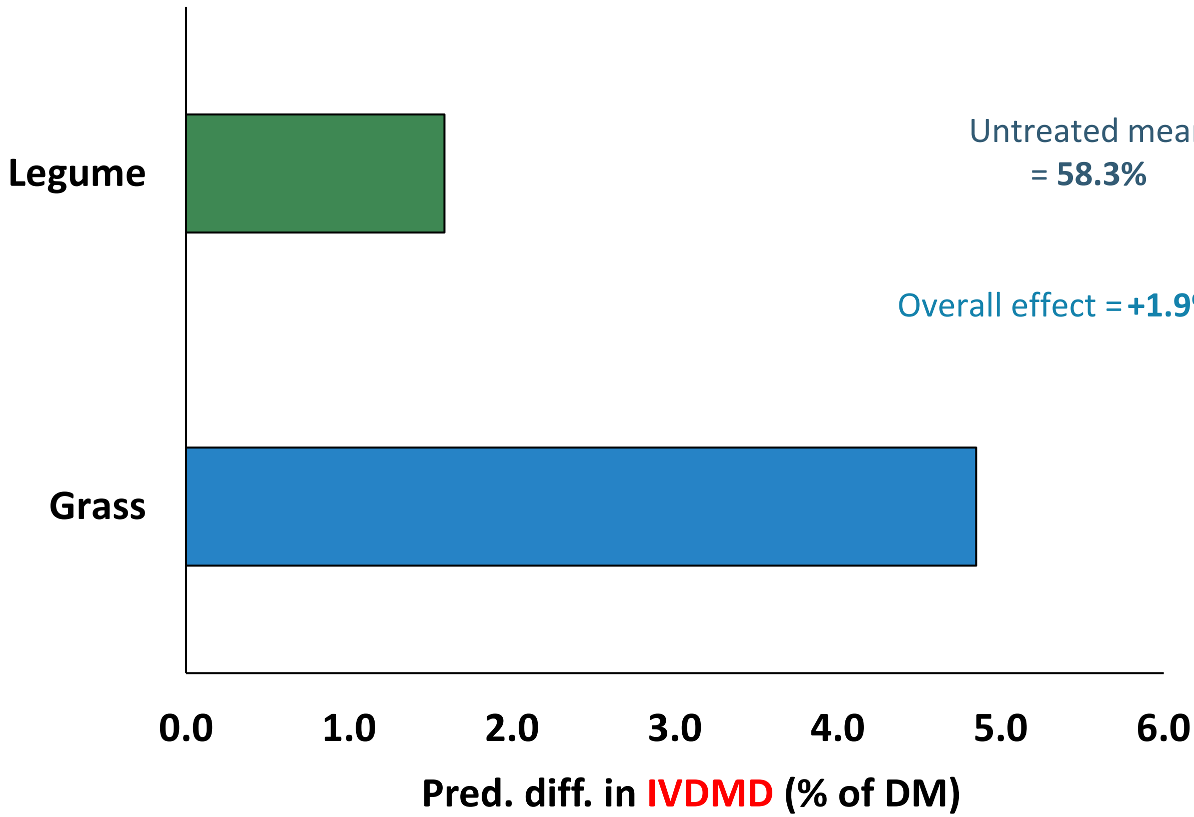
Forage Type: *P* < 0.001

Pred. diff. = Treated– Untreated

(Killerby et al., 2022)

In vitro DM digestibility

@AR= 0.83%
@MC= 27.5%



Untreated mean
= **58.3%**

Overall effect = **+1.9% units**

More positive diferences = better!

Forage Type: *P* < 0.001

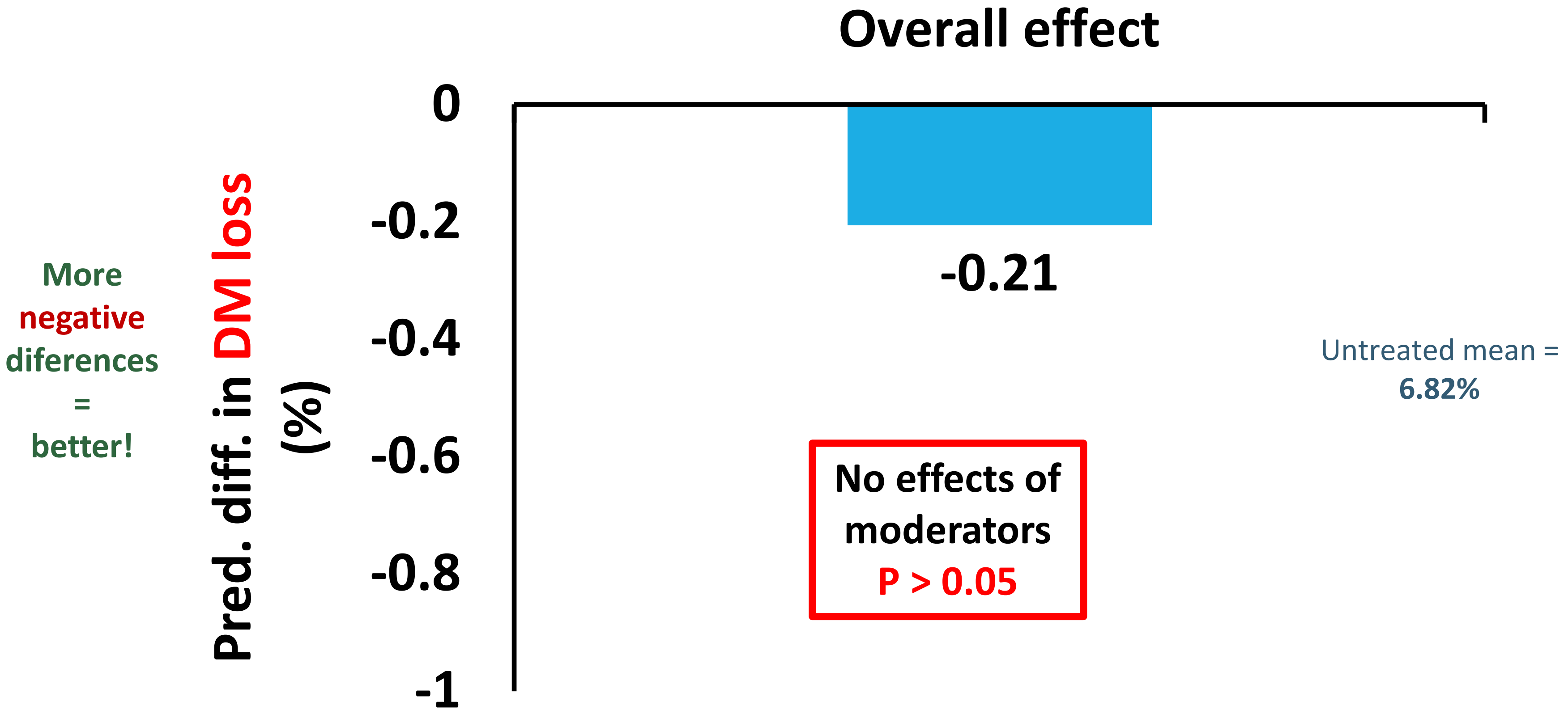
Pred. diff. = Treated– Untreated

(Killerby et al., 2022)

RESULTS

Microbial inoculants

DM loss



(Killerby et al., 2022)

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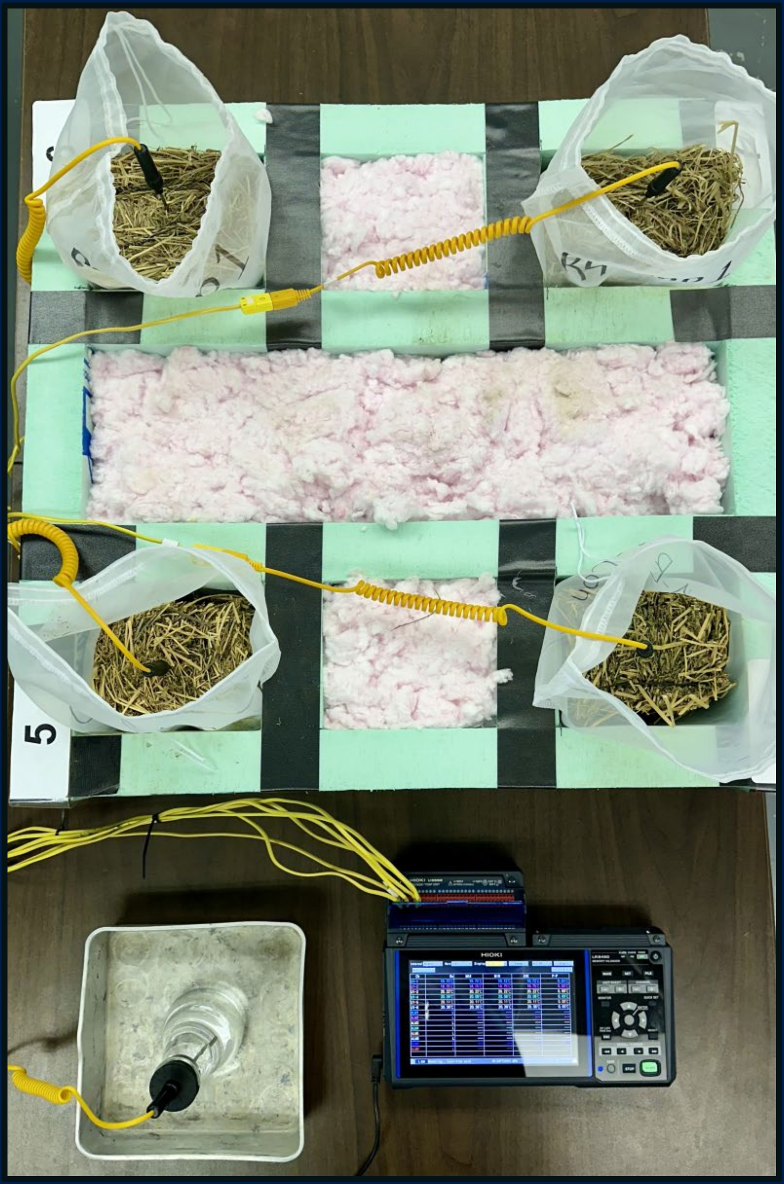
OBJECTIVES

1. Evaluate the responsiveness of alfalfa, grasses, and mixtures to propionic acid (UMaine).
2. Compare propionic acid and ammonium propionate as hay preservatives (UMaine).
3. Evaluate the effects of propionic acid on alfalfa hay microbial community dynamics (UMaine).
4. Isolate hay molds across Northeastern and Northcentral regions to assess spoilage potential (All).
5. Assess the effects of film wrapping and cutting during baling on the preservation of alfalfa hay that cannot be treated with chemicals (UNH).
6. Raise awareness on the consequences of hay spoilage and the proper utilization of preservatives to mitigate nutrient losses (UW-Madison, UVermont, and UMaine).



Obj. 2: Compare propionic acid and ammonium propionate as hay preservatives

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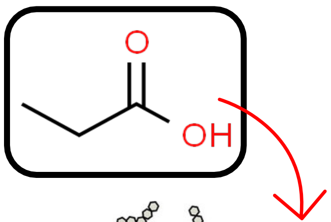
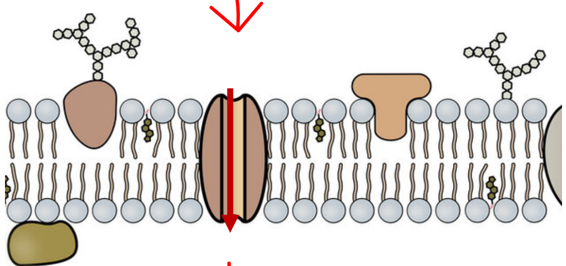
HAY PRESERVATIVES

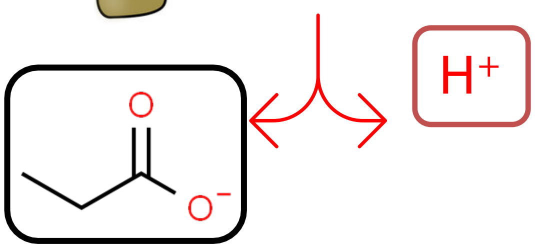
- Propionic acid (PRP)

- high volatilization (up to 70%)[1,8]
- inconsistent effects[6]
- corrosive and hazardous



- lipophilic





reduces pH

energy reserves depleted – microbial cell DIES![9]

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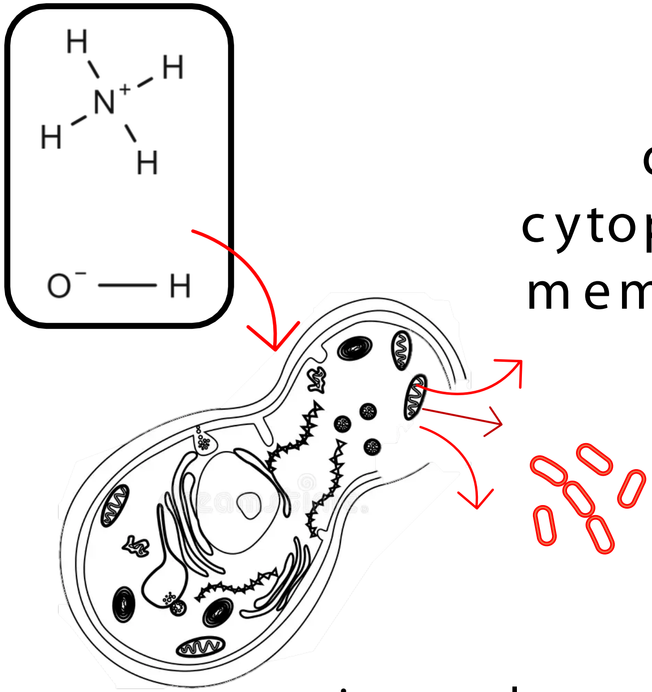
HAY PRESERVATIVES

❑ Ammonium PRP

- ❑ PRP + ammonium hydroxide (NH_4OH)
- ❑ Superior antifungal activity than PRP *in vitro*[11].
- ❑ NH_4^+ is effective regardless of pH[11]



disrupts cytoplasmic membrane[4]

internal contents leak - microbial cells DIES![4]

TREATMENTS

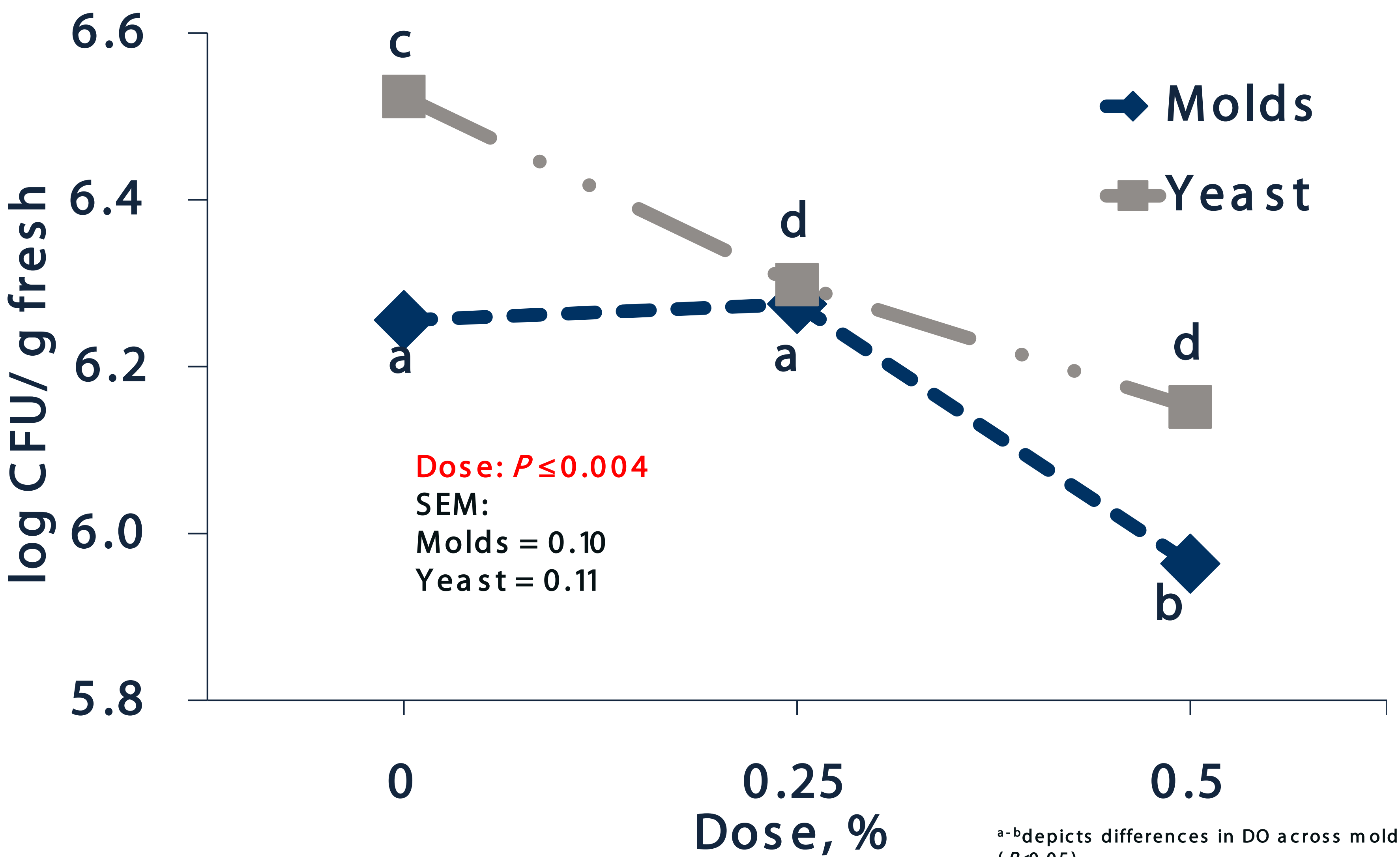
Type (TY)	Dose (DO)
❑ **PRP** 67% v/v propionic acid ❑ **AMP** PRP + 5% v/v NH_4OH ❑ **FC**: Fresh Cut Plus®, a commercial mixture of organic acids buffered with NH_4OH	❑ **0%** ❑ **0.25%** ❑ **0.5%** *w/w, (fresh basis), volatile organic acid equivalent basis (i.e., propionic plus acetic acid). **0% = control, untreated hay**

Hay Nutrient Comp and Microbial Counts

Item, %	Storage Phases		SEM	*P*-value
	d 0	d 77		
DM	70.6[b]	85.9[a]	0.37	<0.001
NDF	62.2[b]	71.7[a]	0.29	<0.001
ADF	38.4[b]	42.3[a]	0.24	<0.001
Hemicellulose	23.8[b]	29.3[a]	0.19	<0.001
Molds	5.73[b]	6.60[a]	0.08	<0.001
Yeast	7.04[a]	5.60[b]	0.09	<0.001
pH	6.32[b]	7.25[a]	0.07	<0.001

[a-b]Means with different superscripts in the same row are statistically different ($P<0.05$). SEM=standard error of mean.

MICROBIAL COUNTS



[a-b]depicts differences in DO across molds ($P<0.05$).
[c-d]depicts differences in DO across yeast ($P<0.05$).
SEM=standard error of mean.

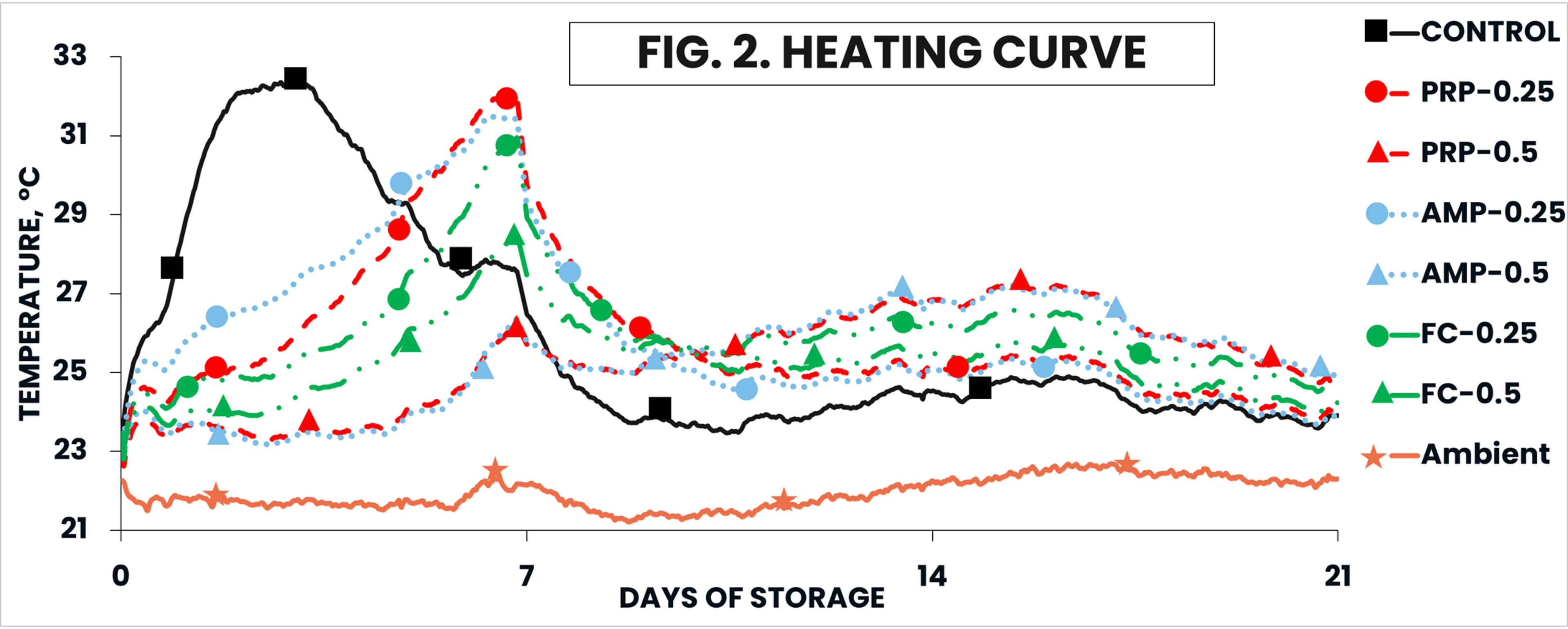


FIG. 2. HEATING CURVE
TEMPERATURE, °C
33
31
29
27
25
23
21
0
7
14
21
DAYS OF STORAGE
CONTROL
PRP-0.25
PRP-0.5
AMP-0.25
AMP-0.5
FC-0.25
FC-0.5
Ambient

DATA COLLECTION

Road Hay Fires

U.S. Fire Administration

Filtered with R Studio

1999-2022
(2857 results)

2950 results

Keywords: "Hay fire"

All reports available
(93 results)

Google News

TikTok

ProQuest U.S. Newsstream

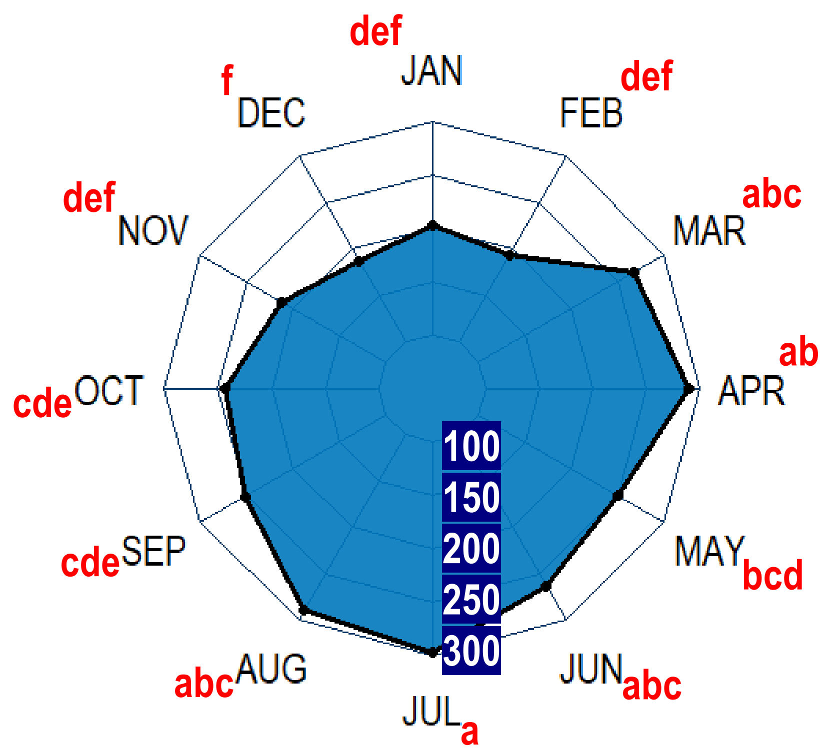
Only results that involved vehicles, started with hay, were not intentional, and were from the US were included.

There is a road hay fire every three days in the US

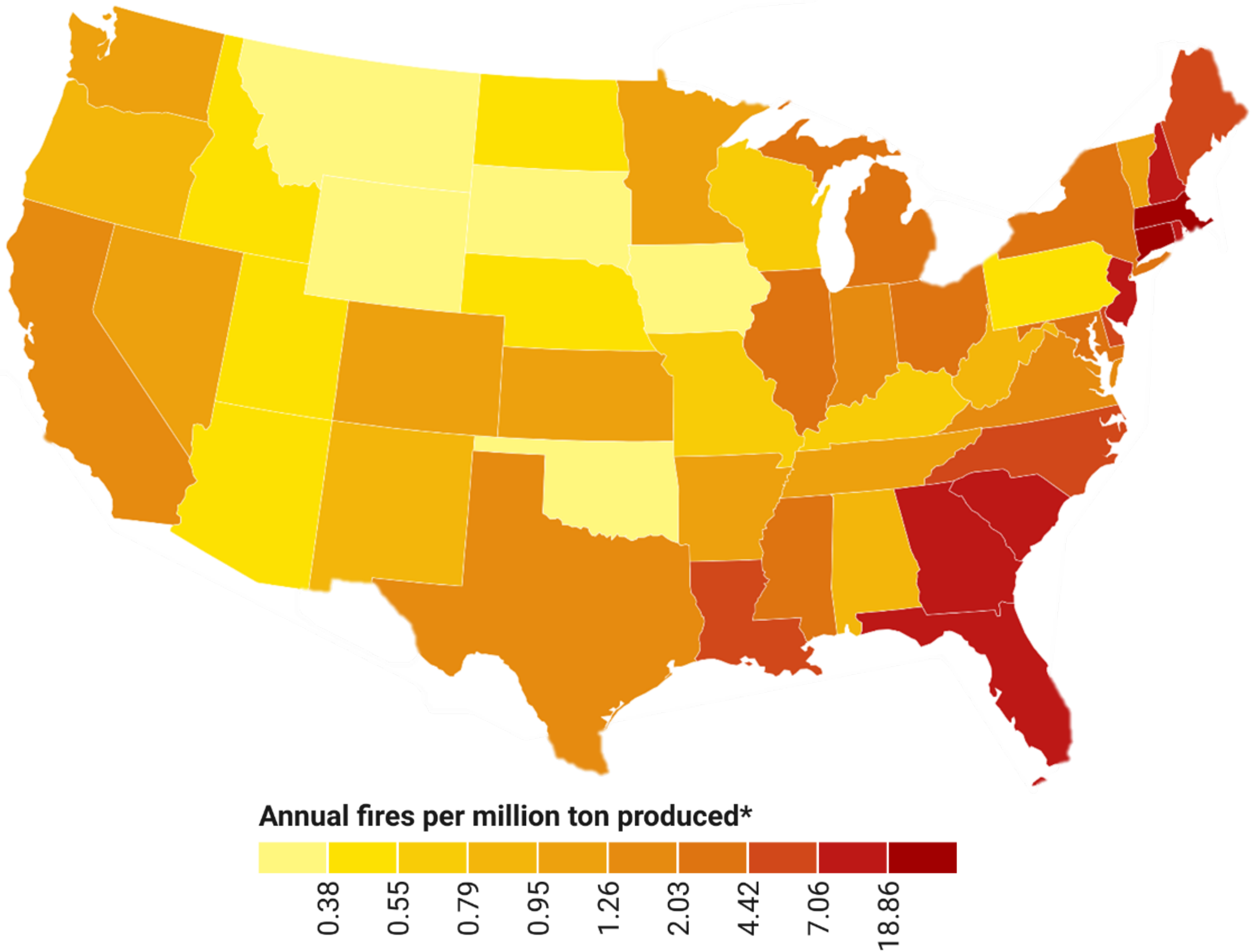
Cost of Road Hay Fires (1999-2022).

Type of cost	Average per incident (USD)	Average per year (USD)	Total cost (USD)
Traffic	43	5,009	120,208
Farmer's time	168	19,719	473,256
Firefighters	608	71,293	1,711,022
Hay	627	73,526	1,764,616
Secondary fires	4,914	576,012	13,824,293
Vehicle	32,620	3,823,283	91,758,790
Road maintenance	65,776	7,709,485	185,027,650
Total	104,756	12,278,326	294,679,835

Total road hay fires per month (1999-2022). Letters represent differences ($p<0.05$) across regions.

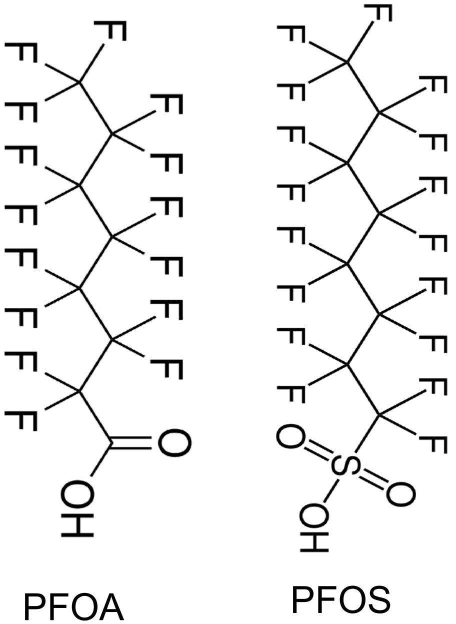


Annual distribution (1999-2022) of road hay fires per state's annual hay production (million metric tons).



What are Per-and poly fluoroalkyl substances (PFAS)?

- Introduced in early 1940’s
  - Heat resistant properties
  - “Forever chemicals” (non-degradable in environment)
- Exposure to PFAS via consumer products, **food**, water, dust, etc.
- EPA: decreased fertility, low birth weight, accelerated puberty , decreased immunity, reduced vaccine response, and hormonal balance disruption.



(Ateia et al, 2018; Death et al., 2020; U.S. Agency for Toxic Substances and Disease Registry; US EPA, 2024)

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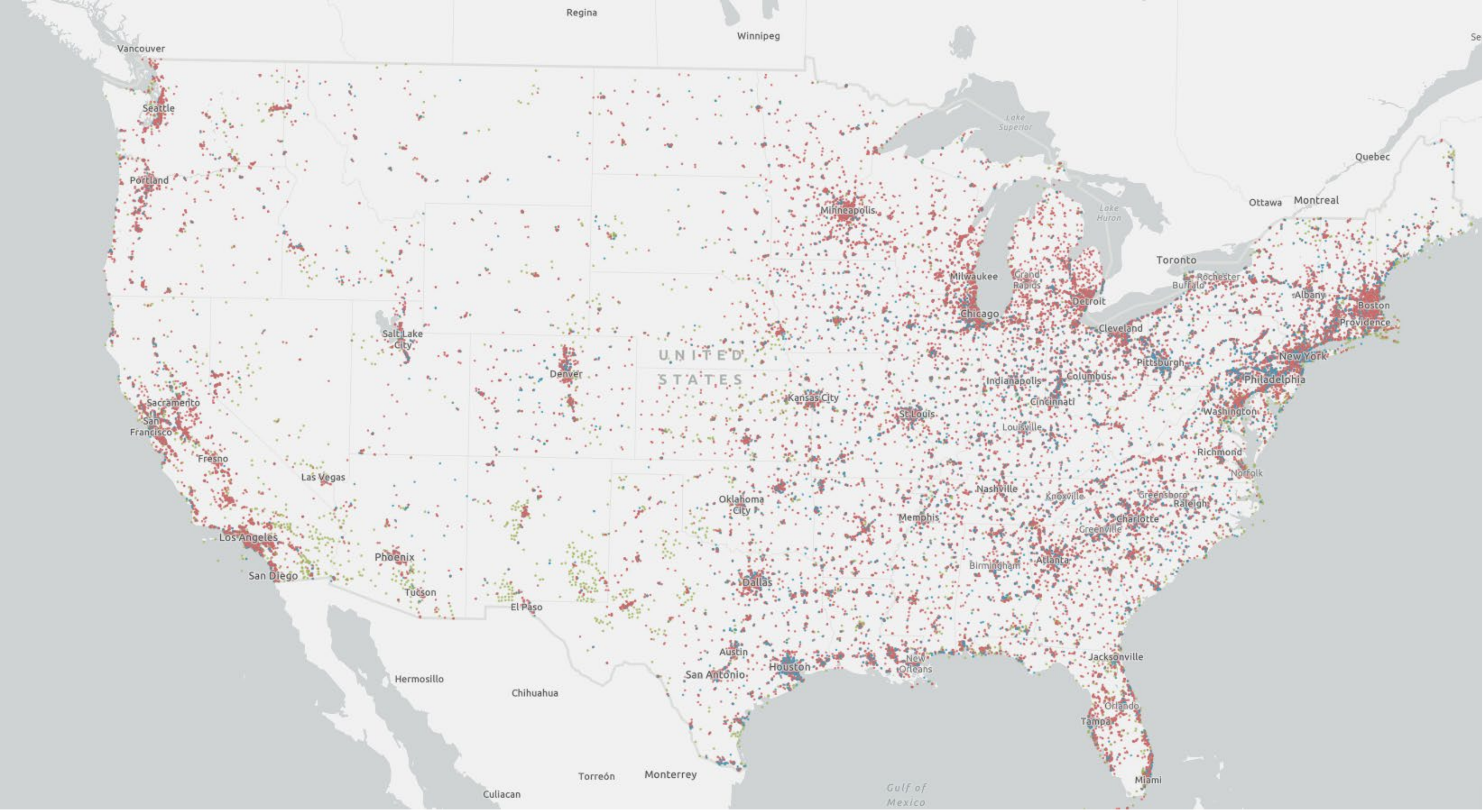
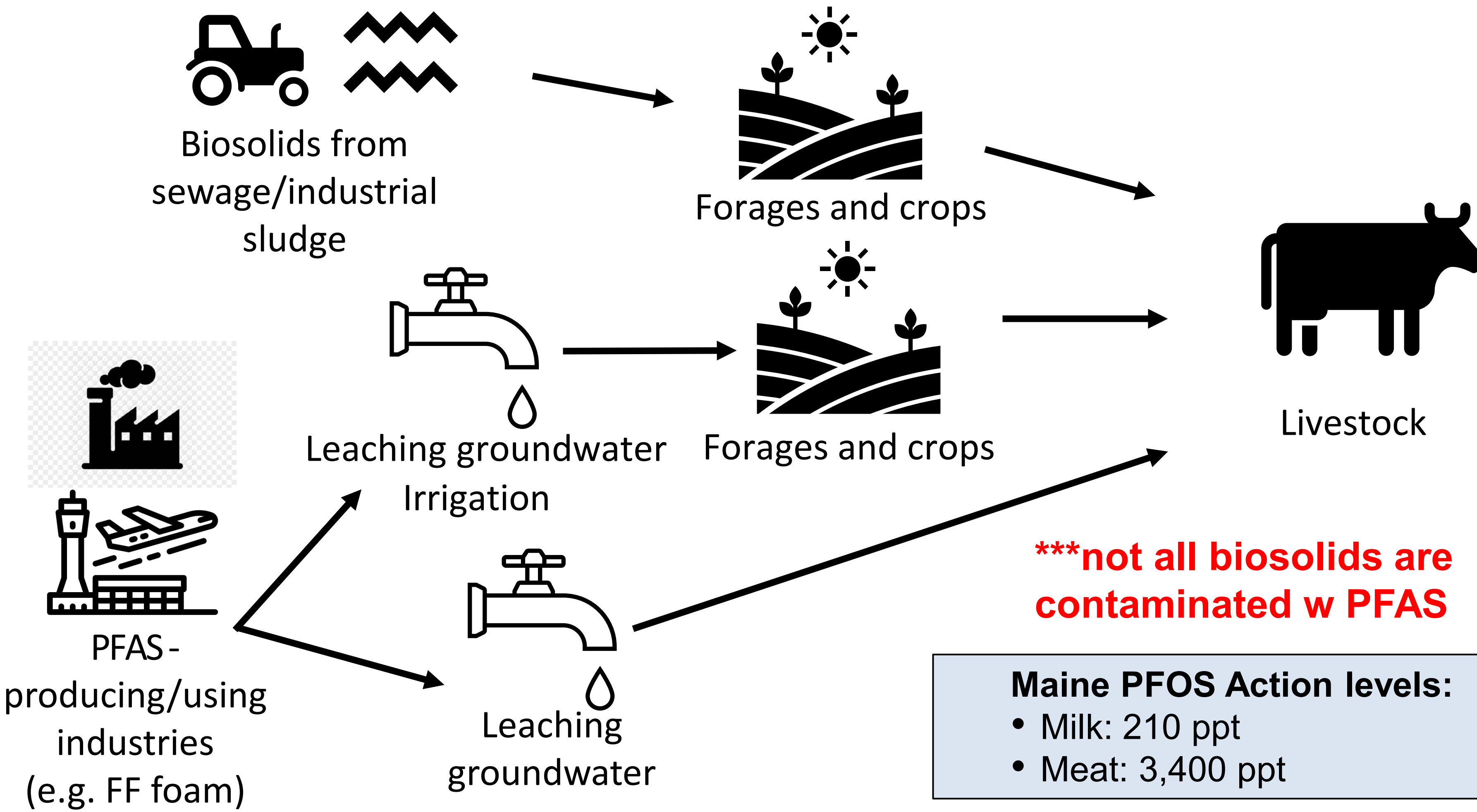
PFAS – US MAP

Presumptive PFAS contamination – NEU (2023)



https://experience.arcgis.com/experience/12412ab41b3141598e0bb48523a7c940/page/Page-1/?views=Presumptive-Contamination

Example of PFAS Pathway Contamination: farm to folk



*****not all biosolids are contaminated w PFAS**

Maine PFOS Action levels:
- Milk: 210 ppt
- Meat: 3,400 ppt

Acknowledgements

USDA

NIFA

ASAFS program, project number ME 02022-05755.