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The role of legumes in forage mixtures: Effects on your bottom line

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NODPA Virtual Annual Meeting
September, 2020

Outline

- Dietary and management strategies to improve energy intake in forage-based rations

- Why legumes are important in dairy diets?

- Effect of different legume-grass mixtures on milk production and milk fatty profile in dairy cows: **Results from feeding trials conducted at the University of New Hampshire Organic Dairy Research Farm (Lee, NH)**

- Summary and Conclusions

High-forage feeding survey results

Question 6 – In the herds that have increased the level of forage in the ration, what have been the benefits? (More than 1 answer can be selected).

Benefit	% of Responses
Increased milk production	32.2
Increased milk fat and protein levels	74.5
Lower purchased feed costs	84.7
Improved animal health	76.3
Lower culling rate	20.3
Cows stay in the herd longer	28.8
Improved profitability	76.3

Source: Chase (2017)

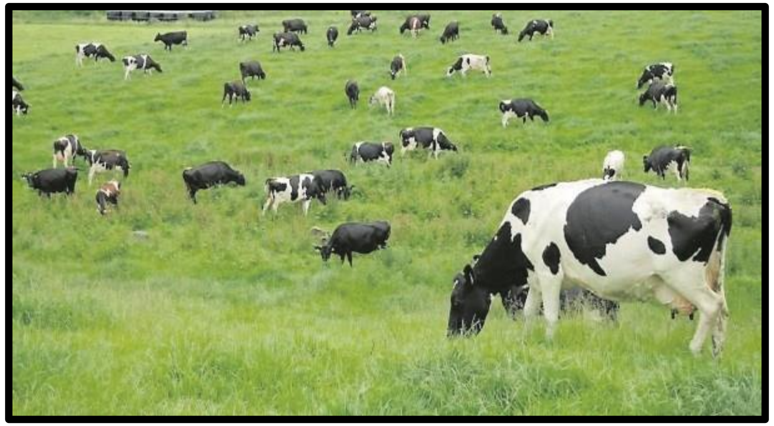
Pasture net energy of lactation (NE_L) in northeastern organic dairies

Table 2. Summary statistics (n = 380) of forage quality parameters and macro minerals and the effect of year, month, and farm on forage quality and macro mineral concentration of pastures in 2012, 2013, and 2014

					P-value		
Item	Mean[1]	SD[1]	Min[1]	Max[1]	Year	Month	Farm
Forage quality							
CP, %	19.5	4.10	6.60	32.4	0.25	<0.01	<0.01
ADF, %	31.4	4.79	18.0	73.0	0.75	<0.01	<0.01
NDF, %	51.0	8.67	24.2	71.0	<0.01	<0.01	<0.01
NE_L, Mcal/kg	1.39	0.15	0.77	1.76	0.03	<0.01	<0.01
Macro minerals[2]							
Ca, %	0.76	0.25	0.19	1.66	<0.01	<0.01	<0.01
P, %	0.36	0.08	0.07	1.04	0.23	<0.01	<0.01
Mg, %	0.28	0.06	0.10	0.46	<0.01	<0.01	<0.01
K, %	2.68	0.60	0.26	4.69	0.02	0.03	<0.01
S, %	0.28	0.05	0.09	0.44	0.14	<0.01	<0.01

[1]Mean, SD, minimum (Min), and maximum (Max) values across all farms and all months sampled in 2012, 2013, and 2014.

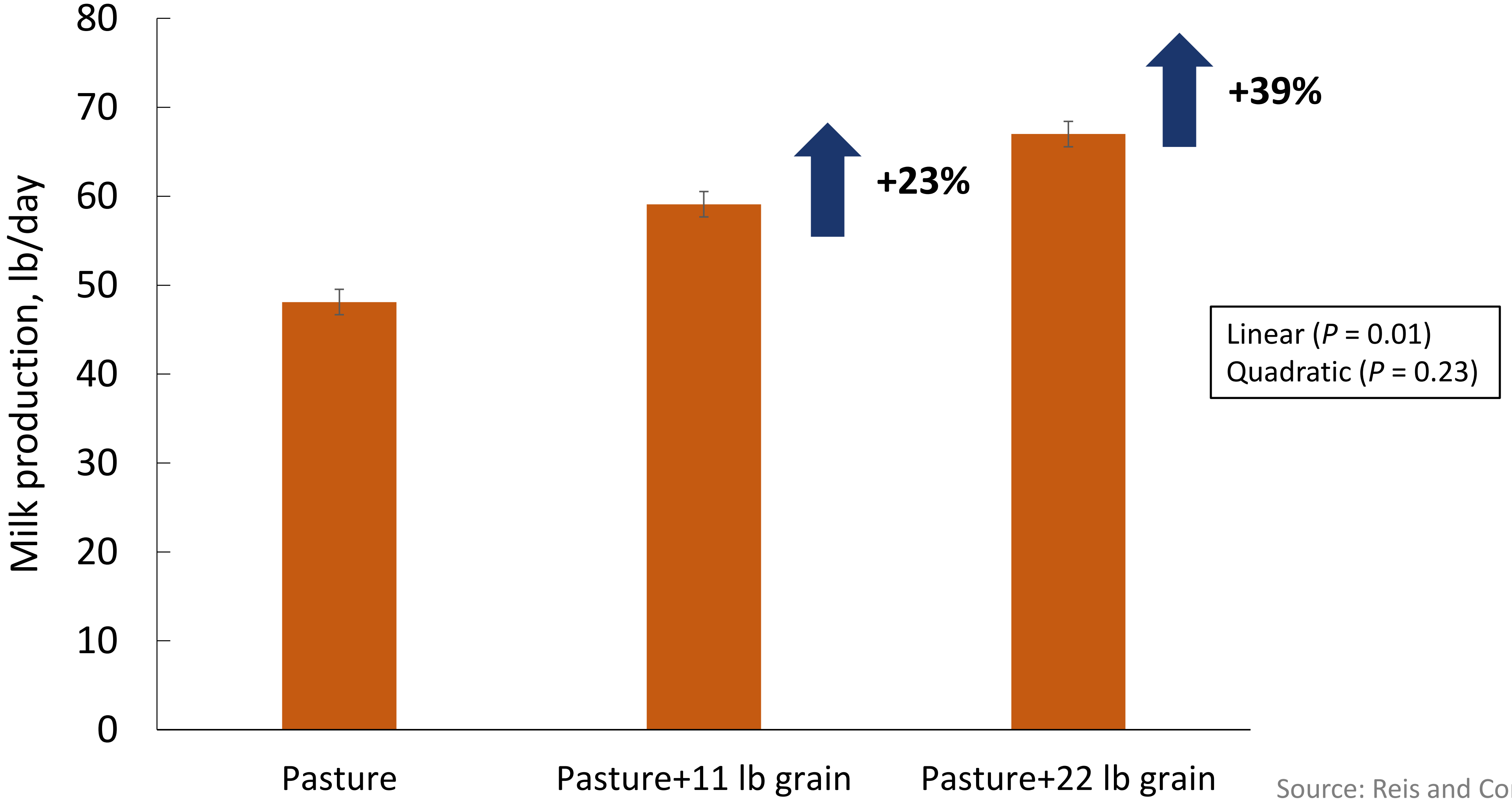
[2]Near-infrared reflectance spectroscopy analysis for sodium was missing on many samples; therefore, it is not included.



NE_L
Mean = 0.63 Mcal/lb
Minimum = 0.35 Mcal/lb
Maximum = 0.80 Mcal/lb

Source: Hafla et al. (2016)

Milk production response to increasing levels of ground corn-based grain in grazing Holstein cows



Source: Reis and Combs (2000)

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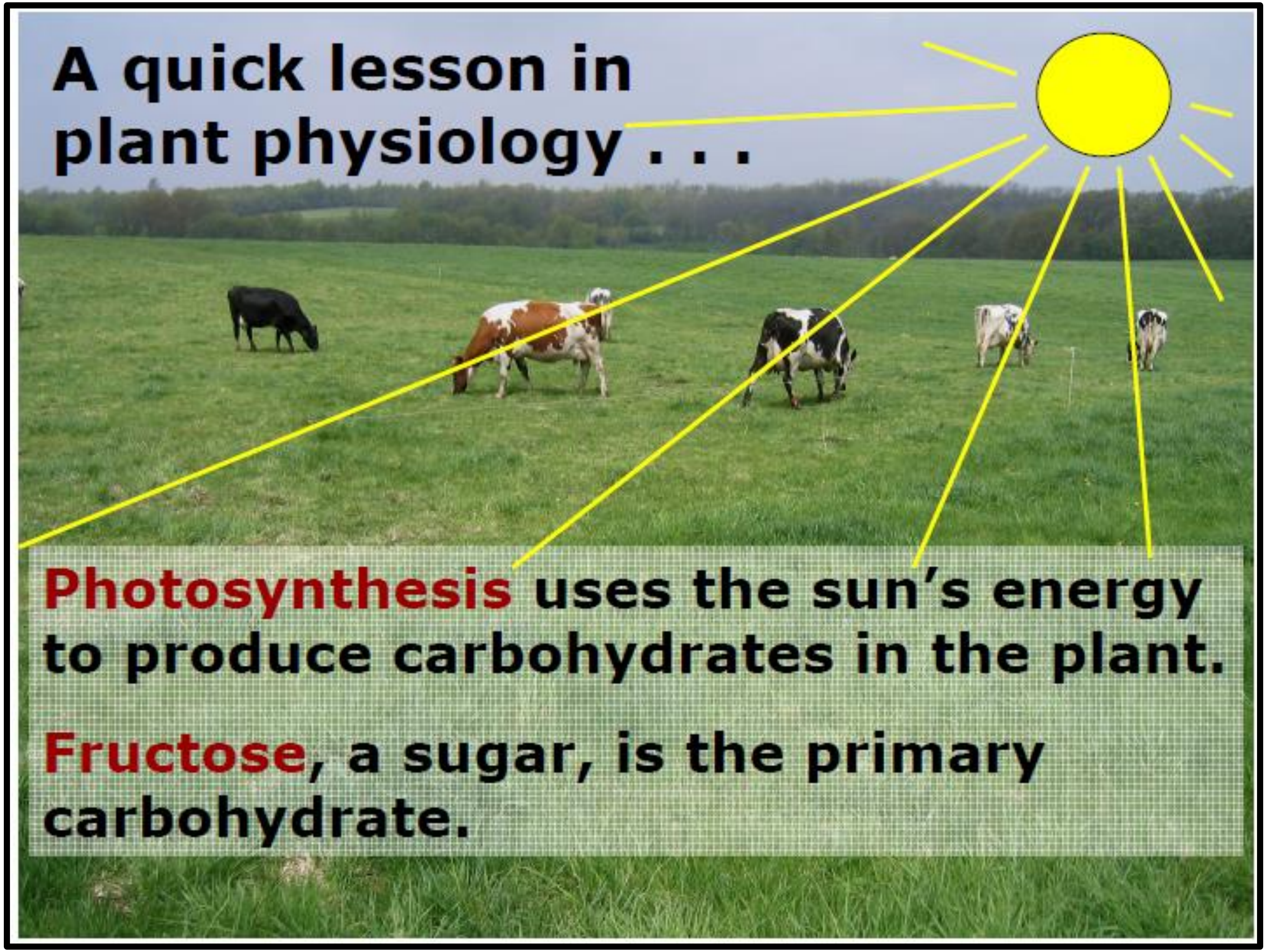
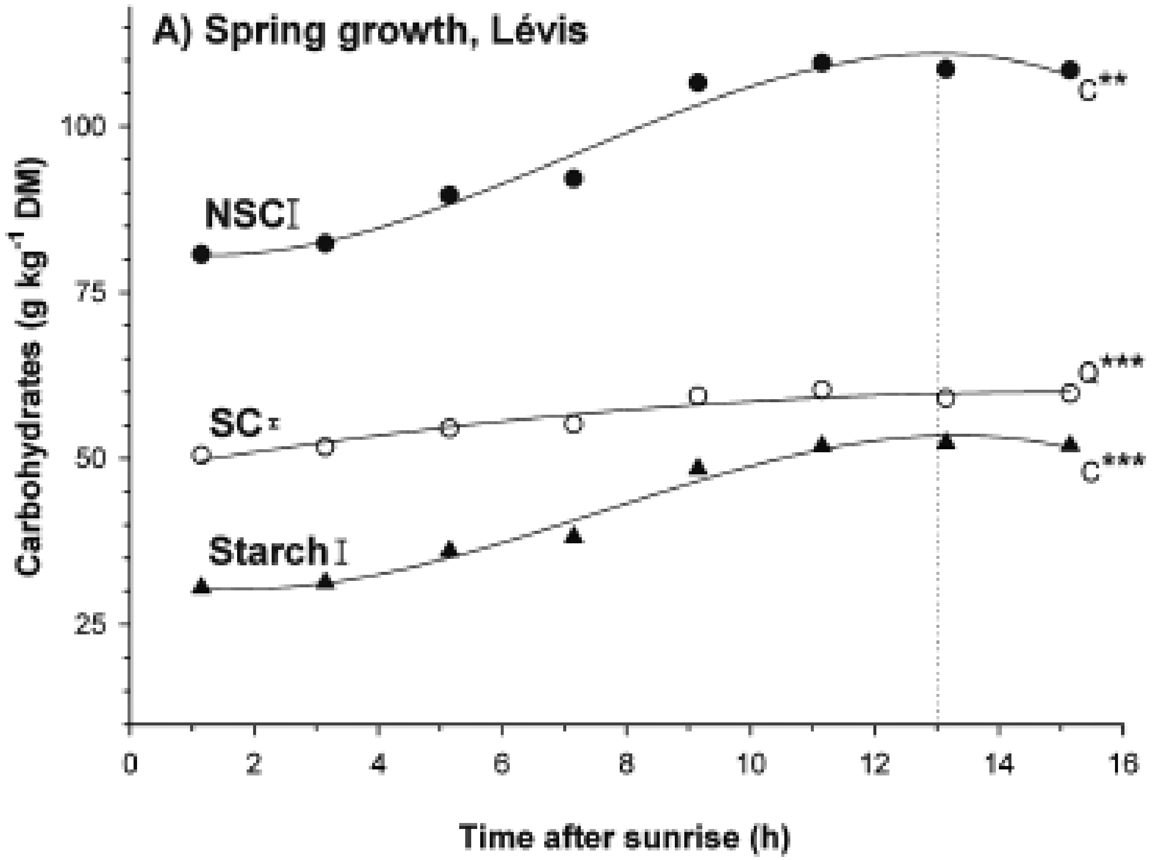
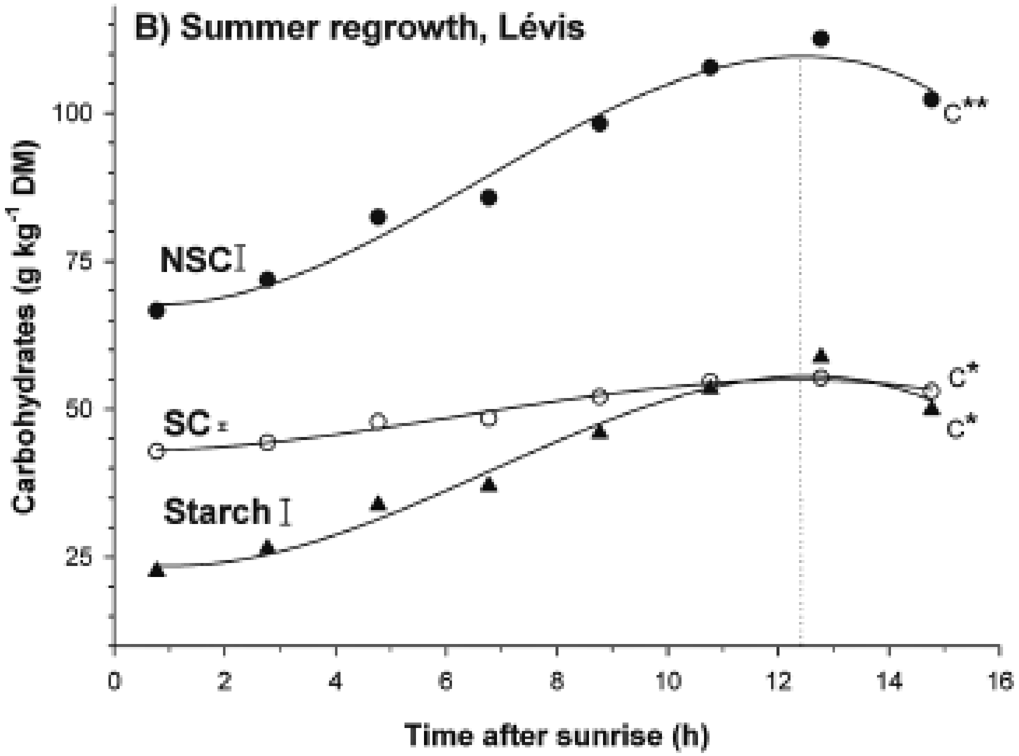


Source: Brink

Diurnal variation in sugars and starch in alfalfa





NSC = non-structural carbohydrates
SC = soluble carbohydrates
Source: Pelletier et al. (2010)

Sugars and starch in PM- vs. AM-cut alfalfa baleage

Item[1]	Time of cutting: PM	AM	SED[2]	*P*-value[3]
DM, g/kg of fresh matter	537	524	15.4	0.44
	g/kg of DM			
TNC[4]	128	105	3.00	<0.01
Total reducing sugars	89.0	67.5	2.30	<0.01
Pinitol	22.0	26.0	0.80	<0.01
Starch	17.1	11.4	0.67	<0.01
WSC[5]	111	93.5	2.50	<0.01

TNC = total nonstructural carbohydrates
WSC = water soluble carbohydrates
Source: Brito et al. (2008)

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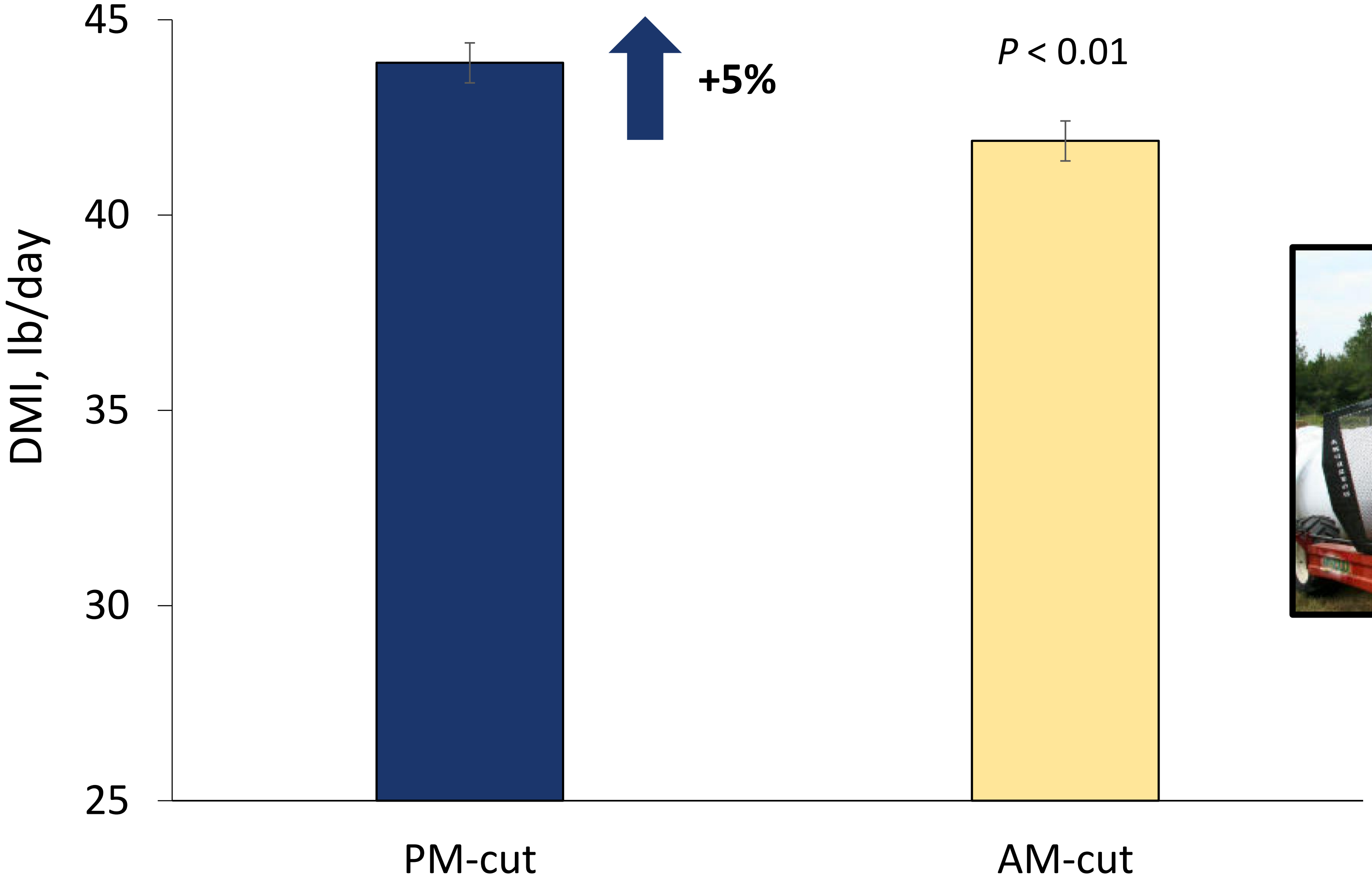
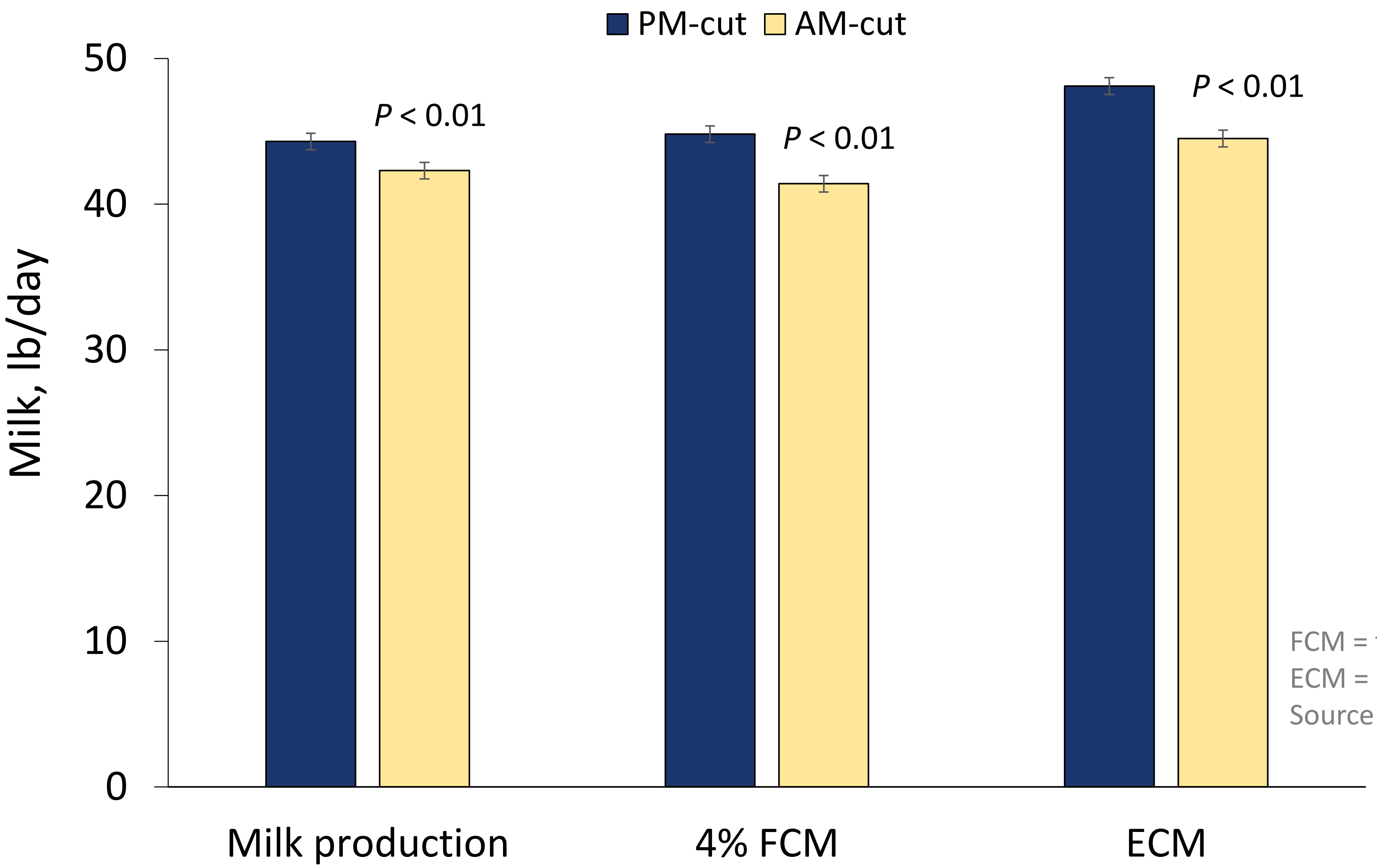
Intake increased in dairy cows fed PM-cut alfalfa baleage



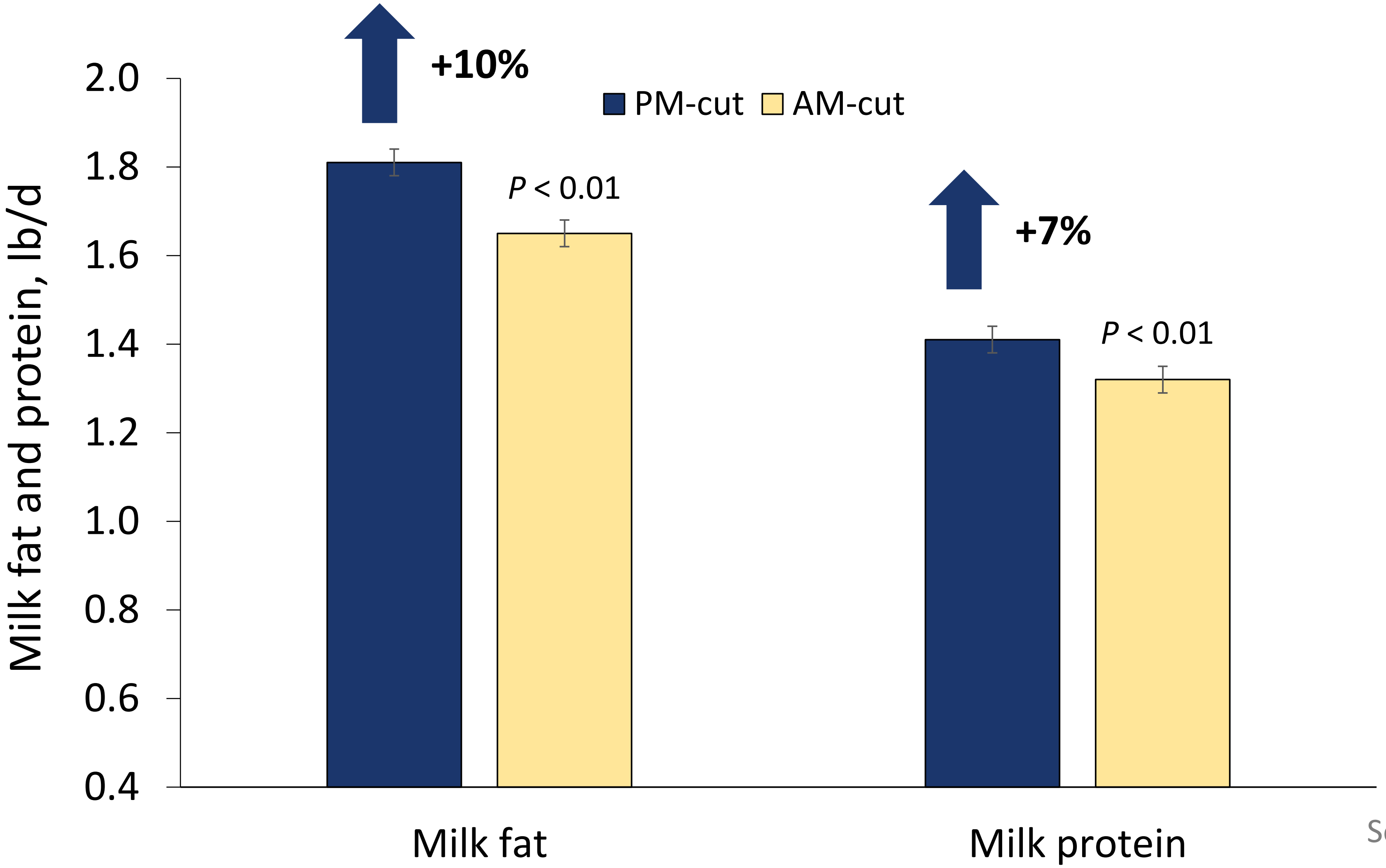
DMI = dry matter intake
Source: Brito et al. (2008)

Increased milk production in cows fed PM-cut alfalfa baleage



FCM = fat-corrected milk production
ECM = energy-corrected milk production
Source: Brito et al. (2008)

Milk fat and protein production in cows fed PM-cut alfalfa baleage



Source: Brito et al. (2008)

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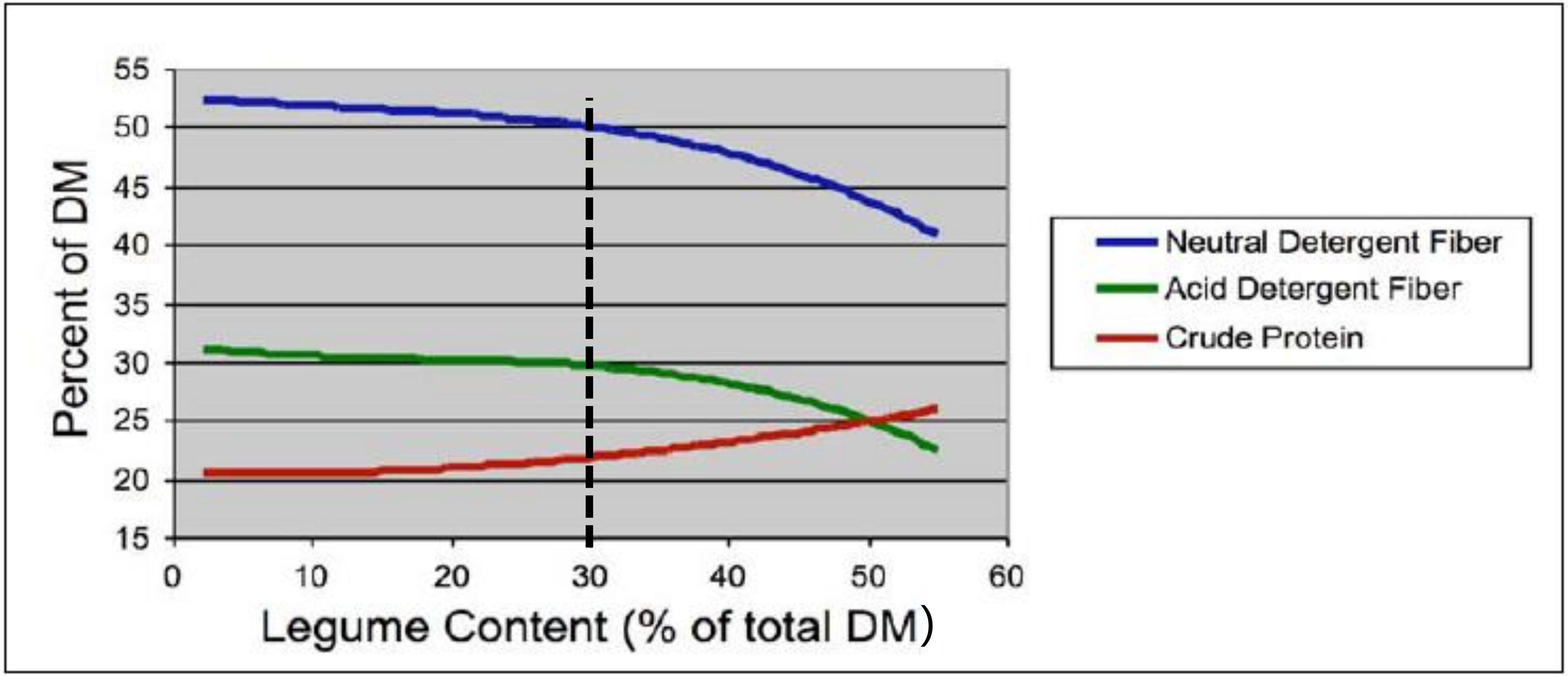
Correlation between legume proportion in pasture and forage quality traits

Parameter	Correlation coefficient	Significance
Crude protein	0.41	*
Soluble protein	0.00	ns
Acid detergent fiber	-0.58	**
Neutral detergent fiber	-0.57	**
Net Energy of Lactation	0.53	**
Total digestible nutrients	0.58	**
Phosphorus	0.08	ns
Potassium	-0.09	ns
Magnesium	0.28	ns
Calcium	0.54	**

Source: Bosworth and Cannella (2007)
ns = not significant

Relationship between legume proportion in pasture and forage quality traits



Source: Bosworth and Cannella (2007)

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Effect of forage type on feed intake and milk production

	Forage type		
Item	Grasses	Legumes	*P*-value
Dry matter intake, lb/day	40.3	43.2	0.001
Milk production, lb/day	54.0	57.5	<0.001
Energy-corrected milk, lb/day	53.6	55.8	0.006
Feed efficiency[1], lb/lb	1.33	1.30	0.20
OM digestibility[2], %	70.4	67.9	0.01

[1]Feed efficiency = energy-corrected milk/dry matter intake
[2]OM = organic matter
Source: Johansen et al. (2018)

Effect of forage type on feed intake and milk production

	Forage type					
Item	Grasses	White clover	Red clover	Alfalfa	Birdsfoot	*P*-value
Dry matter intake, lb/d	41.7[b]	44.1[ab]	44.1[a]	46.3[a]	48.1[ab]	<0.001
Milk production, lb/d	57.8[c]	65.3[a]	60.2[b]	61.1[b]	69.2[a]	<0.001
Energy-corrected milk, lb/d	56.7[d]	61.9[ab]	57.5[cd]	59.5[bc]	67.0[a]	<0.001
Feed efficiency[1], lb/lb	1.35	1.39	1.31	1.30	1.43	0.07
OM digestibility[2], %	71.5[ab]	73.6[a]	69.4[b]	66.0[c]	67.2[abc]	<0.001

[a,b,c,d]Values in same line with different letters differ at $P < 0.05$

[1]Feed efficiency = energy-corrected milk/dry matter intake

[2]OM = organic matter

Source: Johansen et al. (2018)

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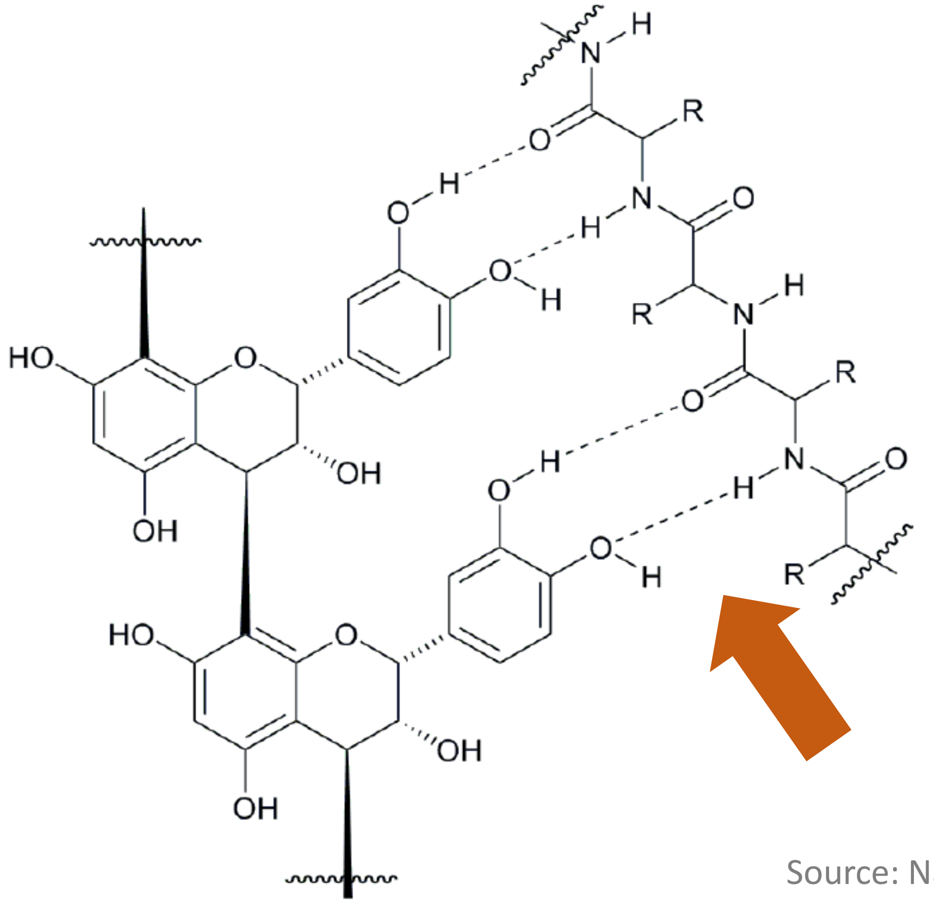
Condensed tannins

- ✓ Condensed tannins are secondary plant metabolites with complex and diverse chemical structures with a general affinity for binding to protein and to a lesser extent complex carbohydrates (Mueller-Harvey, 2006; Waghorn, 2008)



Source: Naumann et al. (2017)

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Effect of legume type on feed intake and milk production

	Silage sources[1]						
Item	ALF	RC	LBFT	NBFT	HBFT	SEM	*P*-value
Dry matter intake, lb/day	54.5	56.4	54.5	52.9	55.6	2.05	0.69
Milk production, lb/day	68.1^{c}	67.9^{c}	73.9^{b}	76.3^{ab}	78.0^{a}	2.36	<0.01
Feed efficiency[2], lb/lb	1.27^{bc}	1.24^{c}	1.38^{abc}	1.49^{a}	1.42^{ab}	0.07	0.01
Milk fat, lb/day	2.60^{bc}	2.78^{c}	2.71^{abc}	2.98^{a}	2.91^{ab}	0.17	0.03
Milk protein, lb/day	2.20^{c}	2.09^{c}	2.36^{b}	2.38^{ab}	2.51^{a}	0.08	<0.01
MUN[3], mg/dL	11.4^{a}	11.0^{ab}	11.4^{a}	9.70^{c}	10.1^{bc}	0.63	0.04

[a,b,c,d]Means in the same line with different letters differ at $P \leq 0.05$

[1]ALF = alfalfa silage; RC = red clover silage; LBFT = low condensed tannin birdsfoot trefoil silage; NBFT = normal condensed tannin birdsfoot trefoil silage; HBFT = high condensed tannin birdsfoot trefoil silage

[2]Feed efficiency = energy-corrected milk/dry matter intake

[3]MUN = milk urea nitrogen

Source: Hymes-Fecht et al. (2013)

Pasture botanical composition in northeastern organic dairies

Table 3. Pasture availability and botanical composition of participating farms in the northeastern United States during the 2012, 2013, and 2014 grazing seasons

				P-value	
Item	**2012 (SEM)**	**2013 (SEM)**	**2014 (SEM)**	**Year**	**Month × year**
Pasture availability, kg/ha	1,320 (185)	1,048 (151)	871 (161)	<0.01	0.01
Botanical composition, %					
Grasses	61 (6)	54 (6)	50 (6)	0.04	0.16
Legumes	22 (5)	29 (4)	37 (5)	<0.01	0.07
Weeds	13 (3)	13 (2)	15 (3)	0.68	0.49

Source: Hafla et al. (2018)

Developing advanced perennial legume-grass mixtures harvested as stored feeds to improve herd productivity and mitigate greenhouse gas emissions in organic dairies in the Northeast

The UNIVERSITY of VERMONT

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SARE
Sustainable Agriculture Research & Education

USDA NIFA
United States Department of Agriculture
National Institute of Food and Agriculture

Research objectives

- Evaluate productivity and forage quality of grass-legume mixtures

- Balance the energy:protein ratios of forages through species selection and stand management

- Evaluate animal performance

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University of New Hampshire Organic Dairy Research Farm

- Area (111.3 ha): **48.6 ha (woodland), 40.5 ha (hayfields), and 22.3 ha (pasture)**
- ~45 lactating cows: **pure-bred Jerseys**
- Rolling herd average: **6,473 ± 503 kg**
- Milk fat: **4.88 ± 0.09**
- Milk protein: **3.63 ± 0.06**
- Milk SCC: **135,000**
- MUN: **11.1 ± 2.9 mg/dL**
- Grazing season: **40% pasture + 60% TMR**
- Winter season: **TMR (60% baleage + 40% concentrate)**

Feeding trial methods

- Twenty organic-certified mid-lactation Jersey cows were used in both feeding trials
- Cows (n = 10/diet) were randomly assigned to 1 out 2 diets fed as TMR: **alfalfa- or red clover-grass mix (Trial 1); red clover or red clover-white clover mix (Trial 2)**
- Trials 1 and 2 last 7 and 6 weeks, respectively
- Feed intake (Calan gates) and milk production measured throughout the studies
- Samples (feeds, blood, feces, urine, rumen) were collected

Nutritional composition of baleages

	Baleage[1]			
Item	ALF-GR, 2nd cut	ALF-GR, 3rd cut	RC-GR, 2nd cut	RC-GR, 3rd cut
Dry matter (DM), % as fed	42.7	48.9	75.7	32.3
Crude protein (CP), % DM	20.9	21.8	20.1	20.5
Soluble protein, % CP	63.0	62.0	25.5	40.5
aNDFom, % DM	41.0	41.3	41.6	42.1
ADF, % DM	31.7	33.1	29.9	33.7
Lignin, % DM	6.05	7.25	5.05	7.95
Starch, % DM	2.60	1.75	1.40	0.85
Sugars, % DM	4.95	3.05	6.90	4.05
Crude fat, % DM	3.20	3.65	3.75	3.35
NE_L, Mcal/lb	0.63	0.60	0.68	0.57

[1]ALF-GR = alfalfa-grass mix; RC-GR = red clover-grass mix

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Polyphenol oxidase (PPO) in red clover

- Oxidises phenols to quinones in the presence of oxygen
- Quinones are very reactive
- Quinones bind to proteins to give protein-quinone complexes

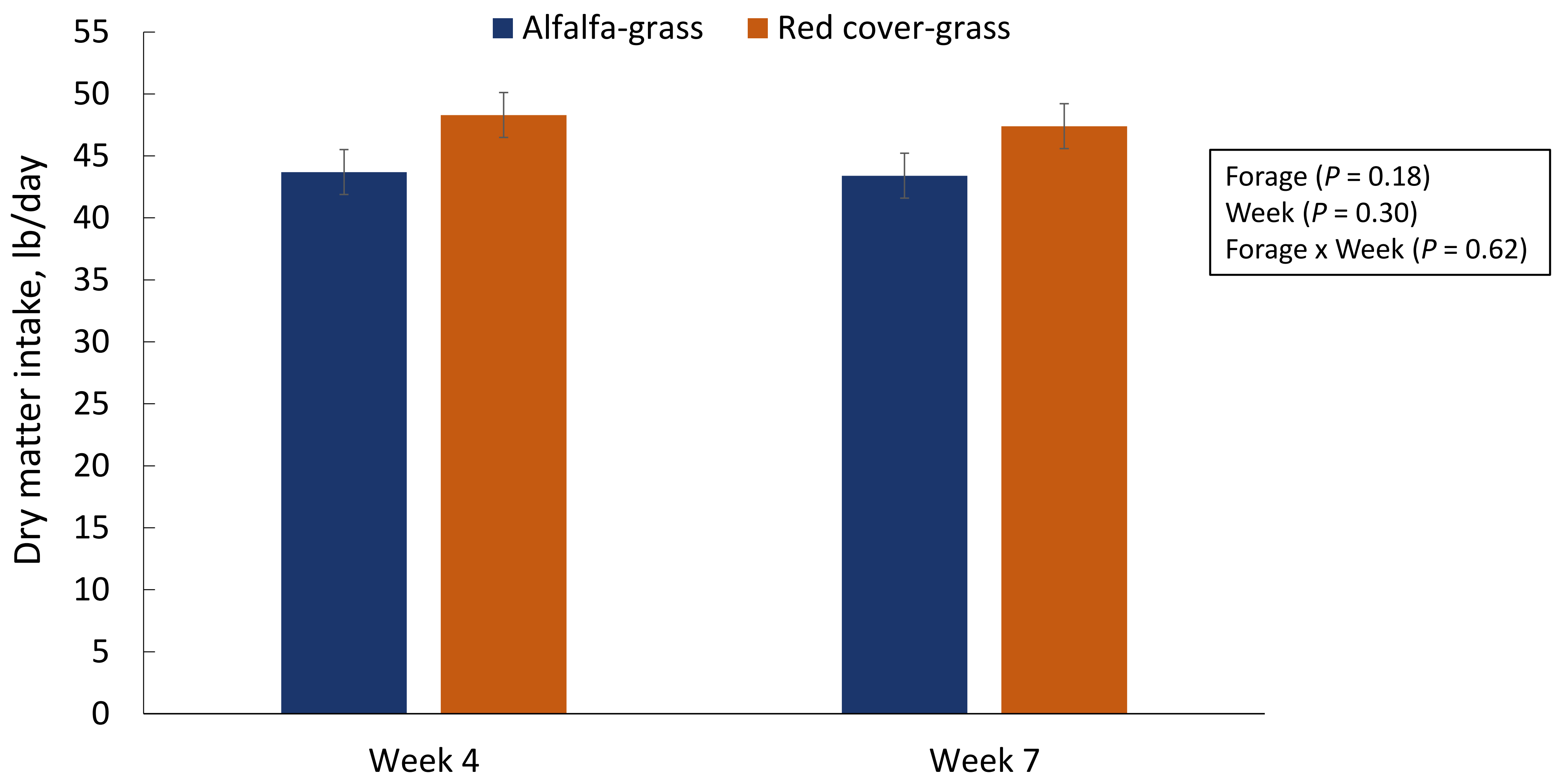
Source: Lee (2015)

Experimental diets

Item	Diets	
	Alfalfa-grass mix	Red clover-grass mix
	----------% of diet dry matter----------	
Alfalfa-grass mix, 2nd cut baleage	32.5	-
Red clover-grass mix, 2nd cut baleage	-	32.5
Alfalfa-grass mix, 3rd cut baleage	32.5	
Red clover mix, 3rd cut baleage	-	32.5
Grain mash	35.0	35.0

Calan gates

Dry matter intake in cows fed alfalfa- or red clover-grass mix



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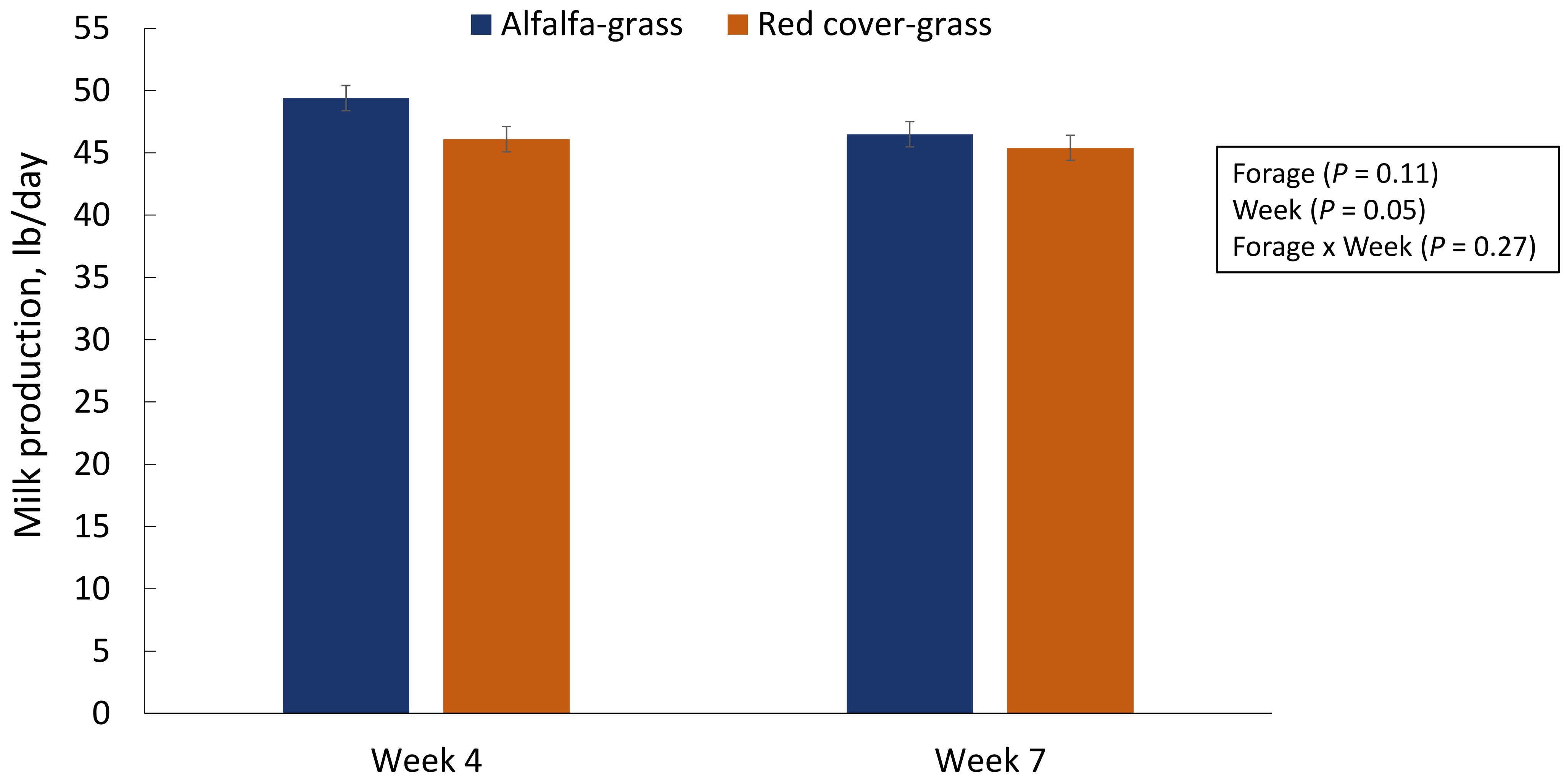
Milk production in cows fed alfalfa- or red clover-grass mix



Milk composition in cows fed alfalfa- or red clover-grass mix

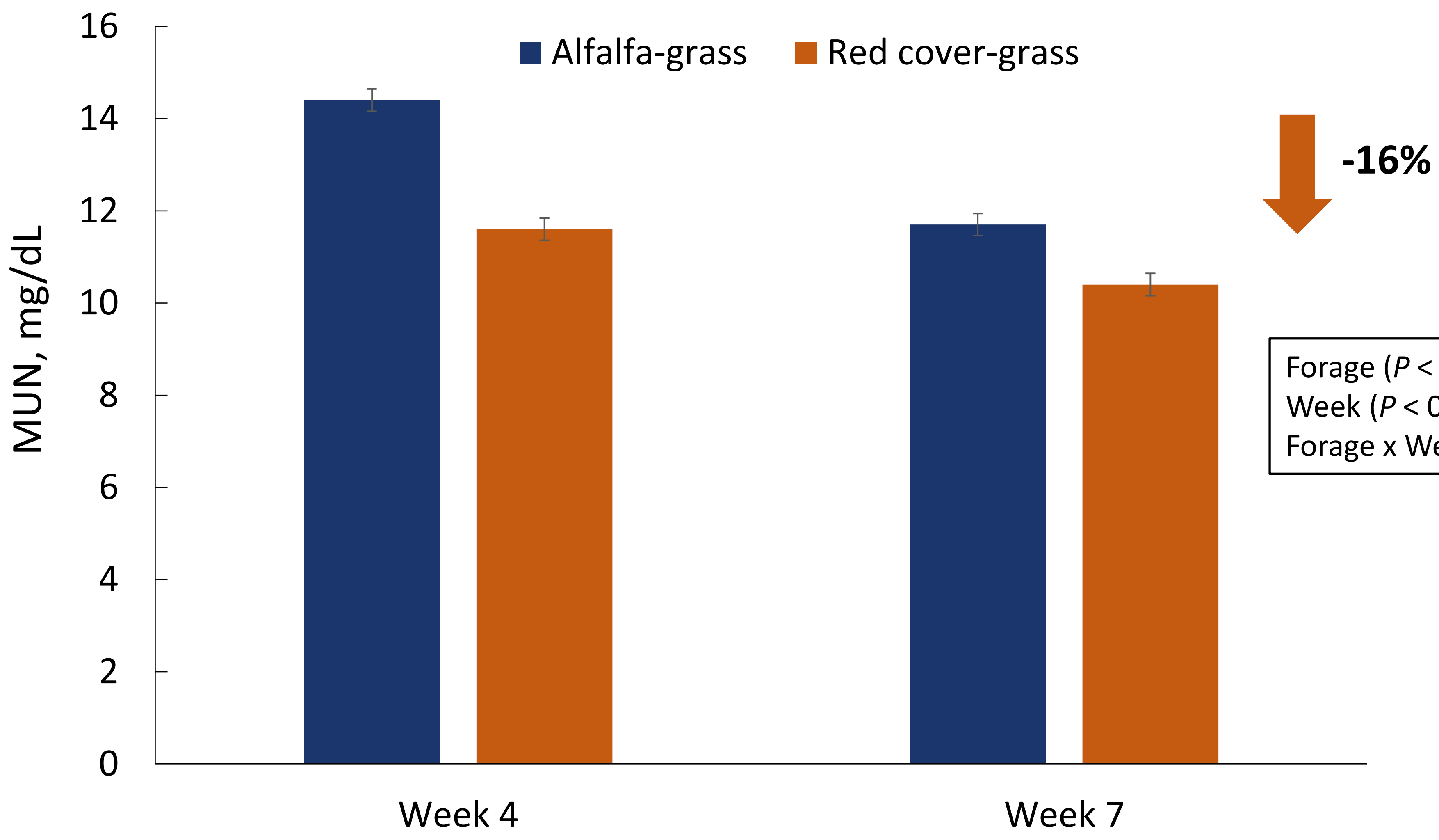
	Week 4		Week 7			*P*-value		
Item	ALF-GR[1]	RC-GR[1]	ALF-GR[1]	RC-GR[1]	SEM[2]	Forage	Week	Forage × Week
Milk fat, %	5.61	5.32	5.36	5.27	0.10	0.18	0.03	0.13
Milk fat, lb/day	2.78	2.45	2.49	2.38	0.09	0.05	0.02	0.13
Milk protein, %	3.64	3.57	3.73	3.60	0.10	0.48	0.19	0.44
Milk protein, lb/day	1.79	1.65	1.72	1.63	0.07	0.21	0.18	0.40
Milk lactose, %	4.72	4.73	4.66	4.71	0.02	0.23	0.10	0.55
Milk lactose, lb/day	2.31	2.18	2.16	2.14	0.04	0.21	0.03	0.23

↑ +9.1%

[1]ALF-GR = alfalfa-grass mix; RC-GR = red clover-grass mix

[2]SEM = standard error of the mean

Milk urea nitrogen (MUN) in cows fed alfalfa- or red clover-grass mix



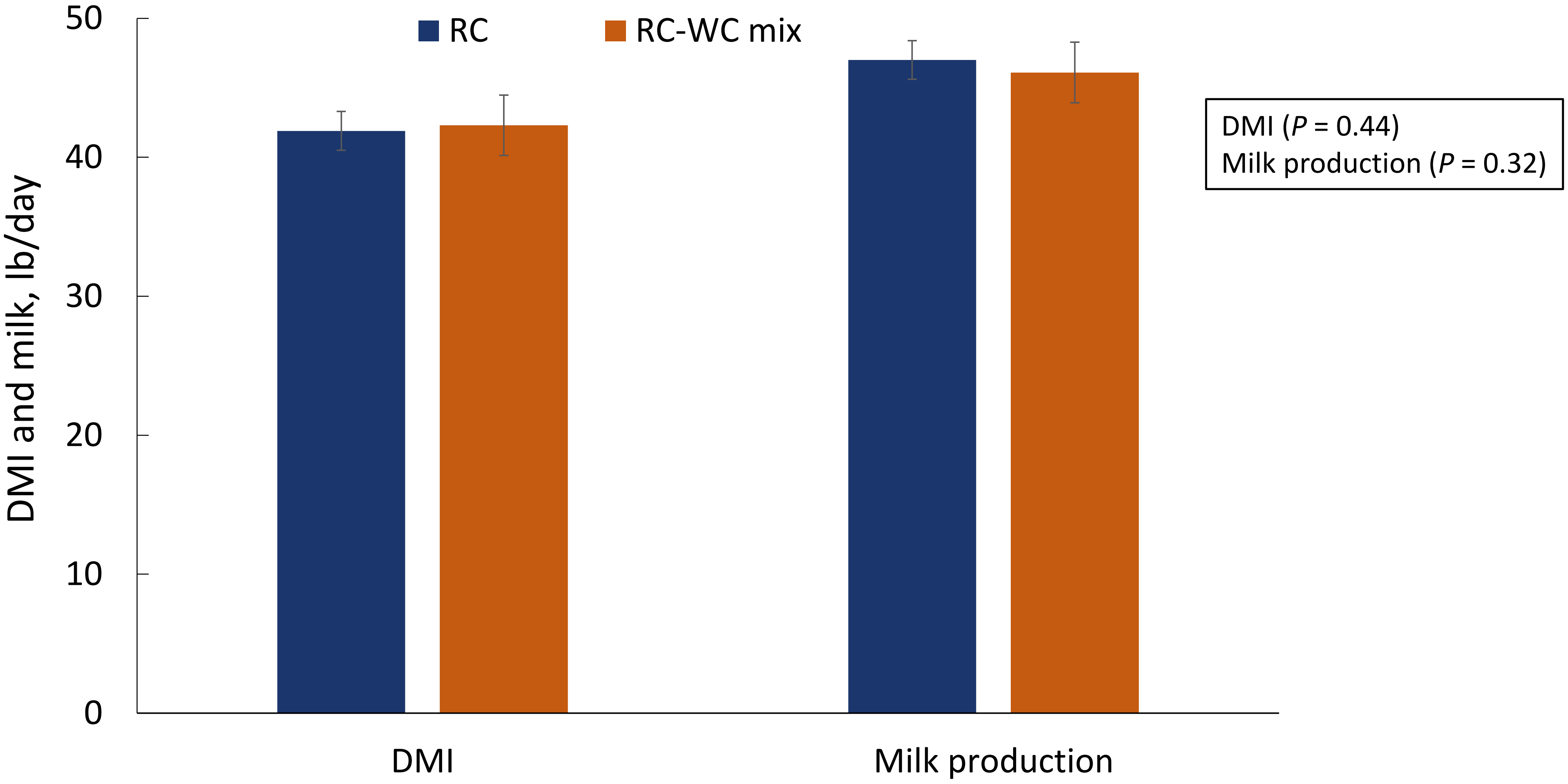
Forage ($P < 0.001$)
Week ($P < 0.001$)
Forage x Week ($P < 0.001$)

Milk fatty acids in cows fed alfalfa- or red clover-grass mix

	Week 4		Week 7			*P*-value		
Fatty acids, %	ALF-GR[1]	RC-GR[1]	ALF-GR[1]	RC-GR[1]	SEM[2]	Forage	Week	Forage × Week
trans-10 18:1	0.15	0.19	0.19	0.21	0.01	0.01	<0.01	0.38
trans-11 18:1	1.12	1.15	1.20	1.20	0.07	0.92	0.02	0.58
cis-9, *trans*-11 18:2 CLA	0.42	0.39	0.46	0.42	0.03	0.37	<0.01	0.67
α-Linolenic acid (ω-3)	0.67[b]	0.85[a]	0.61[b]	0.87[a]	0.03	<0.01	0.05	<0.01
Σ ω-6 fatty acids	2.20	2.43	2.14	2.48	0.07	0.02	0.85	0.09
Σ ω-3 fatty acids	0.73[b]	0.93[a]	0.67[b]	0.95[a]	0.03	<0.01	0.08	<0.01
ω-6/ω-3 ratio	3.04[a]	2.62[b]	3.22[a]	2.62[b]	0.03	<0.01	<0.01	<0.01

[1]ALF-GR = alfalfa-grass mix; RC-GR = red clover-grass mix
[2]SEM = standard error of the mean

Dry matter intake (DMI) and milk production in cows fed red clover (RC) or red clover-white clover (RC-WC) mix (Trial 2)



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Summary and Conclusions

- Increased proportion of legume forages in dairy diets has potential to improve dietary NE_L concentration, as well as feed intake and milk production
- Based on the UNH Feeding Trial 1, alfalfa increased milk fat production while red clover reduced MUN and improved ω-3 fatty acids
- Replacing red clover with white clover did not improve intake and milk production (UNH Feeding Trial 2)
- Further research is needed to evaluate the effect of increasing legume on pastures through interseeding management and measure animal production responses

Acknowledgments

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Questions??