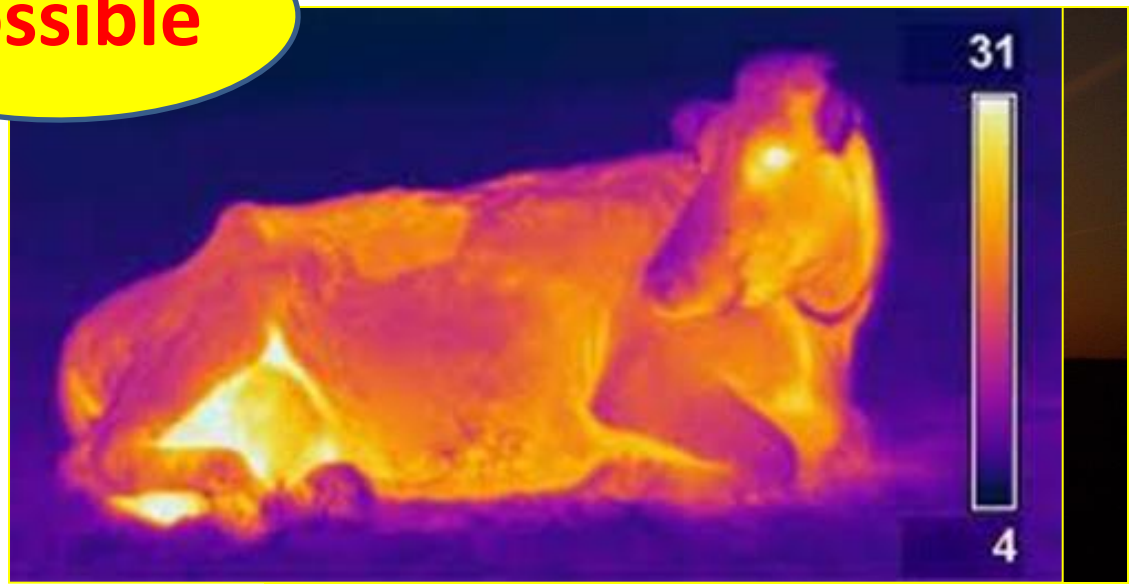
Recent research developments of dairy cow management under heat stress; realities and solutions.

Possible



J. van Eys

Organization of presentation:

1. Introduction (importance/economic impact)
2. Definition and identification of (heat) stress
3. Management options against heat stress
4. Housing Adaptations/improvements
5. Nutritional interventions to alleviate heat stress
    - Basal Ration
    - Additives

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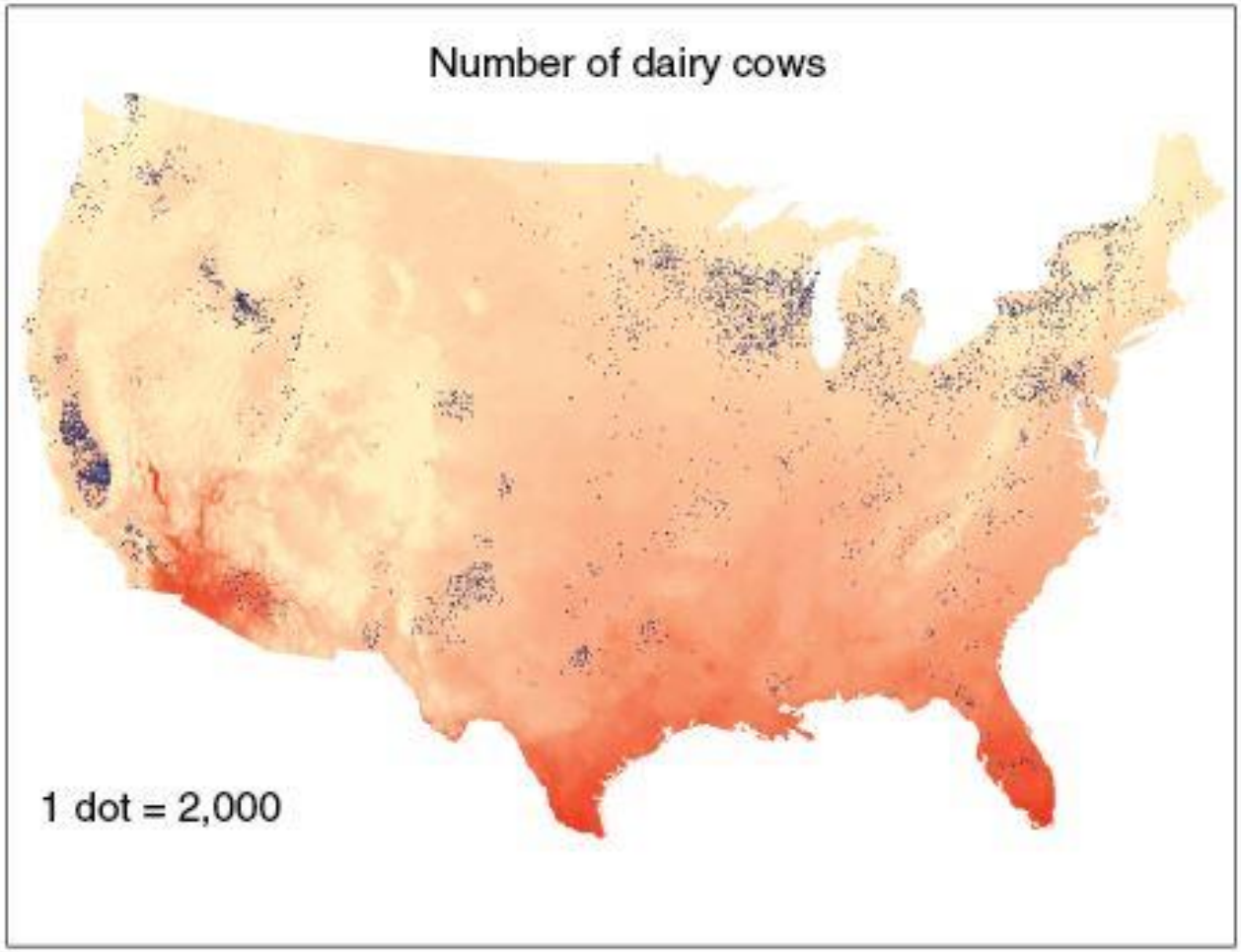
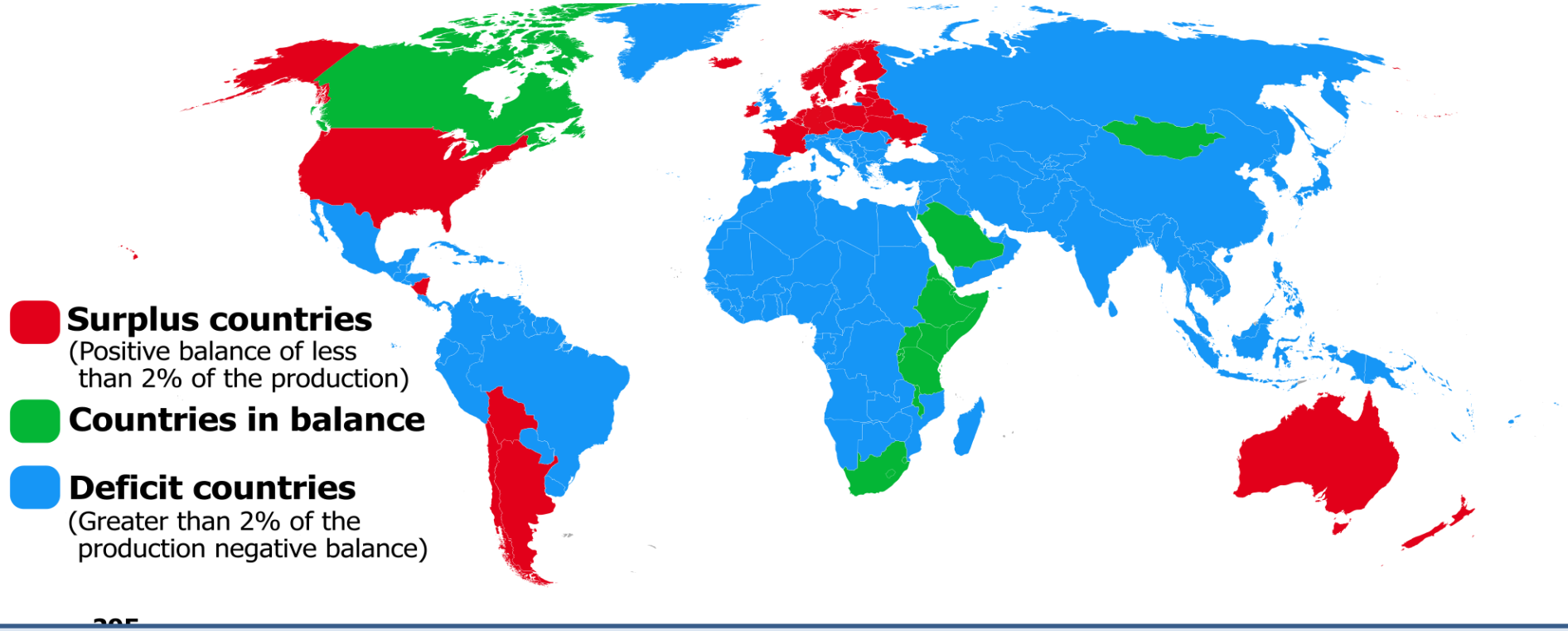
Dairy operations tend to locate in areas with lower annual temperature humidity index loads



World milk production - shortages, excesses and balances.



- World dairy production in “temperate” countries (80 %)*
- Excess heat (THI < 72) limited to a few months.
- Large diurnal variations (poor adaptation).
- Recognition of impact even in more temperate regions – compounded by (increased) production level

J. Dairy Sci. 86:(E. Suppl.):E52–E77

Economic Losses from Heat Stress by US Livestock Industries.

N. R. St-Pierre*, B. Cobanov*, and G. Schnitkey†
*The Ohio State University, Columbus, OH 43210
†University of Illinois, Urbana, IL 61801

CONCLUSIONS

Across the United States, heat stress results in estimated total annual economic losses to livestock industries that are between $1.69 and $2.36 billion. Of these losses, $897 to $1,500 million occur in the dairy industry, $370 million in the beef industry,

2015:

Total: 1.0 to 1.8 billion USD

Or: 106- 191 USD/cow/year

Estimated economic impact of 100d summer heat stress in the EU and NA[a] (per 100 cows):

	Mild	Severe
Loss in milk production. %[b]	- 10	- 20
Reduced fertility, %[c]	- 5	- 10
Vet cost,%	+ 3	+ 5

	Mildly	Severely
Loss in milk production. %[b]	9000	18000
Reduced fertility, %c	6150	12300
Vet. cost,%	150	250
Total	**15300**	**30550**

[a]EU: mild: France, Austria, Hungary; sever: Italy, Spain, Greece, Romania, Bulgaria,
NA: mild: Canada (USA); Severely: USA, Mexico[b]

[c] Milk price € 30/l FCM; base: 30 kg FCM; cow 410 d calving interval @ cost of € 3/d (milk revenue – feed cost); Std vet cost: 5000/yr

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Temperature		% Relative Humidity																		
°F	°C	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90
72	22.0	64	65	65	65	66	66	67	67	67	68	68	69	69	69	70	70	70	71	71
73	23.0	65	65	66	66	66	67	67	68	68	68	69	69	70	70	71	71	71	72	72
74	23.5	65	66	66	67	67	67	68	68	69	69	70	70	70	71	71	72	72	73	73
75	24.0	66	66	67	67	68	68	68	69	69	70	70	71	71	72	72	73	73	74	74
76	24.5	66	67	67	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75	75
77	25.0	67	67	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75	75	76
78	25.5	67	68	68	69	69	70	70	71	71	72	73	73	74	74	75	75	76	76	77
79	26.0	67	68	69	69	70	70	71	71	72	73	73	74	74	75	76	76	77	77	78
80	26.5	68	69	69	70	70	71	72	72	73	73	74	75	75	76	76	77	78	78	79
81	27.0	68	69	70	70	71	72	72	73	73	74	75	75	76	77	77	78	78	79	80
82	28.0	69	69	70	71	71	72	73	73	74	75	75	76	77	77	78	79	79	80	81
83	28.5	69	70	71	71	72	73	73	74	75	75	76	77	78	78	79	80	80	81	82
84	29.0	70	70	71	72	73	73	74	75	75	76	77	78	78	79	80	80	81	82	83
85	29.5	70	71	72	72	73	74	75	75	76	77	78	78	79	80	81	81	82	83	84
86	30.0	71	71	72	73	74	74	75	76	77	78	78	79	80	81	81	82	83	84	84
87	30.5	71	72	73	73	74	75	76	77	77	78	79	80	81	81	82	83	84	85	85
88	31.0	72	72	73	74	75	76	76	77	78	79	80	81	81	82	83	84	85	86	86
89	31.5	72	73	74	75	75	76	77	78	79	80	80	81	82	83	84	85	86	86	87
90	32.0	72	73	74	75	76	77	78	79	79	80	81	82	83	84	85	86	86	87	88
91	33.0	73	74	75	76	76	77	78	79	80	81	82	83	84	85	86	86	87	88	89
92	33.5	73	74	75	76	77	78	79	80	81	82	83	84	85	85	86	87	88	89	90
93	34.0	74	75	76	77	78	79	80	80	81	82	83	85	85	86	87	88	89	90	91
94	34.5	74	75	76	77	78	79	80	81	82	83	84	86	86	87	88	89	90	91	92
95	35.0	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93
96	35.5	75	76	77	78	79	80	81	82	83	85	86	87	88	89	90	91	92	93	94
97	36.0	76	77	78	79	80	81	82	83	84	85	86	87	88	89	91	92	93	94	95
98	36.5	76	77	78	80	80	82	83	83	85	86	87	88	89	90	91	92	93	94	95
99	37.0	76	78	79	80	81	82	83	84	85	87	88	89	90	91	92	93	94	95	96
100	38.0	77	78	79	81	82	83	84	85	86	87	88	90	91	92	93	94	95	96	98
101	38.5	77	79	80	81	82	83	84	86	87	88	89	90	92	93	94	95	96	98	99
102	39.0	78	79	80	82	83	84	85	86	87	89	90	91	92	94	95	96	97	98	100
103	39.5	78	79	81	82	83	84	86	87	88	89	91	92	93	94	96	97	98	99	101
104	40.0	79	80	81	83	84	85	86	88	89	90	91	93	94	95	96	98	99	100	101
105	40.5	80	80	82	83	84	86	87	88	89	91	92	93	95	96	97	99	100	101	102
106	41.0	80	81	82	84	85	87	88	89	90	91	93	94	95	97	98	99	101	102	103
107	41.5	80	81	83	84	85	87	88	89	91	92	94	95	96	98	99	100	102	103	104

No Stress

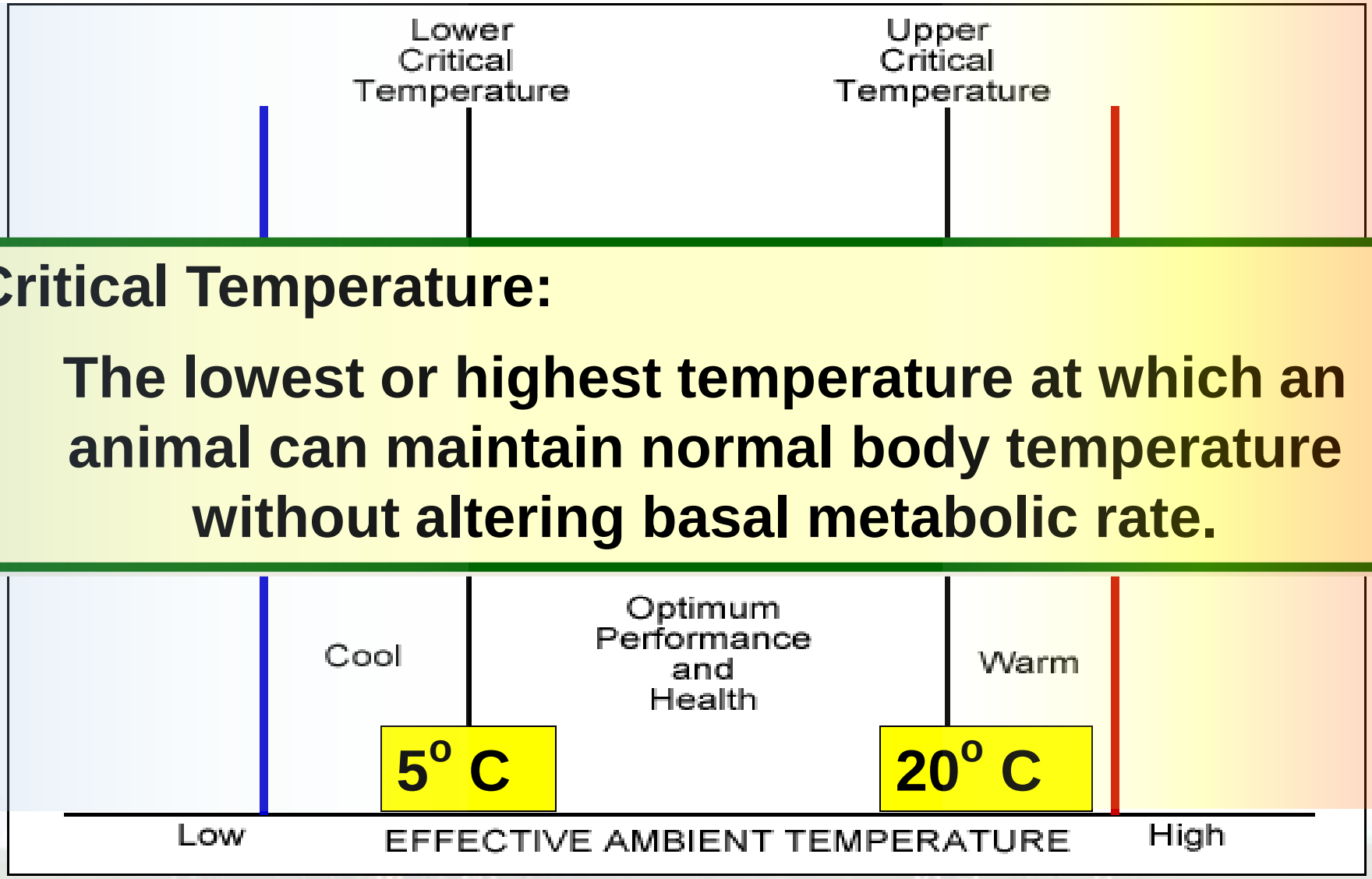
Mild Stress

Distressed

Severe Stress

Fatal

Thermo-neutral Zone



Critical Temperature:

The lowest or highest temperature at which an animal can maintain normal body temperature without altering basal metabolic rate.

Stress in Dairy Cows:

- **Environmental**
- **Physiological**
- **Nutritional** --------
- **Management**

Heat stress

Transition: Ketosis,
Hypocalcemia
Acidosis,
↓
R. placenta,
metritis,
mastitis,
etc.

…and any combination

Stress in Dairy cows.

"Stress develops when external (environmental) and internal (physiological) events exceed the animals normal physiological (coping) mechanisms and lead to major adjustments that depress normal production and health status (in the absence of which the animal's survival is threatened)."

Most common forms of stress in dairy cows:

- **Heat stress**
- **Transition**

} **Additive/Exponential**

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Heat Stress – specific.

ΣH_G (Envir. + Metab) > Σ H_L capacity

"Heat stress develops when the total heat gain (combined effects of environmental and metabolic heat factors) exceeds the animal's heat loss capabilities, leading to:

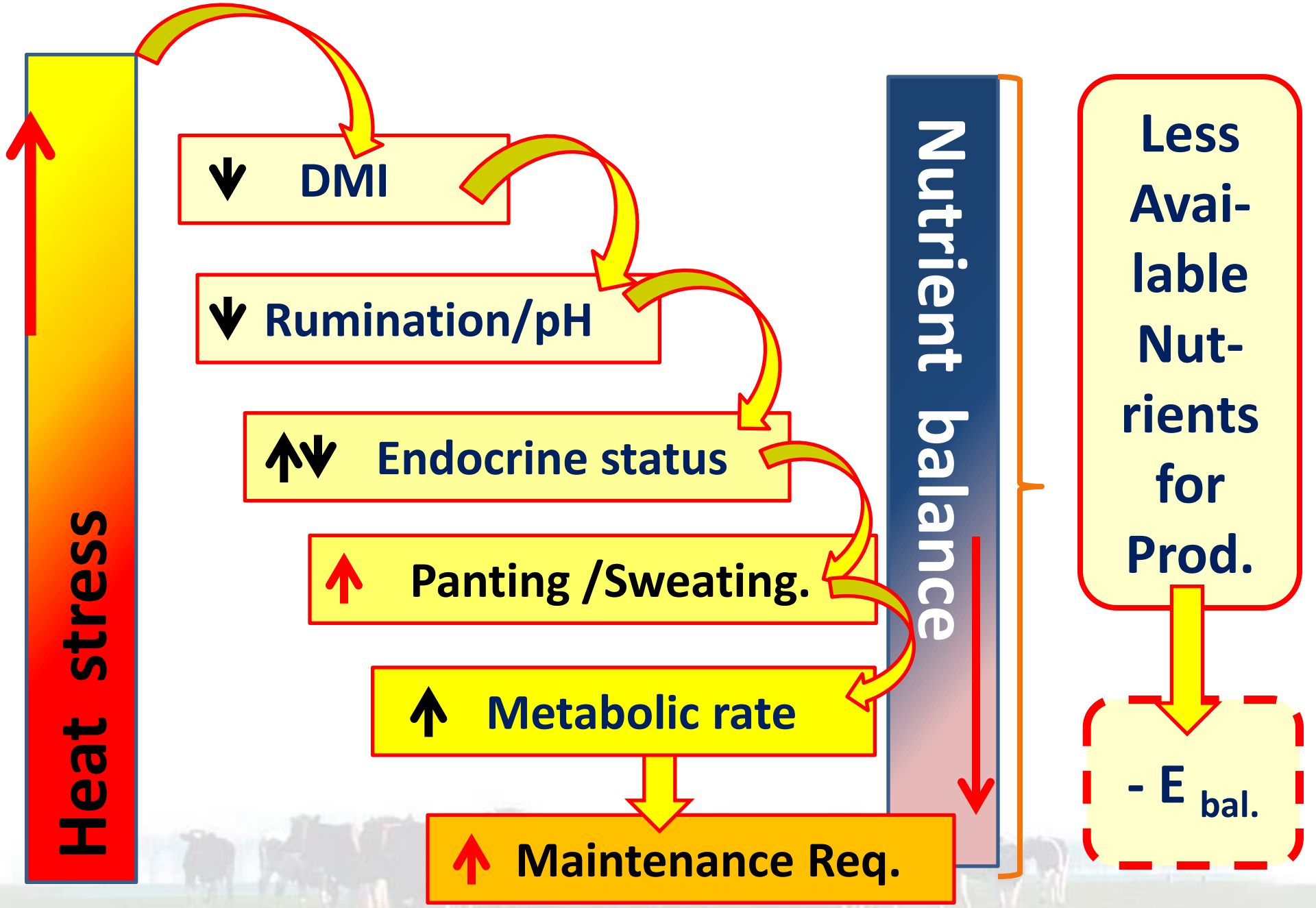
- **Increased body temperatures,**
- **Disrupted behaviors, and**
- **Impaired physiological functions."**

→ Decreased production/reproduction

Biological /Metabolic Consequence Of Heat Stress (Indicators):

- **Reduced Feed intake (10 – 20 %; more variable)**
- **Reduction in rumination ↘**
- **Reduced nutrient absorption,**
- **Reduction in energy balance (EB)**
- **Loss of body weight (reduced gut fill)**
- **Increased maintenance requirements**
- **Respiratory Alkalosis**
- **Depressed Immune response**
- **Altered endocrine status**

(In red Consequences that are specific for Heat stress).



(In yellow Consequences that are specific for Heat stress).

Effects of Heat Stress:

- ↓ Cud chewing and gut motility
- ↓ Rumen pH (more acidic)
  - Reduces milk fat
  - At temperatures above 20°C

A 5°C increase in daily high T causes a 0.1% drop in milk fat.

- ↑ Sweating and panting
  - Water and electrolyte loss

Model Estimation (CNCPS) of the effect of Heat Stress:

- **LW cow: 650 kg**
- **Milk Production: 35 kg FCM**
- **Gestating (4th months)**
- **Temperature and humidity: variable:**

Run	Temperature °C		Humidity
	Day	Night	%
1	16	10	50
2	32	16	50
3	32	16	70
4	32	24	70
5	32	24	80

Model Estimation (CNCPS) of the effect of Heat Stress:

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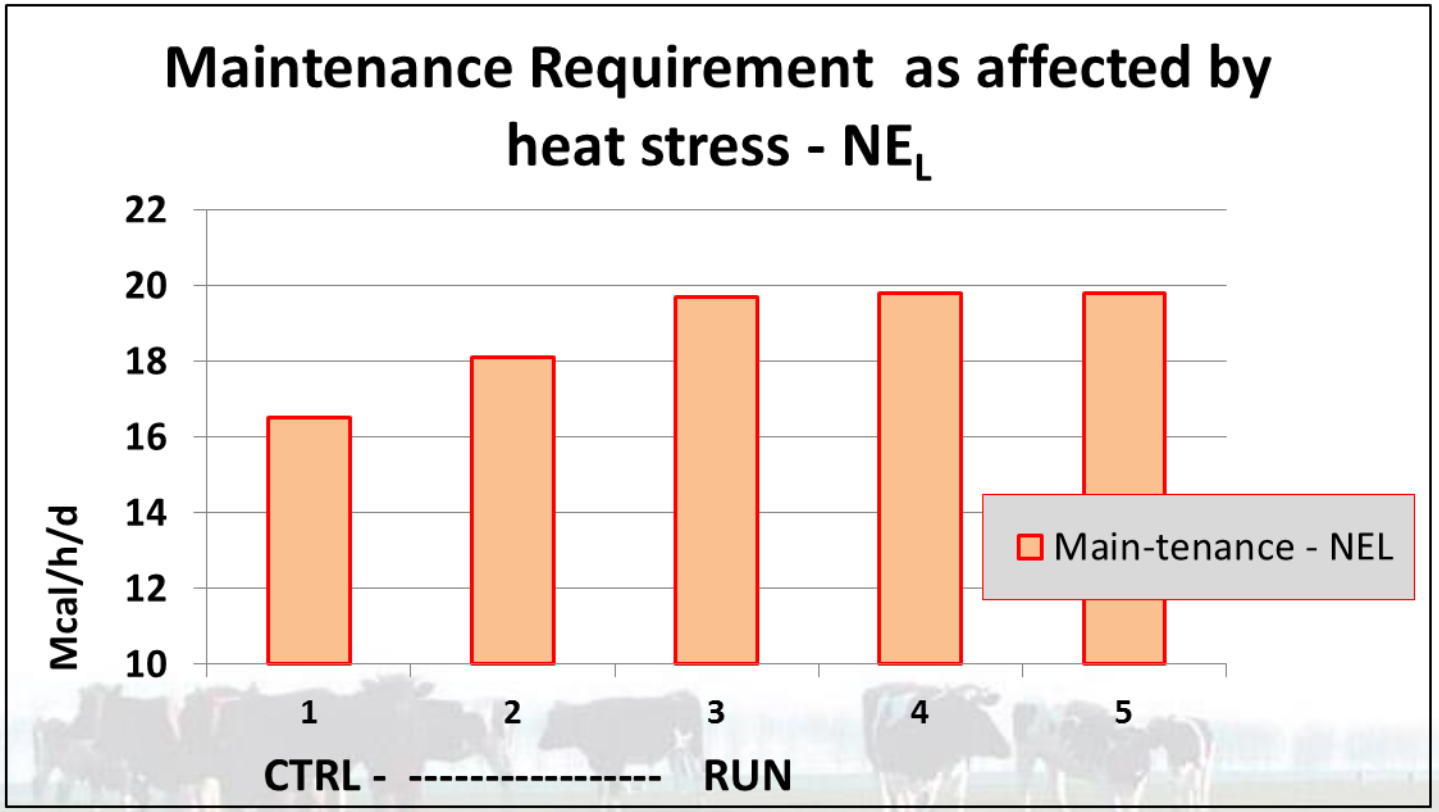
- **Milk Production: 35 kg FCM**
- **Gestating (4th months)**
- **Temperature and humidity: variable:**



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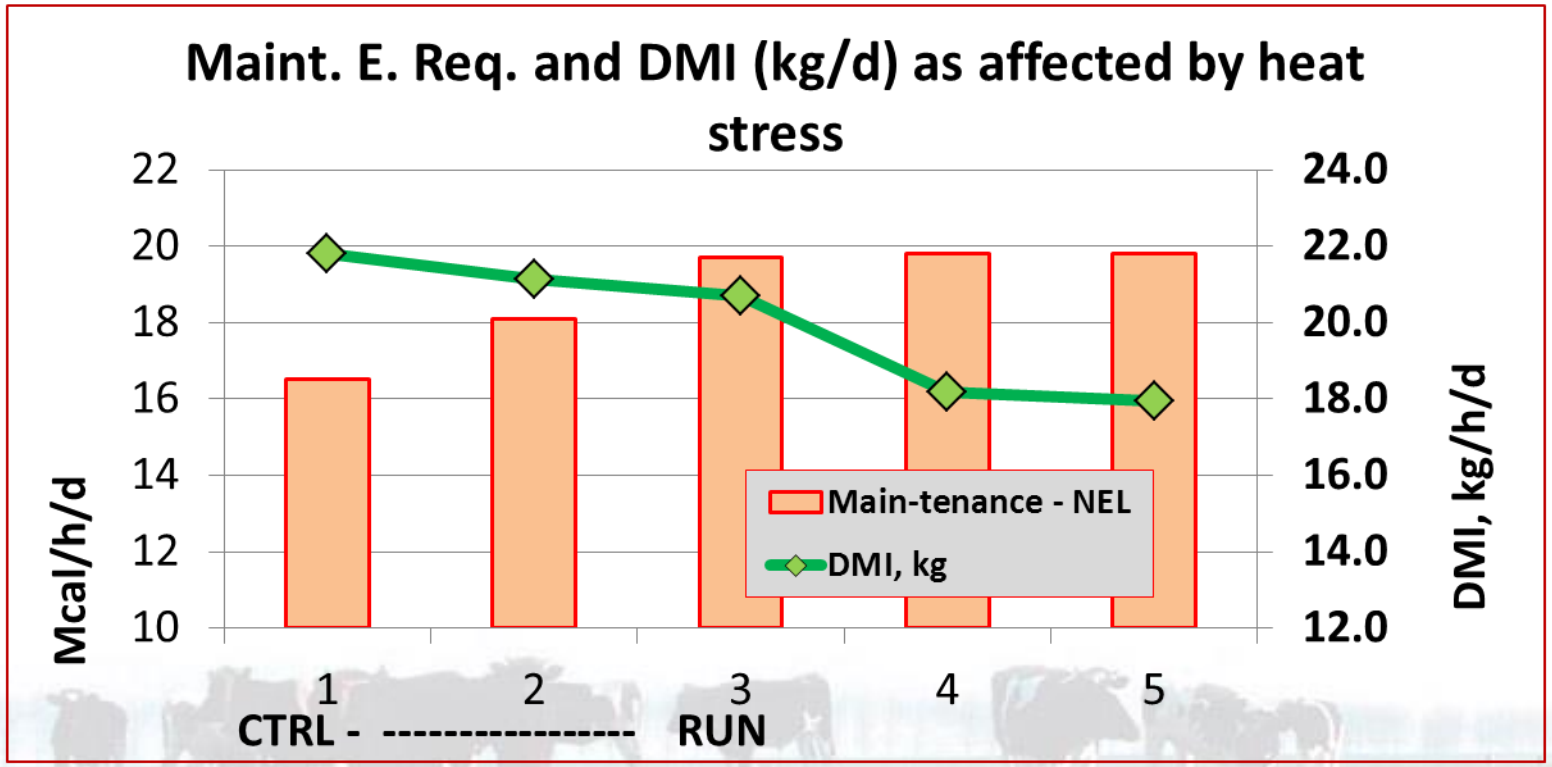

D/N Temp	16/10	32/16	32/16	32/24	32/24
Hum, %	50	50	70	70	80

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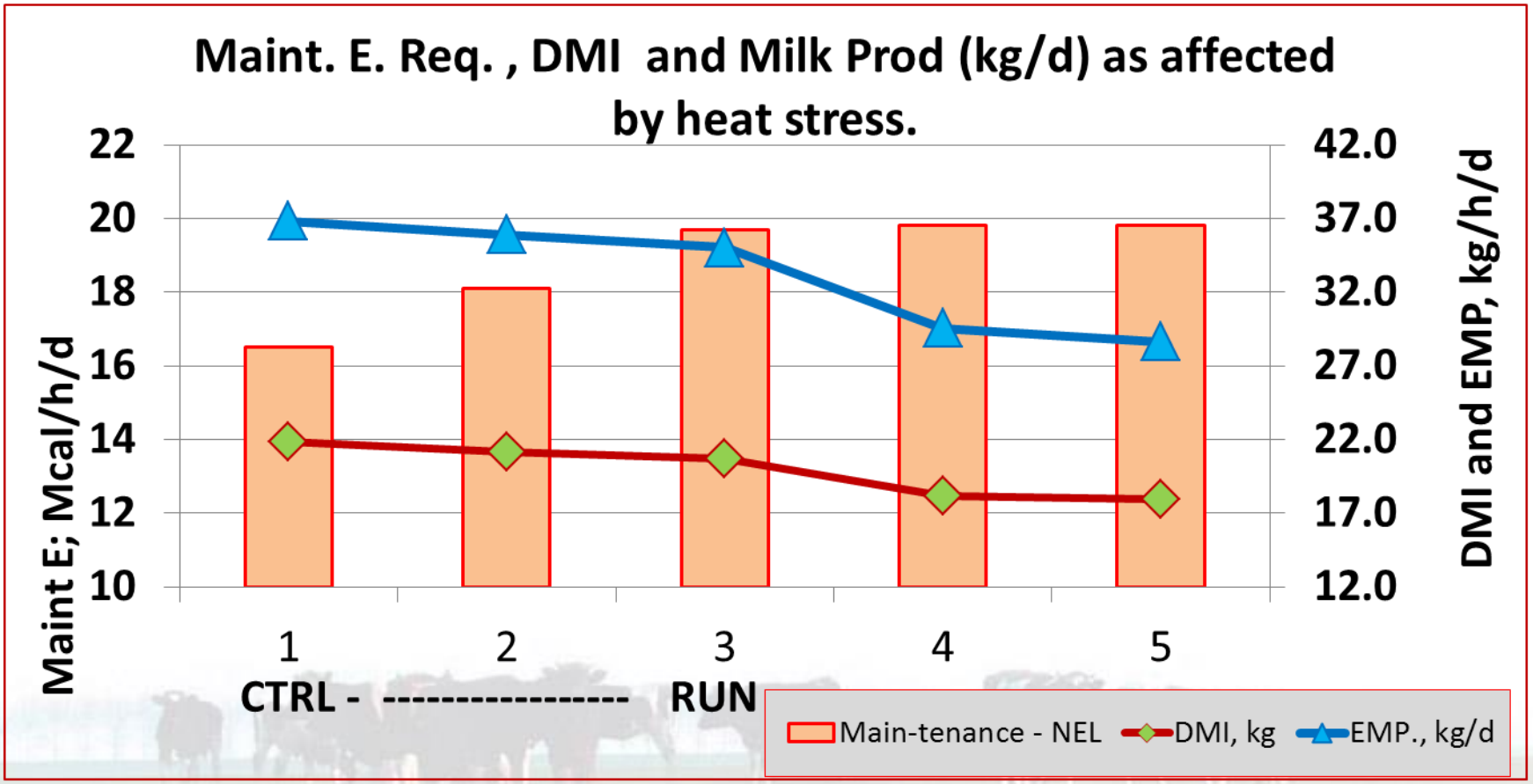

D/N Temp	16/10	32/16	32/16	32/24	32/24
Hum, %	50	50	70	70	80

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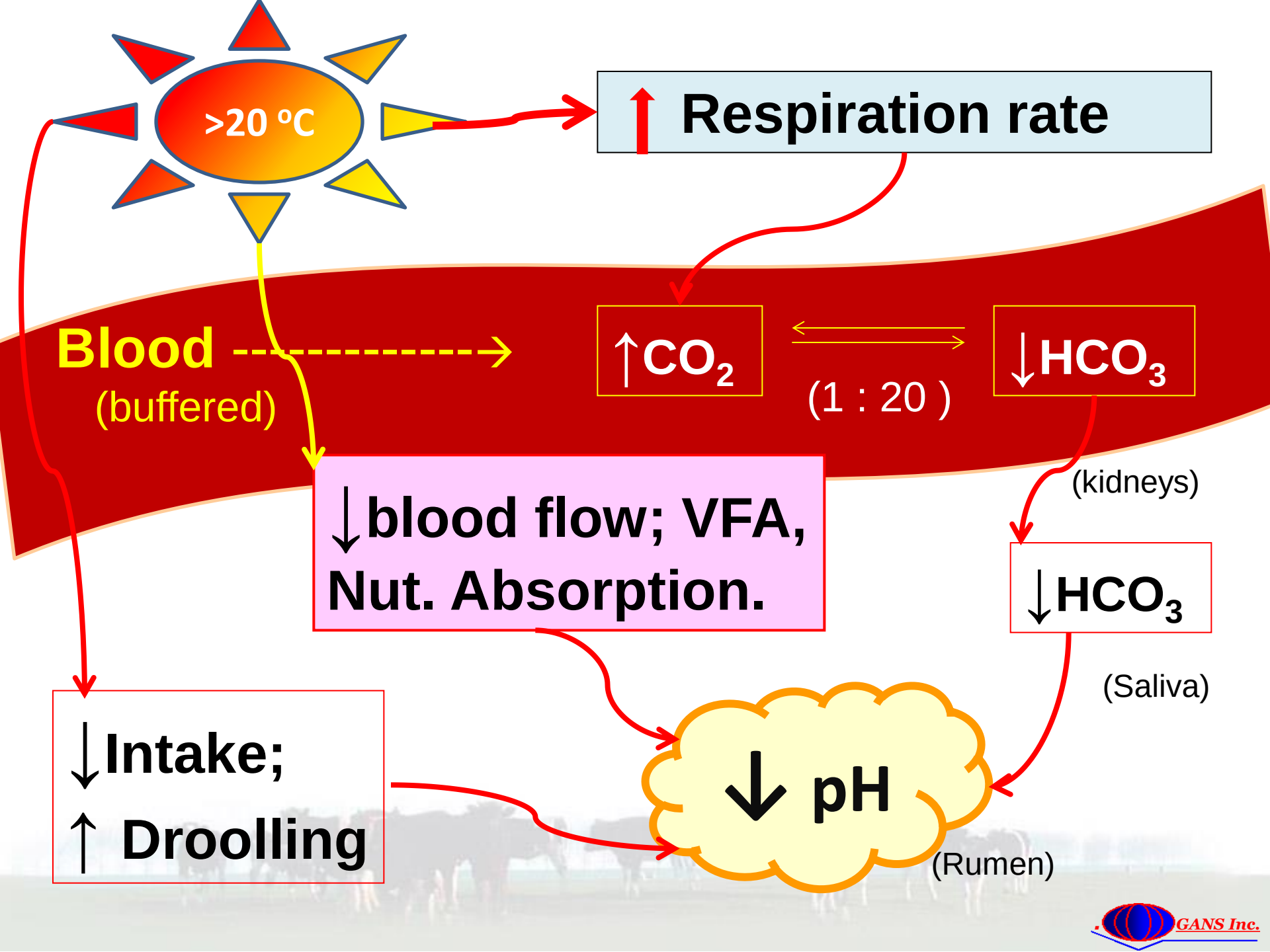
Physiological effects…..


>20 °C
↑ Respiration rate
Blood
(buffered)
↑CO_2
(1 : 20)
↓HCO_3
(kidneys)
↓blood flow; VFA,
Nut. Absorption.
↓HCO_3
(Saliva)
↓Intake;
↑ Droolling
↓ pH
(Rumen)
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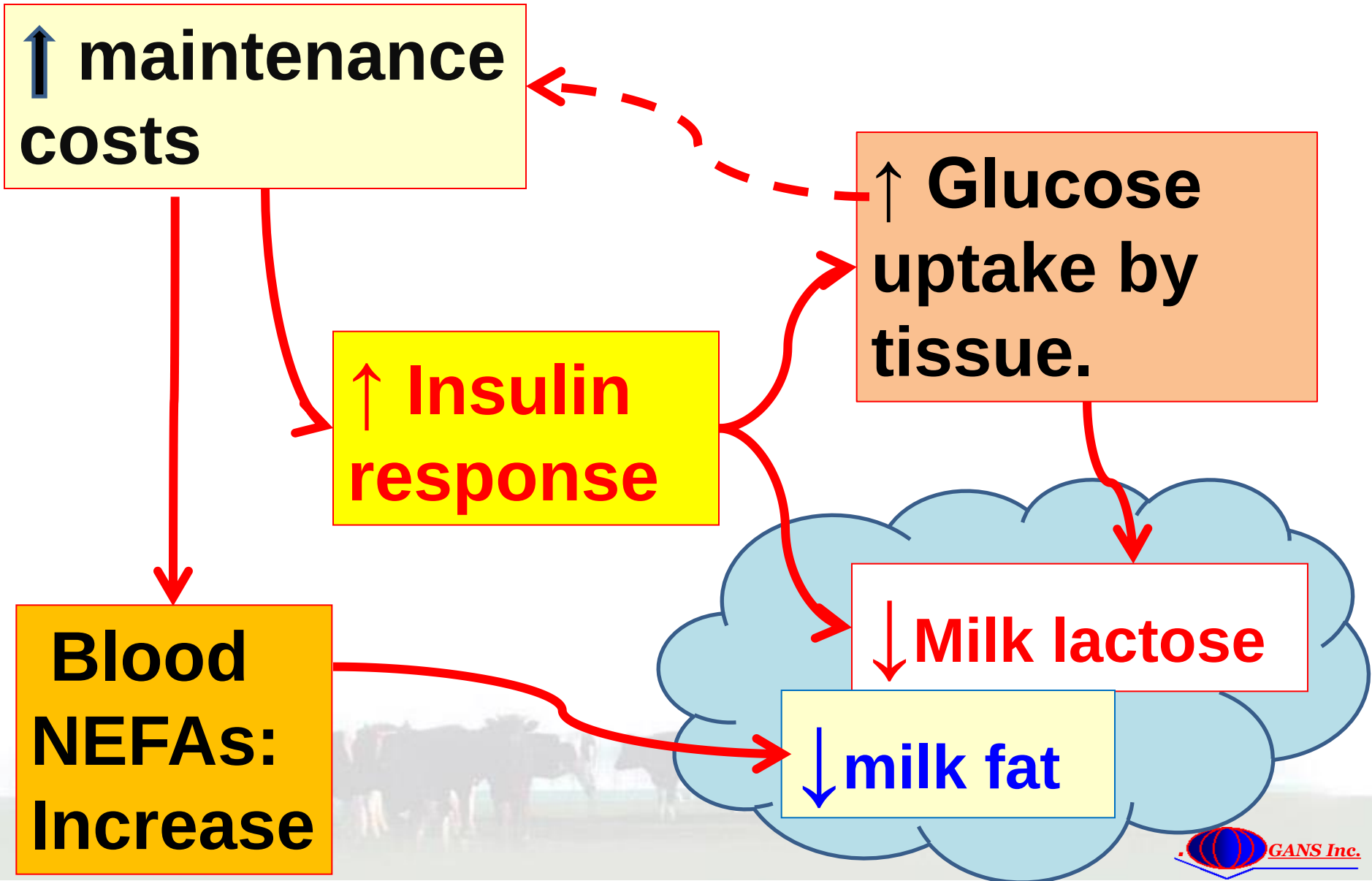
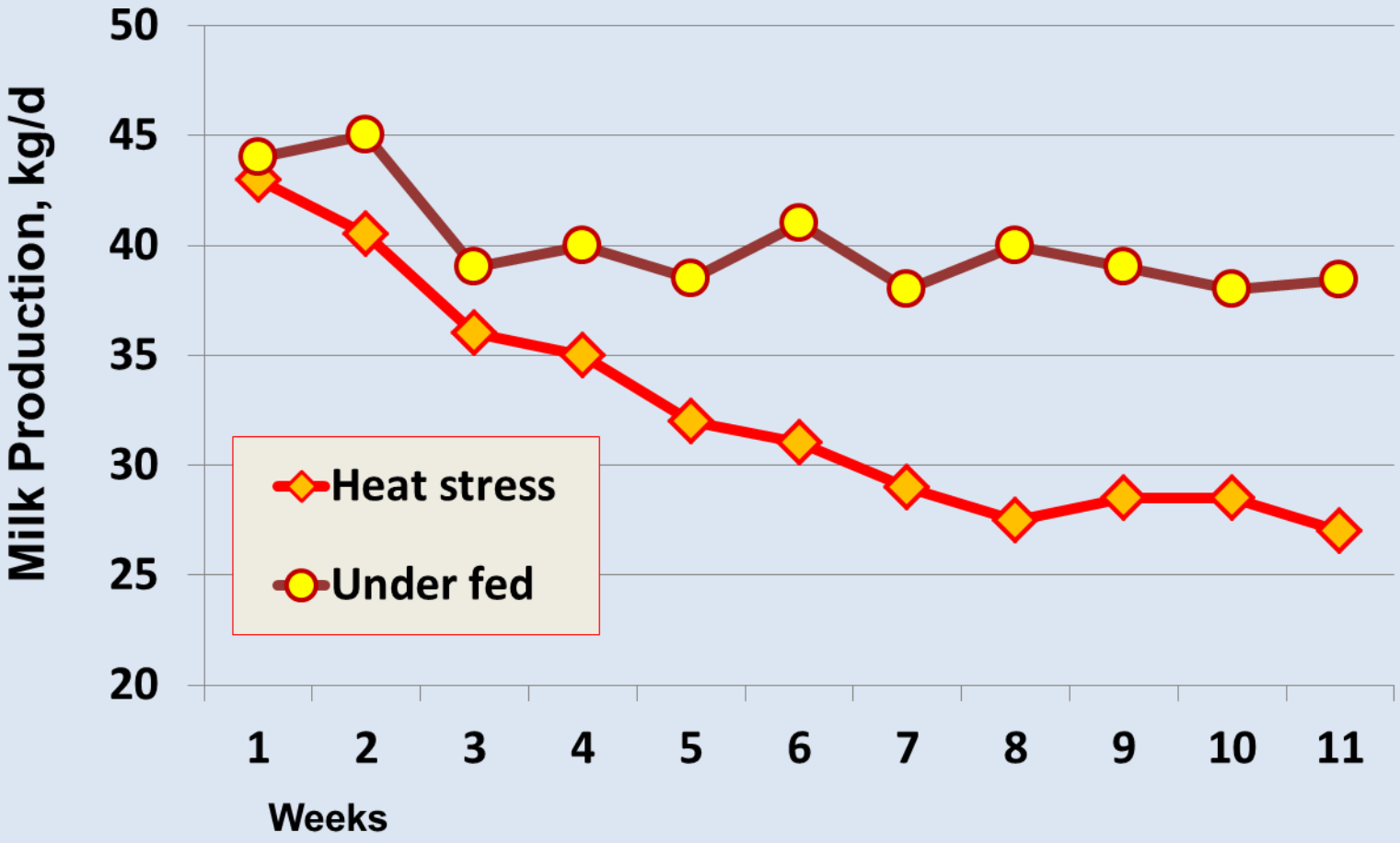
Metabolic Adaptations to Heat Stress

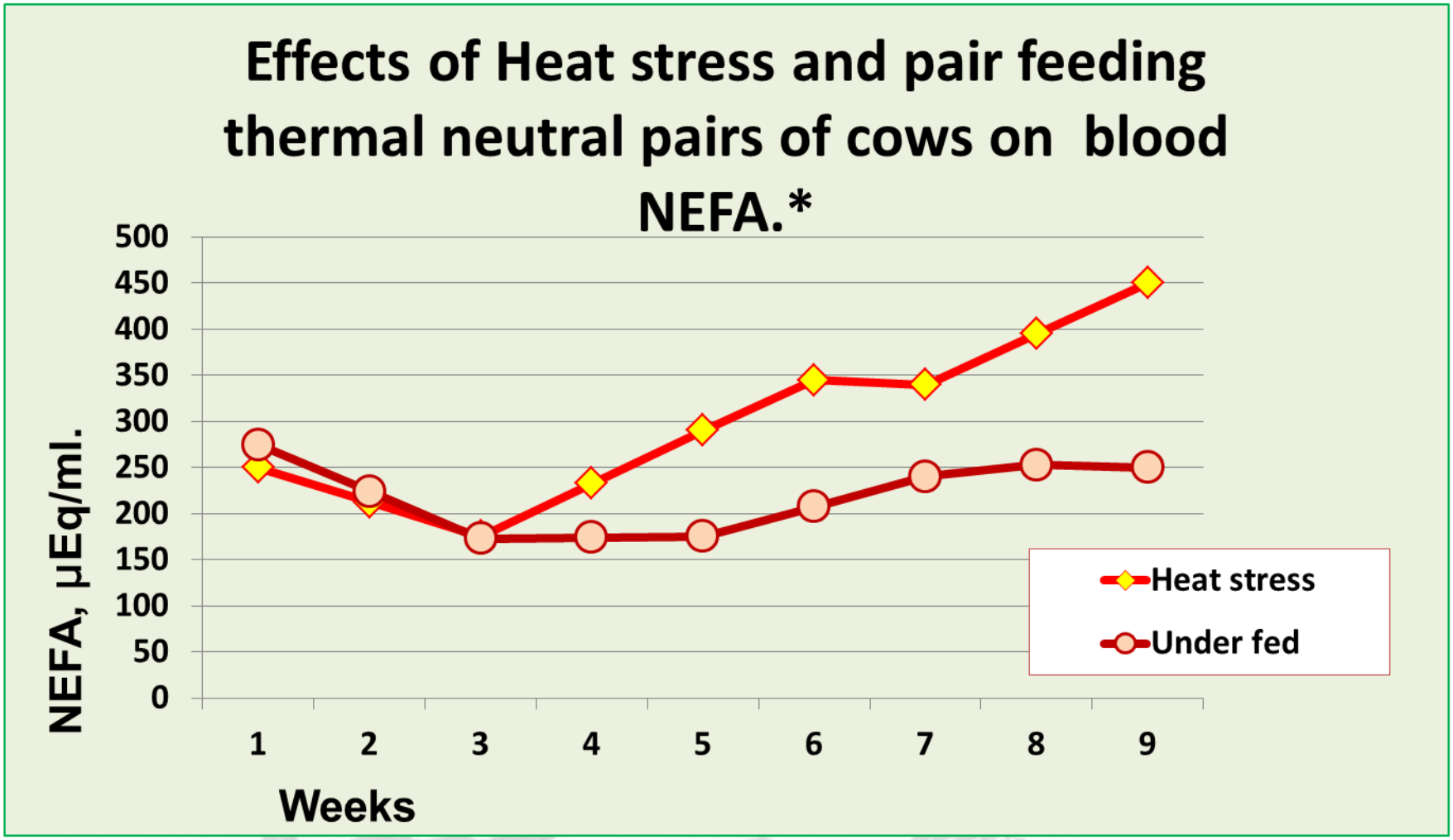


Effect of pair feeding heat stressed and limit fed cows on milk yield, kg/d



Adapted from . Rhoads et al., 2007.

Metabolic Adaptations to Heat Stress.



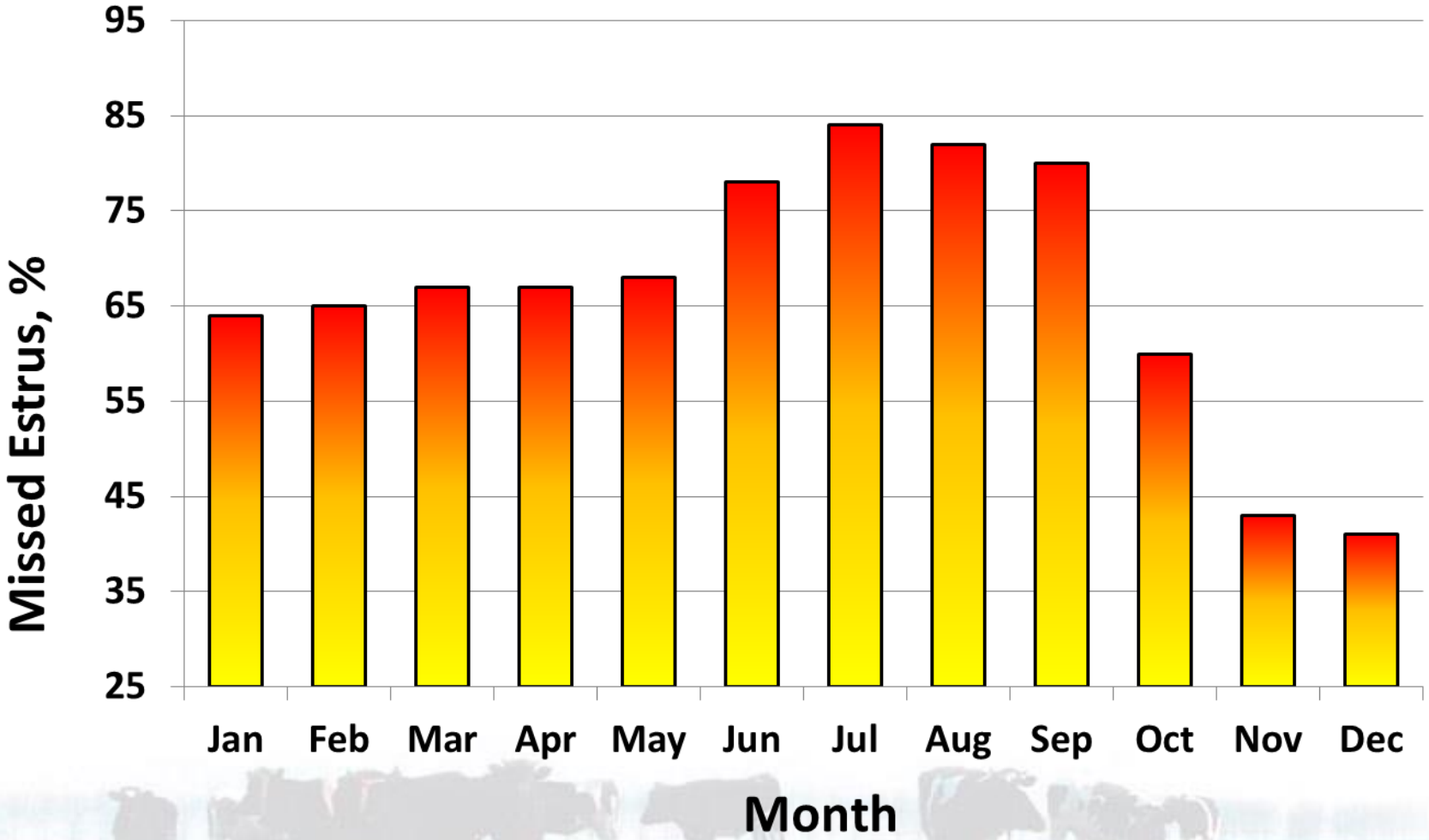
*Adapted from Wheelock et al., 2006.

Effect of Heat stress on Reproduction – Detected Estrus.

Reproductive Hormone Changes:

- **Decreased Plasma estradiol concentrations are.**
- **Reduced number of FSH and LH receptors on granulosa cells.**
- **Reduced LH concentrations.**

Effect of Heat stress on Reproduction – Detected Estrus



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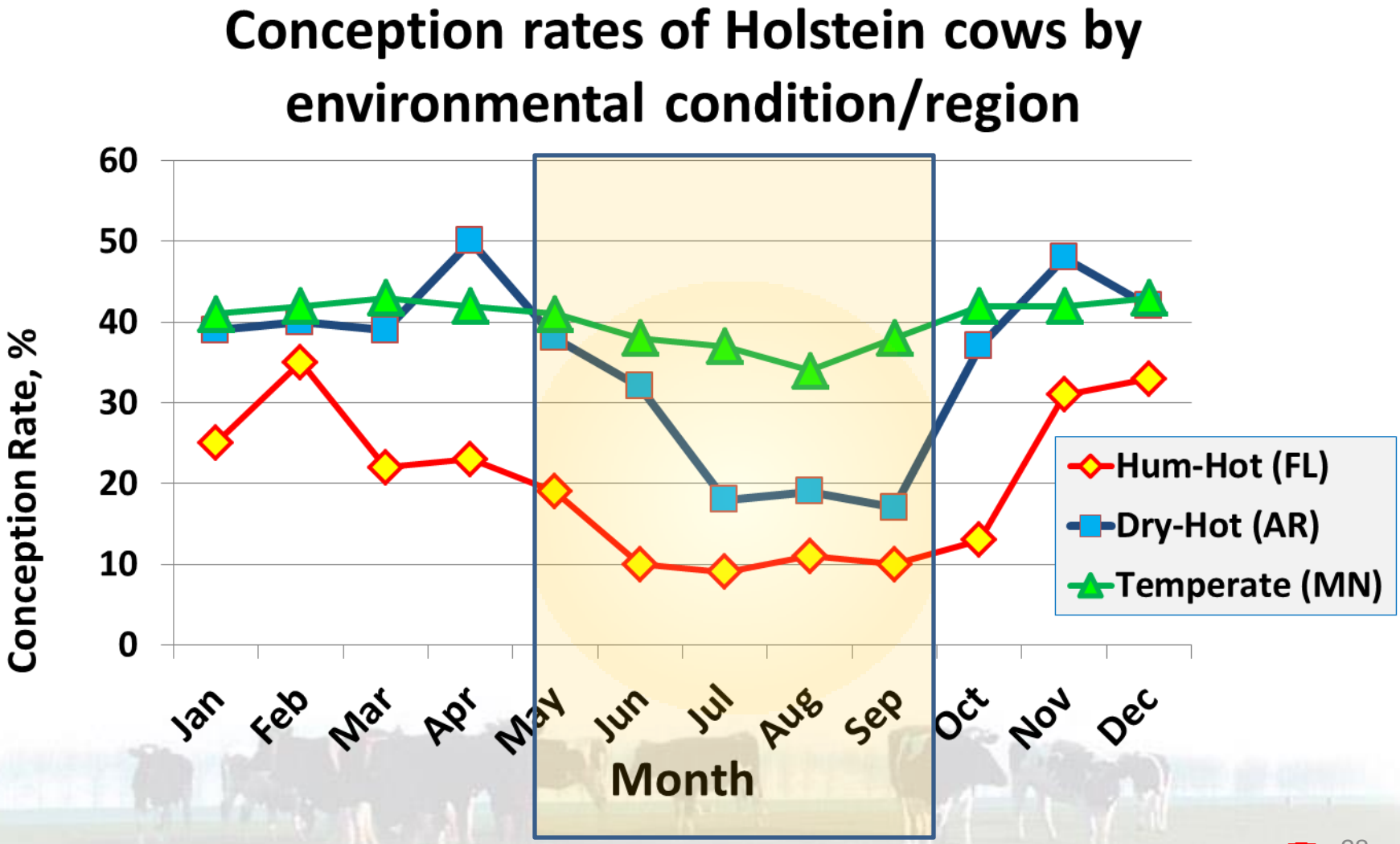
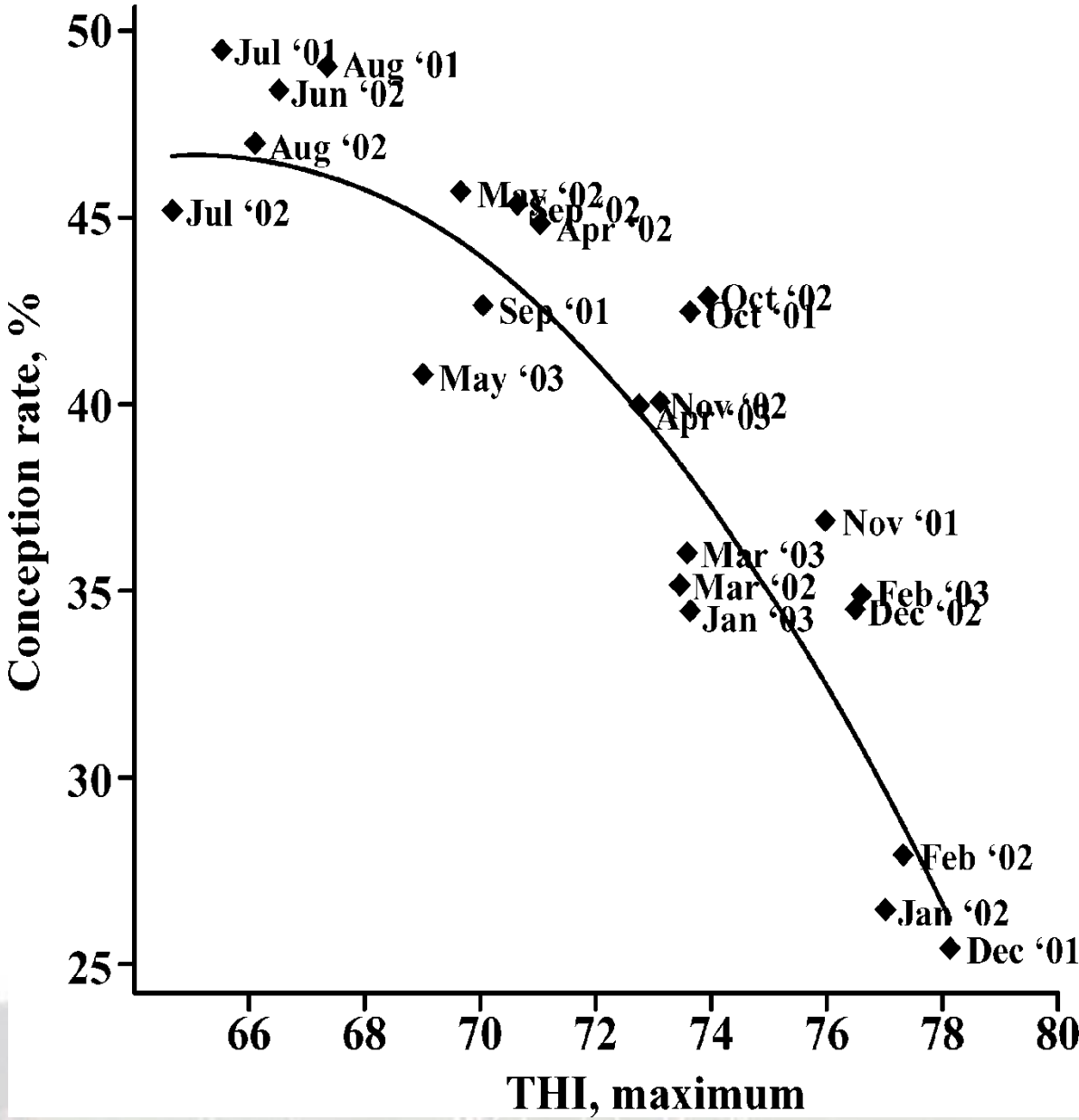
Effect of Heat stress on Reproduction – Conception Rates.



Association between monthly average of daily THI and conception rate.

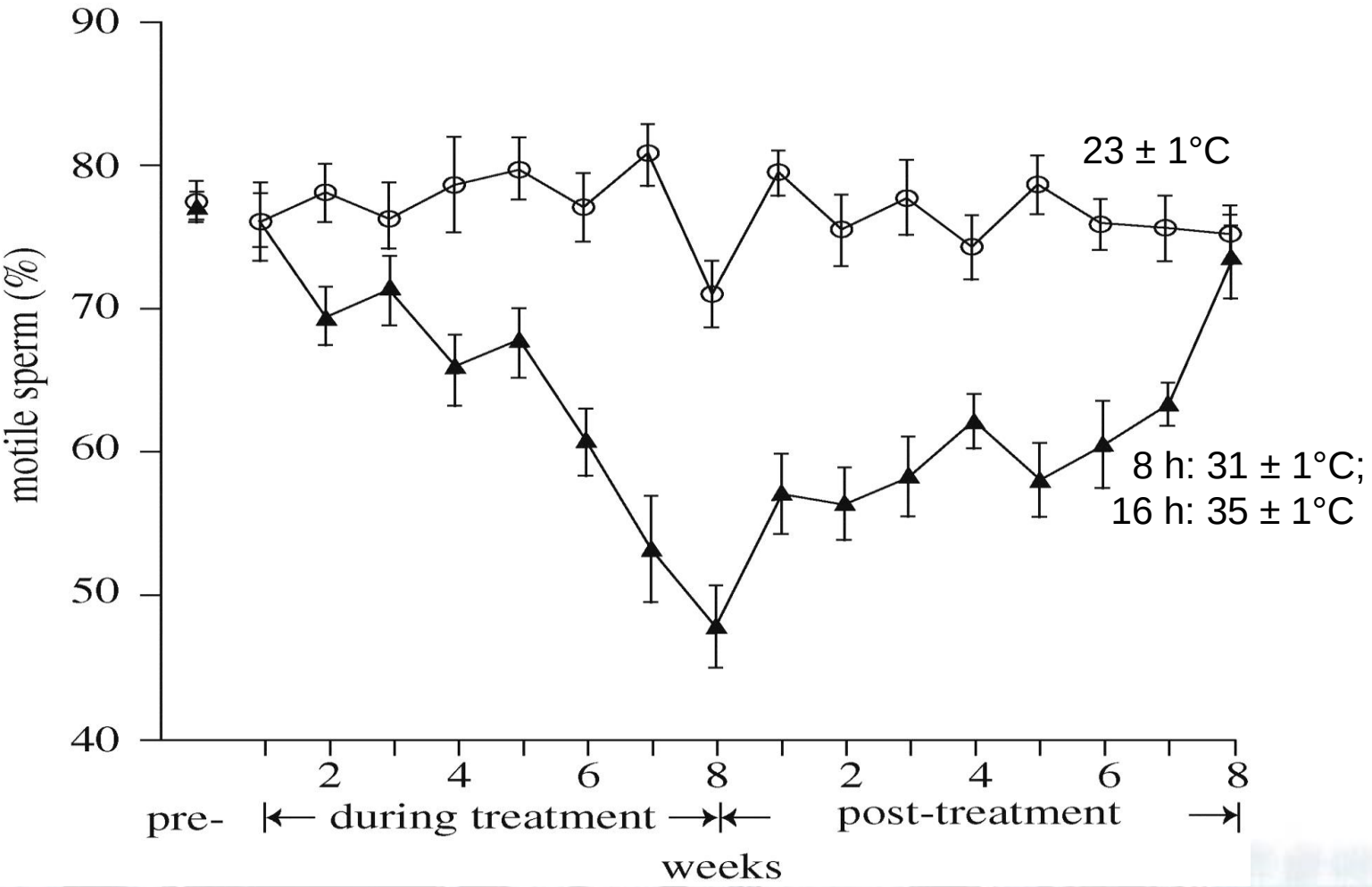
(Morton et al., 2007)



Summer to winter ratios for conception rate in Israeli herds as affected by production level and intensity of cooling.

	High production		Low production	
	Intensive cooling	Moderate cooling	Intensive cooling	Moderate cooling
Conception rate, winter, %	39	39	40	39
Conception rate, summer, %	19	12	25	3
Summer: winter ratio	0.49	0.31	0.62	0.08

Time course of effects of heat stress on motility of spermatozoa (bulls).



P.J. Hansen Phil. Trans. R. Soc. B 2009;364:3341-3350

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    - Additives

What can you do?

1. **Management:**
   - **Breed selection**
   - **Feeding times and frequency (night feeding)**
   - **Milking times and frequency**
   - **Grouping of cows**
   - **Shaving cows**
   - **Reproductive management (season)**
   - **Culling and selection**
   - **Physical and Nutritional adaptations (below)**

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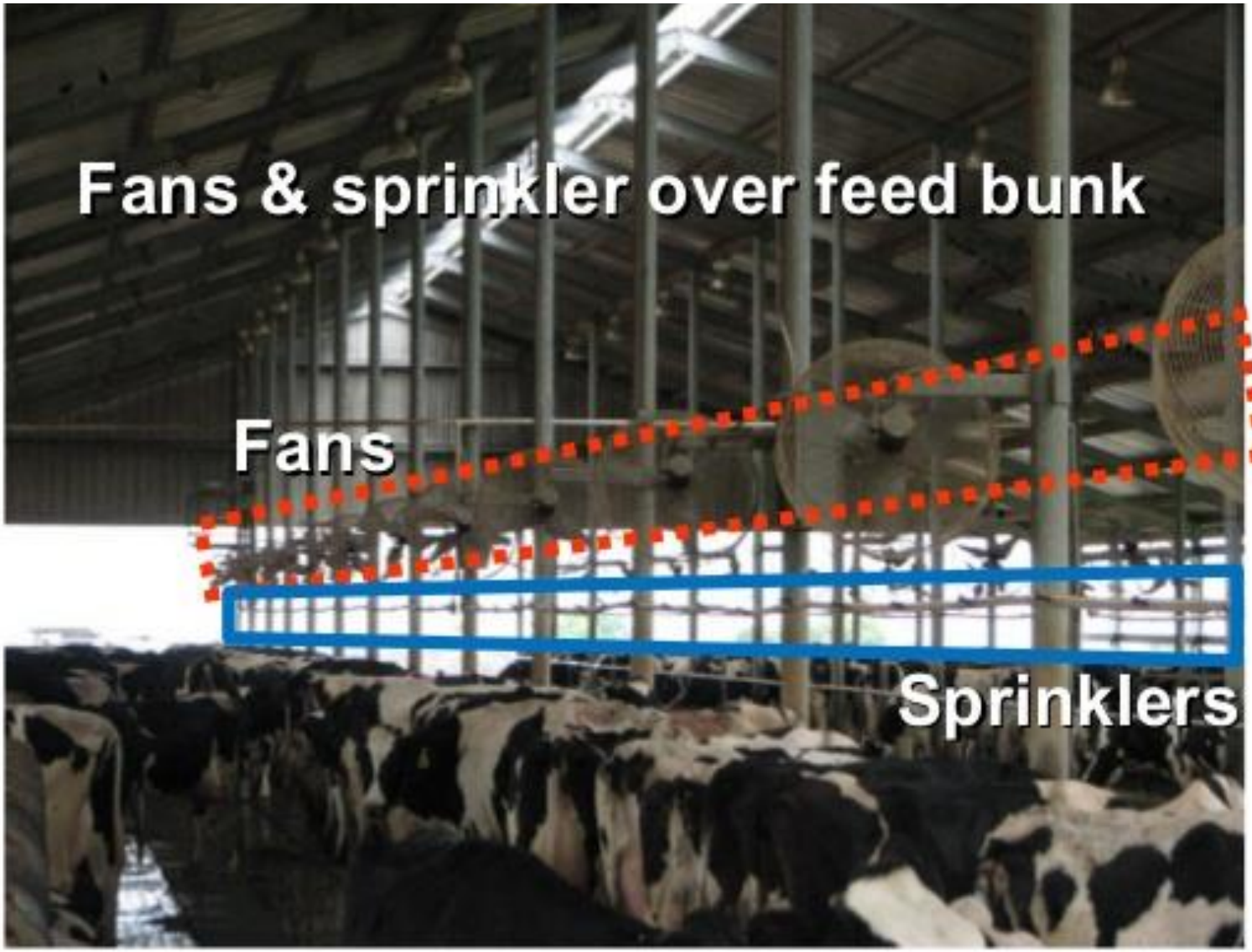
What can you do?

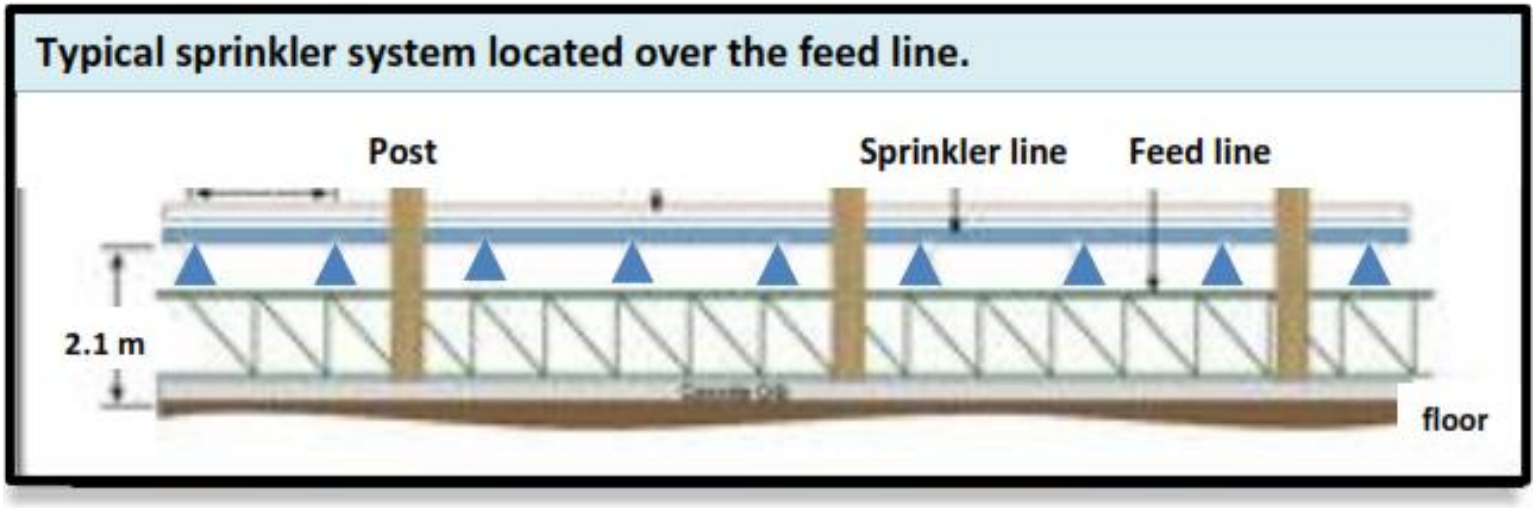
1. **Physical Modifications of the Environment**
   - **Provide shade (over feeding + resting area)**
   - **Open structures – free air currents**
   - **Install Fans**
   - **Install sprinklers - Possibly sprinklers/misters & fans over feeding areas**
   - **Access to water (water intake may increase 50%; drinking space: 5 – 8 cm/cow)**
   - **Sufficient space – separation; avoid overcrowding including before parlor.**
   - **Reduce noise.**

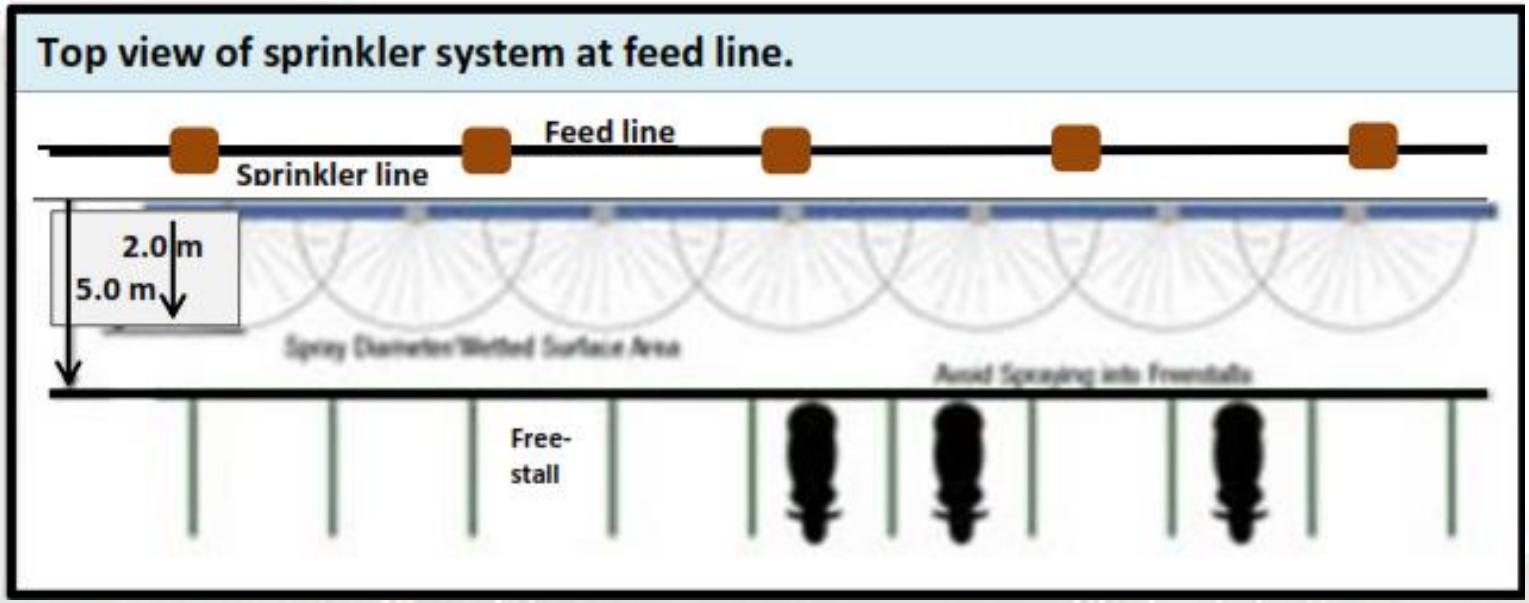
Positioning of fans and sprinklers



Cooling the Cow

Location of sprinklers to control heat stress.





Treatments

1. 0 - Control No Sprinkler or Fan
2. 0 + F - No Sprinkler but a Fan
3. 5 - Sprinkler (1 min on & 4 min off)
4. 5 + F - Sprinkler (1 min on & 4 min off) + Fan
5. 10 - Sprinkler (1 min on and 9 min off)
6. 10 + F - Sprinkler (1 min on and 9 min off) + Fan
7. 15 - Sprinkler (1 min on and 14 min off)
8. 15 + F - Sprinkler (1 min on and 14 min off) + Fan

Sprinkler - 3.5 l/min or 1.25 l/m^2 **Fan – 6.5 to 7.0 CM/Min.**

KSU Cow Comfort Consortium 2001 (Brouk, M.J., J.F. Smith and J.P. Harner, III)

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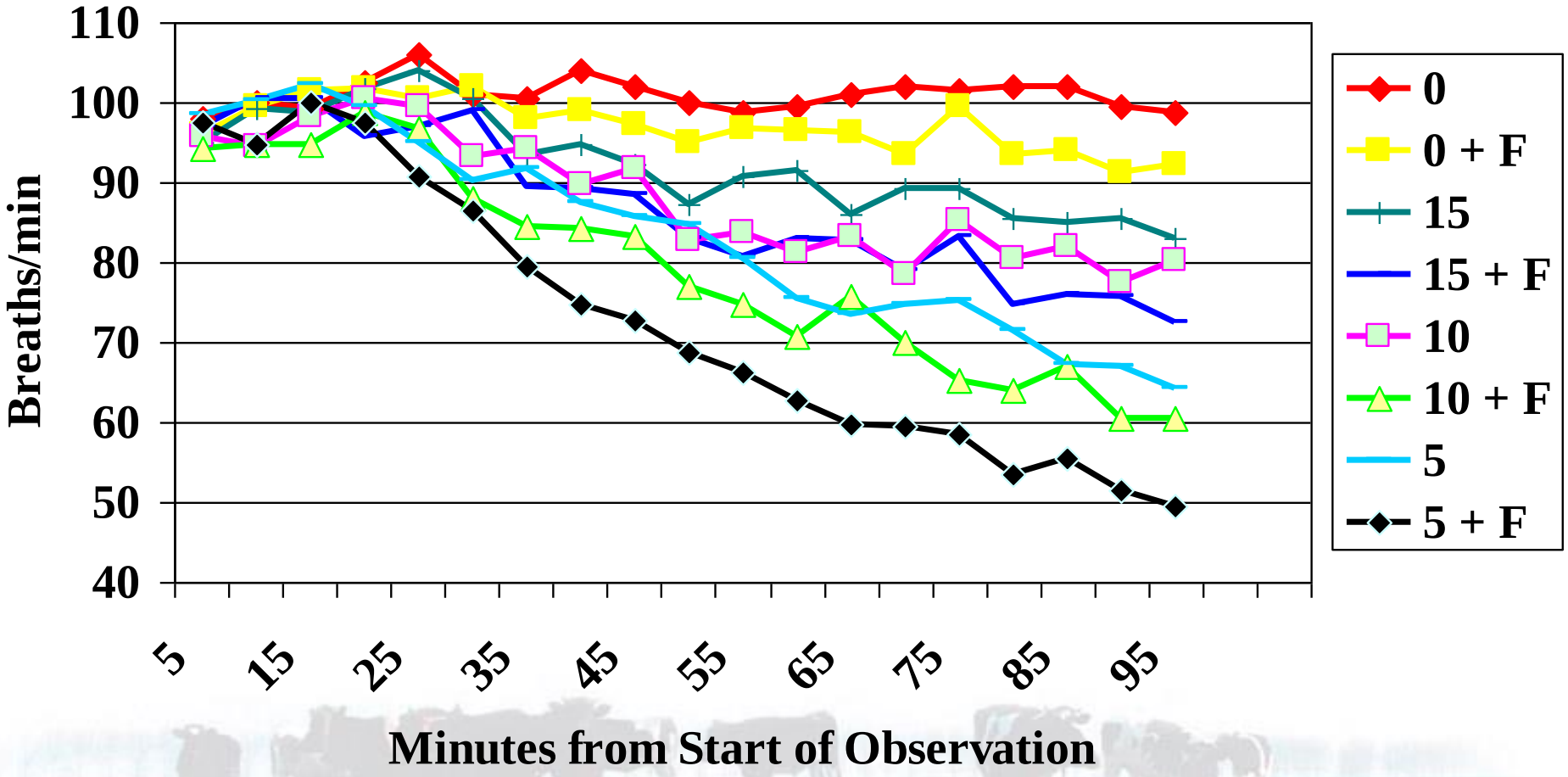
Effect of Sprinkling Frequency and Supplemental Air Movement



KSU Cow Comfort Consortium 2001 (Brouk, M.J., J.F. Smith and J.P. Harner, III)

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Summary of Spray & Fan Systems (Cooling the Cow)

- Fans alone do little to reduce heat stress
- Water is the Magic!!!
- Increasing soaking frequency resulted in reduced respiration rates
- Soaking frequency may need to be increased as temperature increases
- 1 l of water evaporated ~ 2,000 BTU
- These systems do very little to change environmental conditions

Spray and Fan Systems (Cooling the Cow)

- Soak the cow and dry her off
- Maximize the number of wet-dry cycles
- Milk production responses 2-6 kg/cow/day
- Net income of € 1-1.50/cow/day

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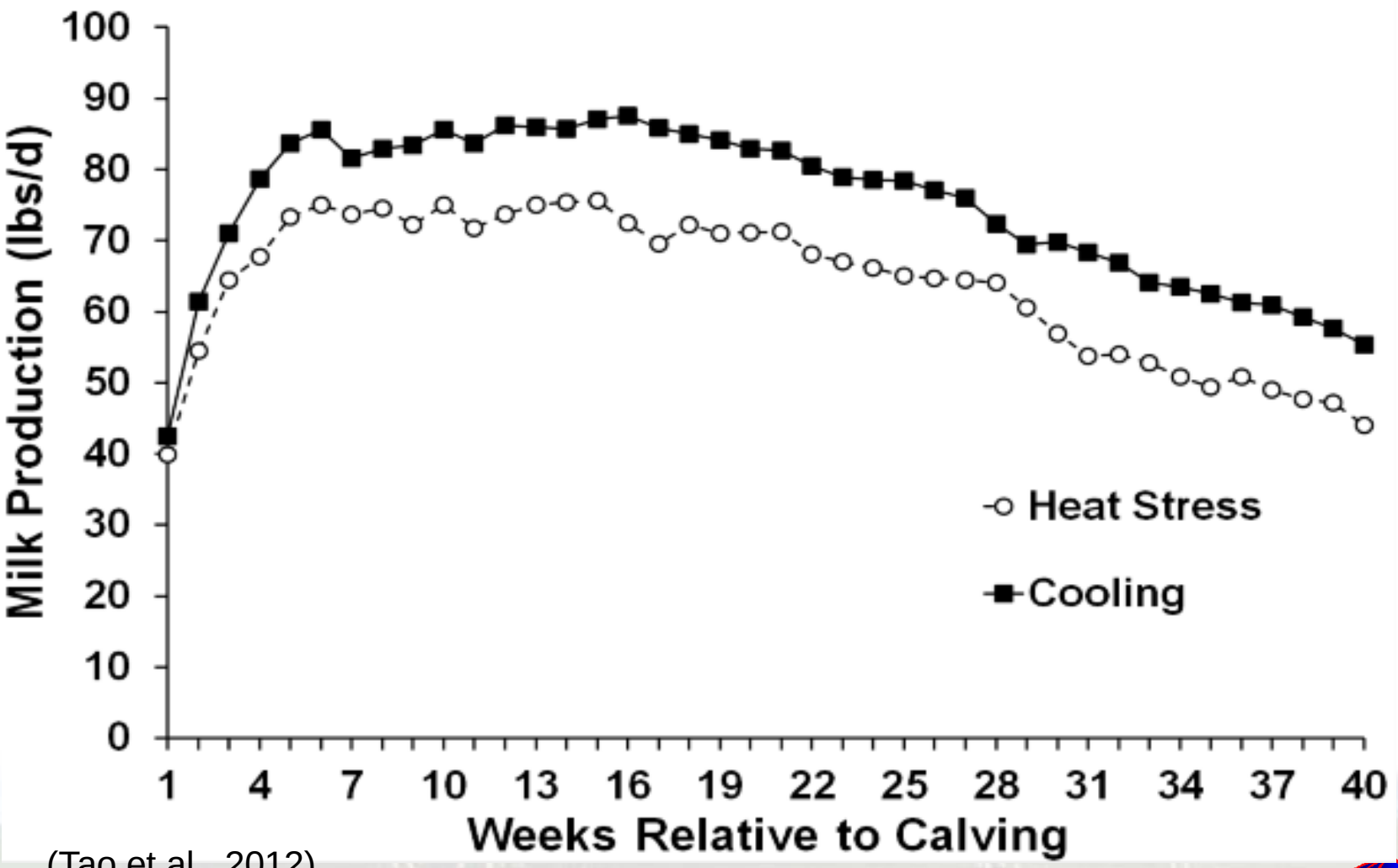
Cooling of cows -----

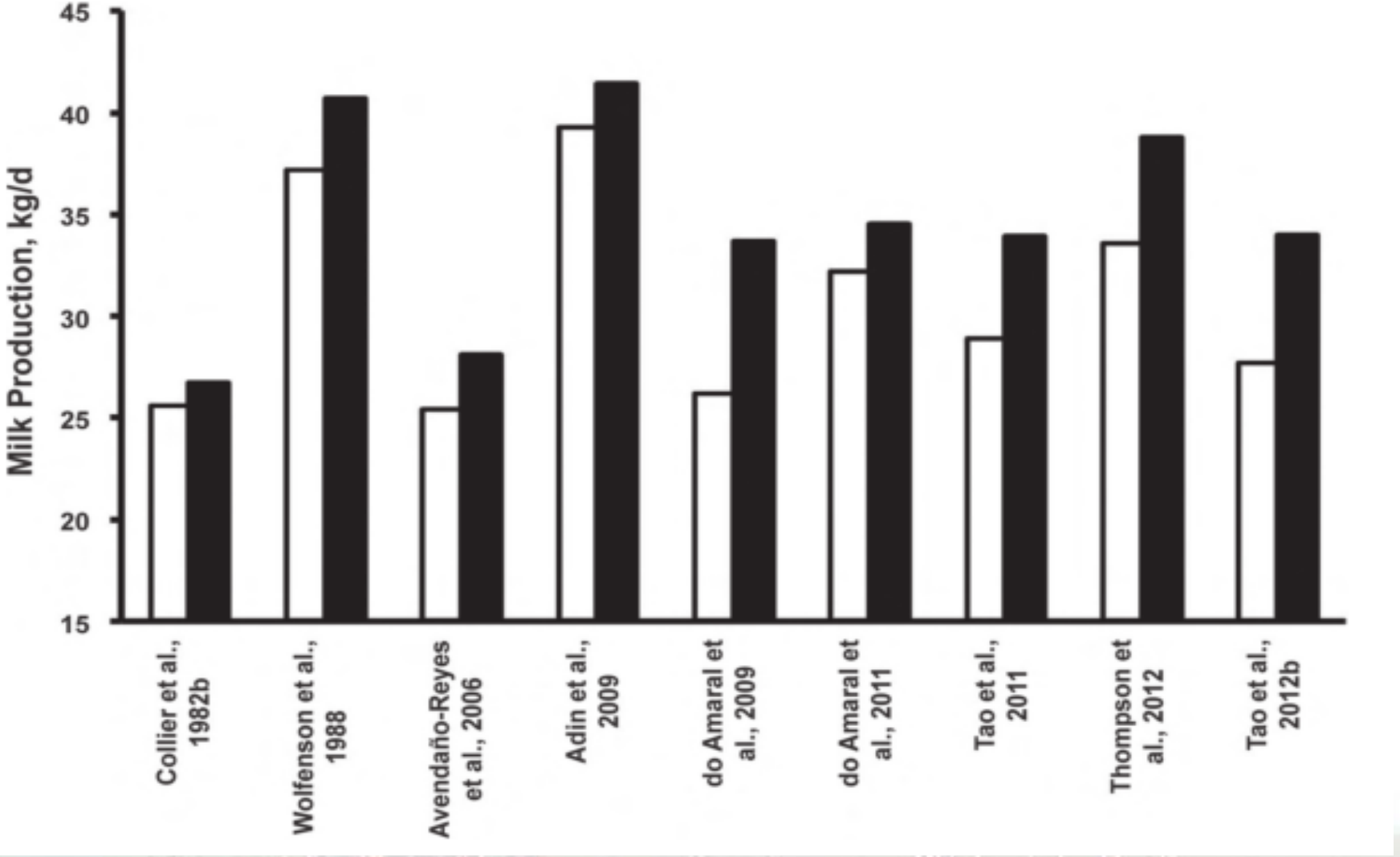
Dry period (?).

Effect of cooling cows during the dry period (from 46 days before expected calving) on subsequent milk yield.



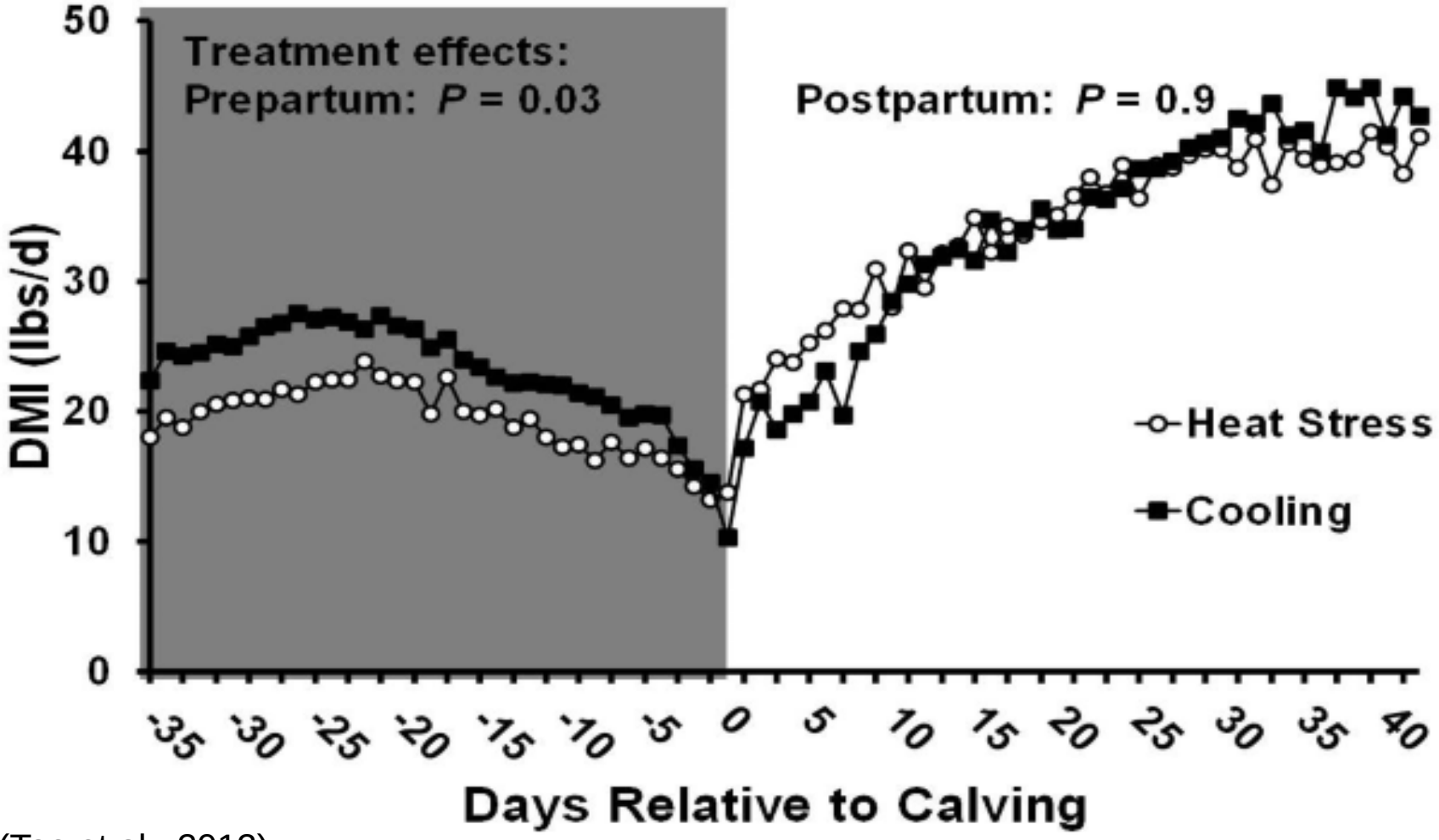
(Tao et al., 2012)

Effect of heat stress and cooling during the entire dry period on milk production.



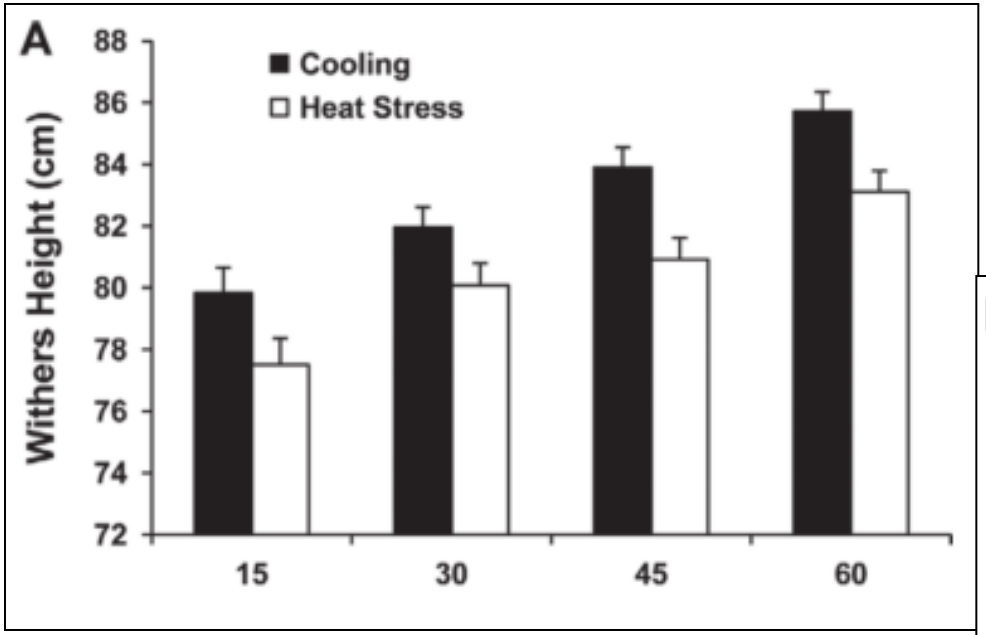
(Tao et al., 2012)

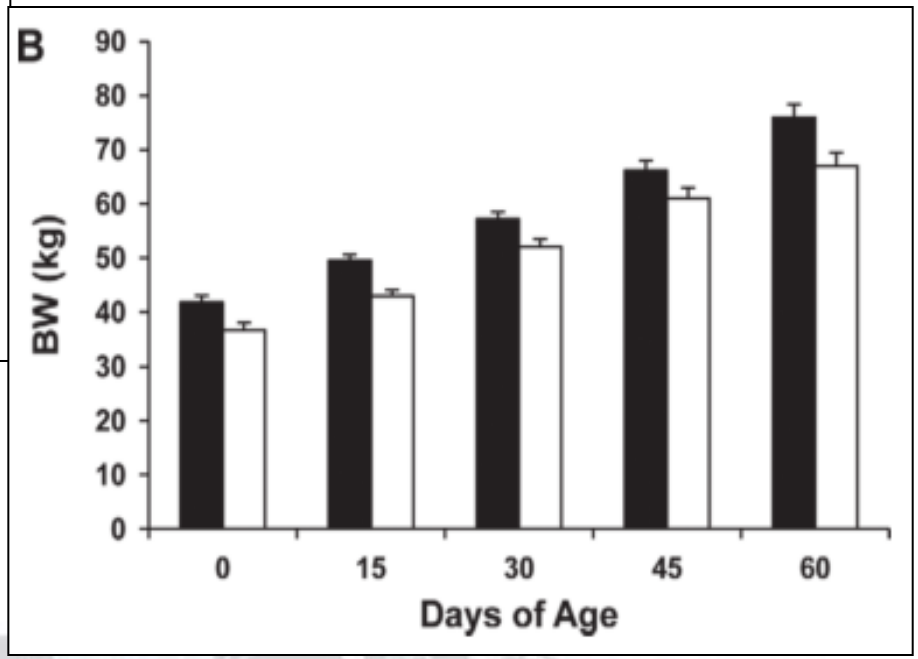
Effect of cooling cows during the dry period (from 46 days before expected calving) on DMI.



(Tao et al., 2012)

Effect of heat stress and cooling cows during the dry period on growth of calves.





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5. **Nutritional interventions to alleviate heat stress**
    - Basal Ration
    - Additives

What can you do?

3. Nutritional adaptations:

- Balanced (TMR) diets – feed more frequently or during cool periods
- Select higher quality forages (lower N fertilization; low Fiber)
- Avoid excess protein, esp. NPN
- Limit fiber – select cool area for extra fiber
- Replace some forages with by product with digestible fiber (BP; SB-Hulls)

What can you do?

3. Nutritional adaptations:

- Add fat – protected
- Include buffers (esp. $KHCO_3$)
- Free min (+ vit) supply
- Additives

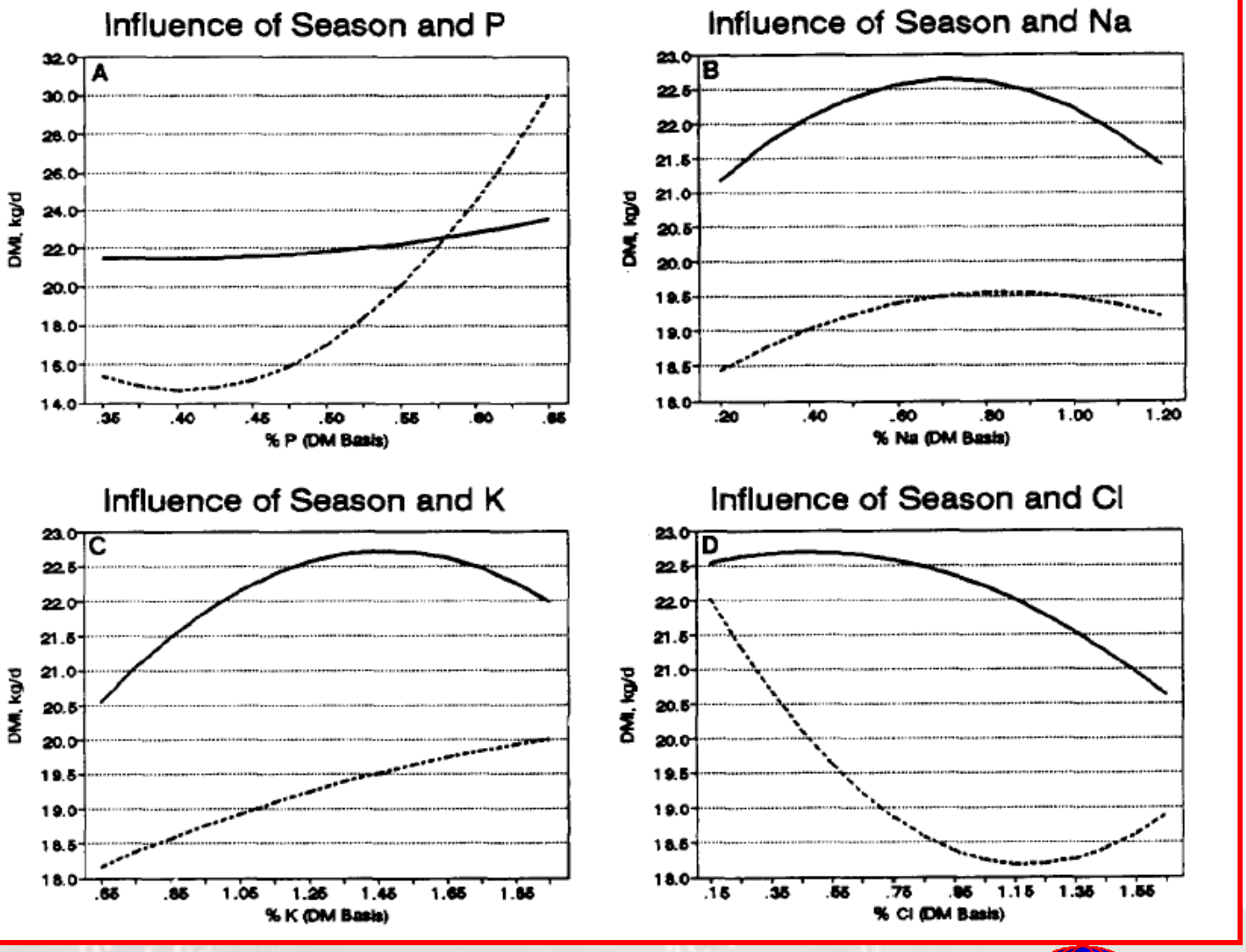
Effect of protected fats in heat stressed cows.

Item	Supplemental Saturated FFAs (% DM)		
	0	1.5	3.0
Heat Stress Measures, 1400 h			
Rectal temperature (°C)	40.0[a]	39.0[b]	39.2[b]
Respiration rate (bpm)	65	67	67
Production Measures			
DMI (kg/d)	20.1	20.1	20.2
Milk Production (kg/d)	26.4[a]	28.5[b]	28.6[b]
Milk Fat (%)	3.39[a]	3.67[ab]	3.81[b]
Milk Fat (g/d)	896[a]	1066[b]	1089[b]
Milk Protein (%)	3.06	2.92	3.07
Milk Protein (g/d)	800	843	863
BCS	2.73	2.71	2.72

Increase Mineral supplements; P, S, K, and Cl Nutrition by Heat Stress Interactions in Dairy Cattle

——— Winter;

– – – Summer.



(W. K. SANCHEZ et al., 1994 J Dairy Sci 77:2051-2079)

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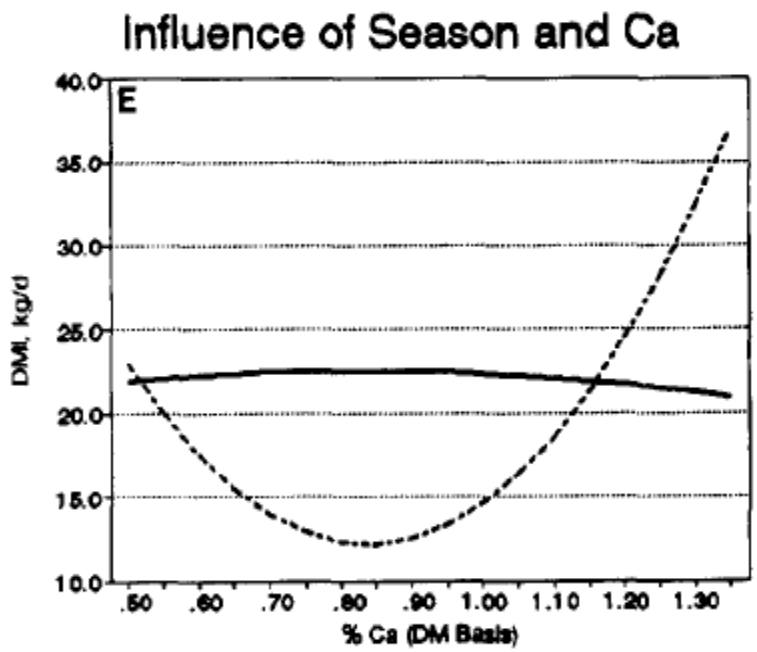
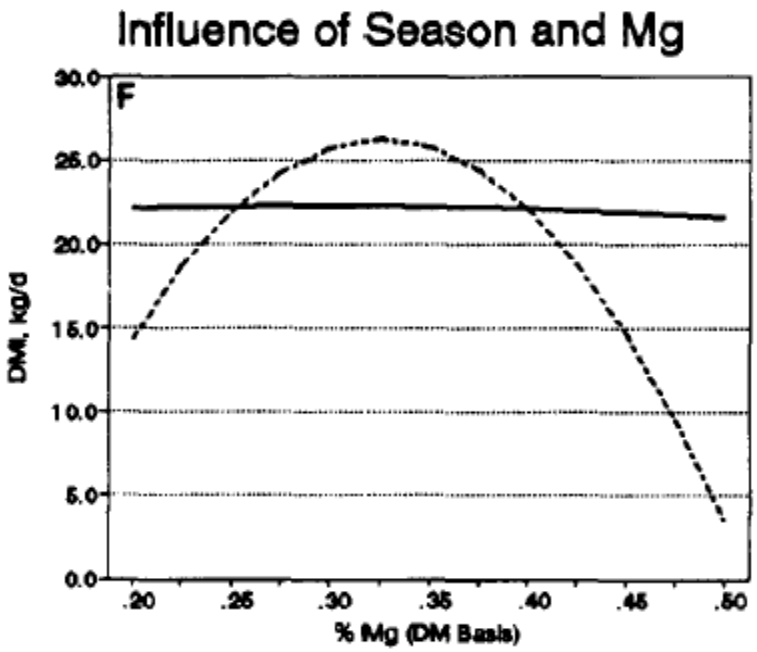
Calcium and Magnesium Nutrition by Heat Stress Interactions in Dairy Cattle





(W. K. SANCHEZ et al., 1994 J Dairy Sci 77:2051-2079)

——Winter; – – - Summer.

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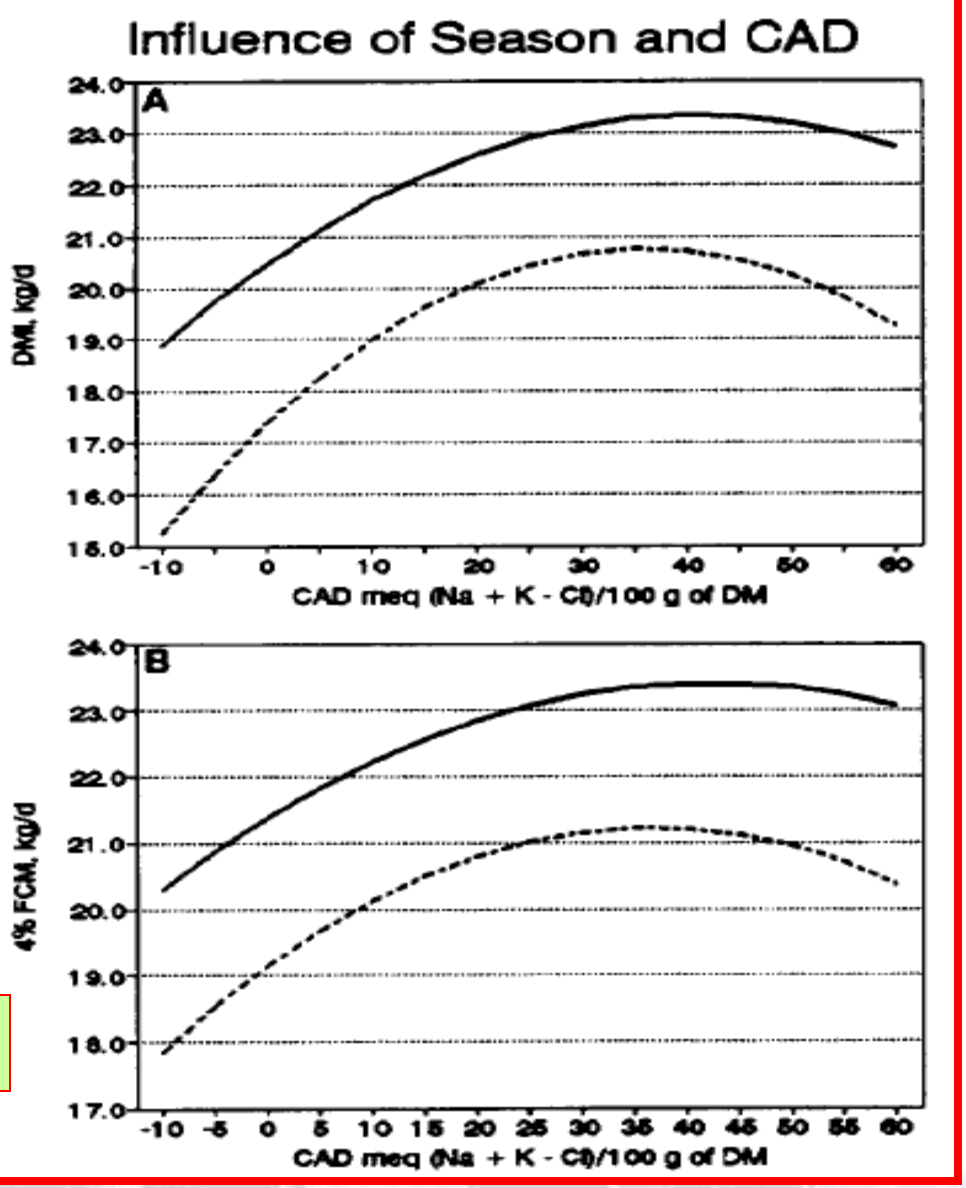
Regression curves for DMI and 4% FCM yield responses in winter and in summer plotted against *CAD*



——Winter; – – - Summer.

(W. K. SANCHEZ et al., 1994 J Dairy Sci 77:2051-2079)

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What can you do?

2. Additives:

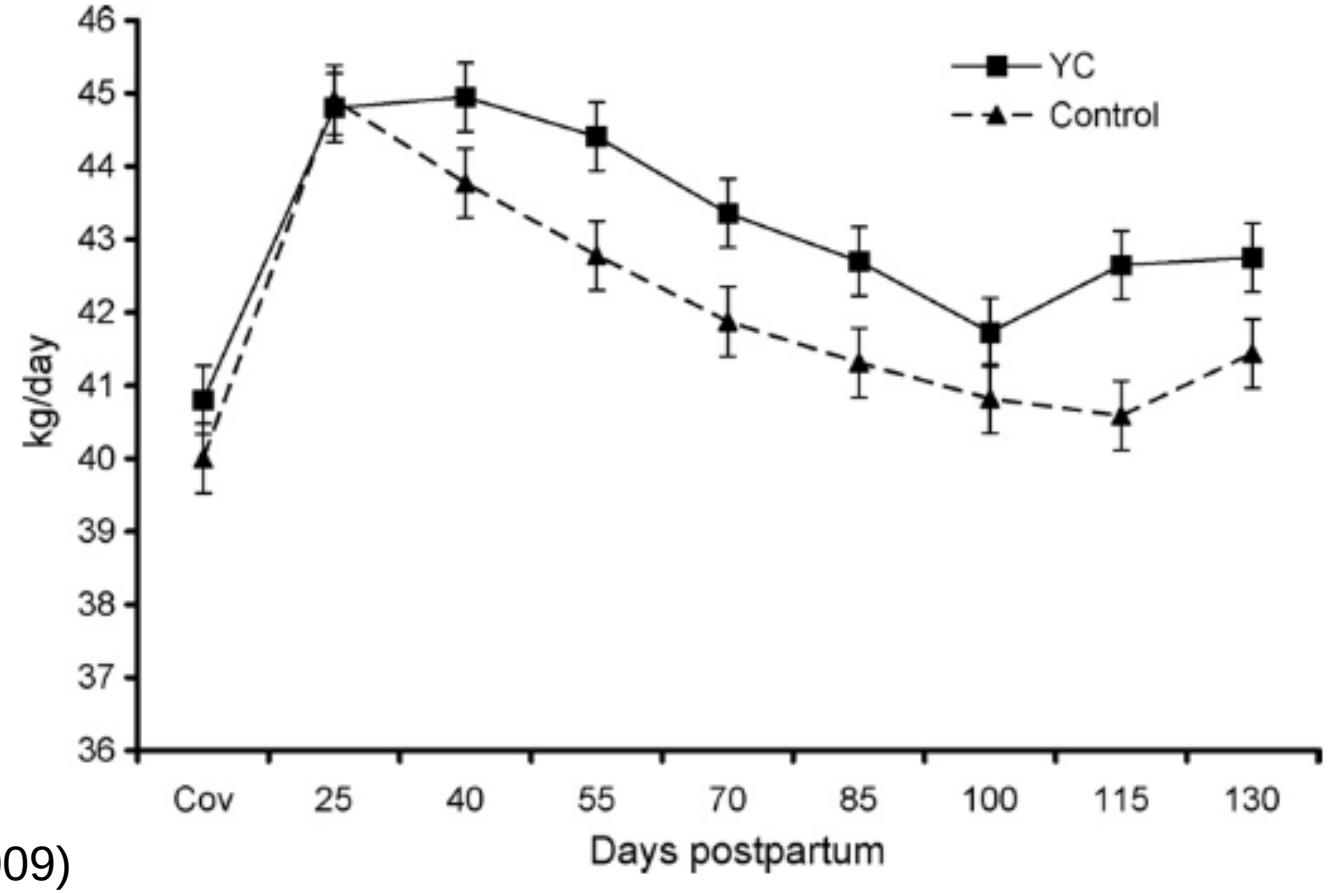
- Yeast
- Fungal Extracts

} DFM

- Niacin
- Herbal extracts

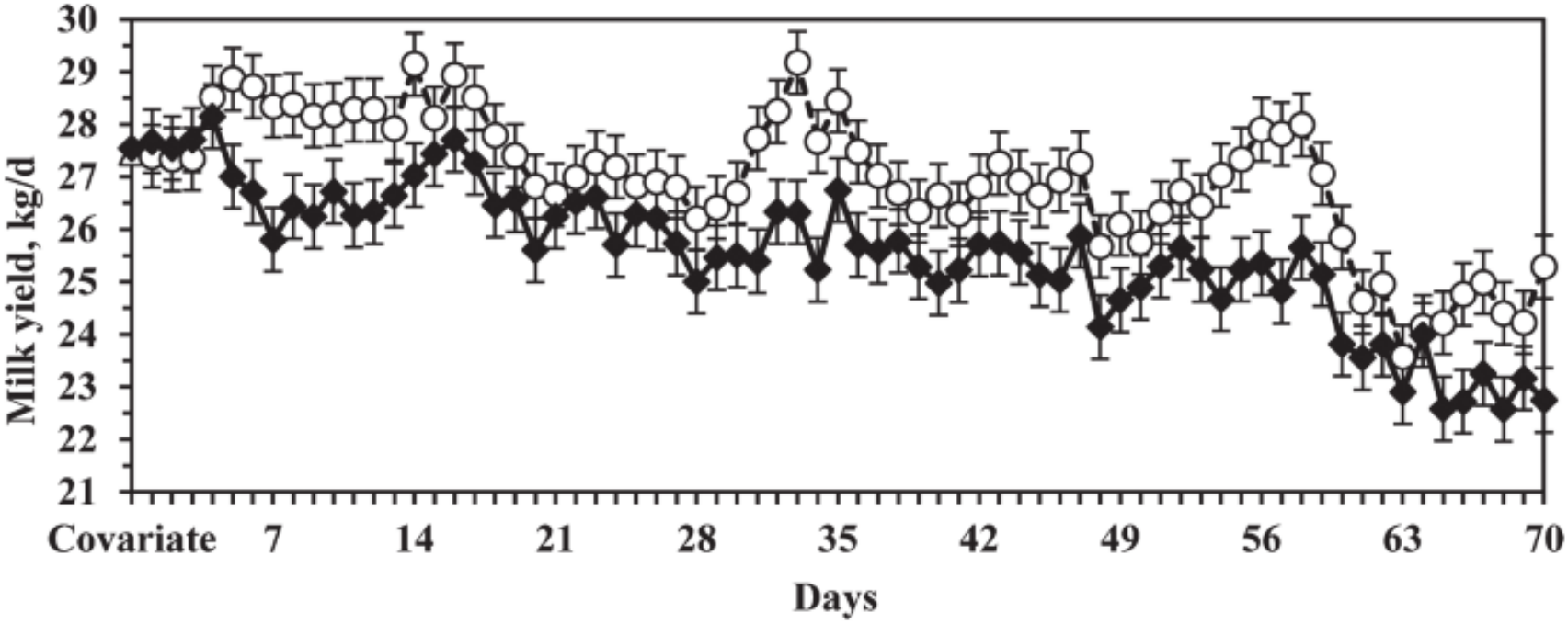
What can you do?

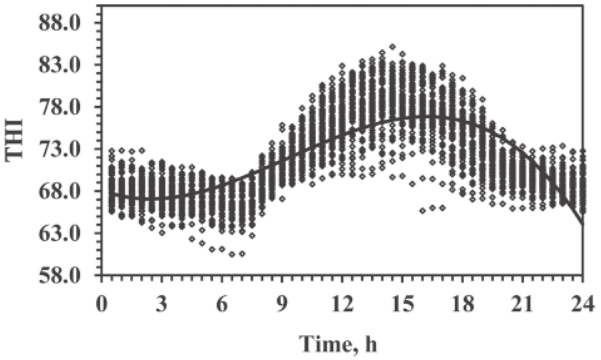
Effect of Yeasts on Milk production in HS-cows:



(Bruno et al., 2009)

Response of lactating cows to live yeast supplementation during heat stress (summer – Brazil).

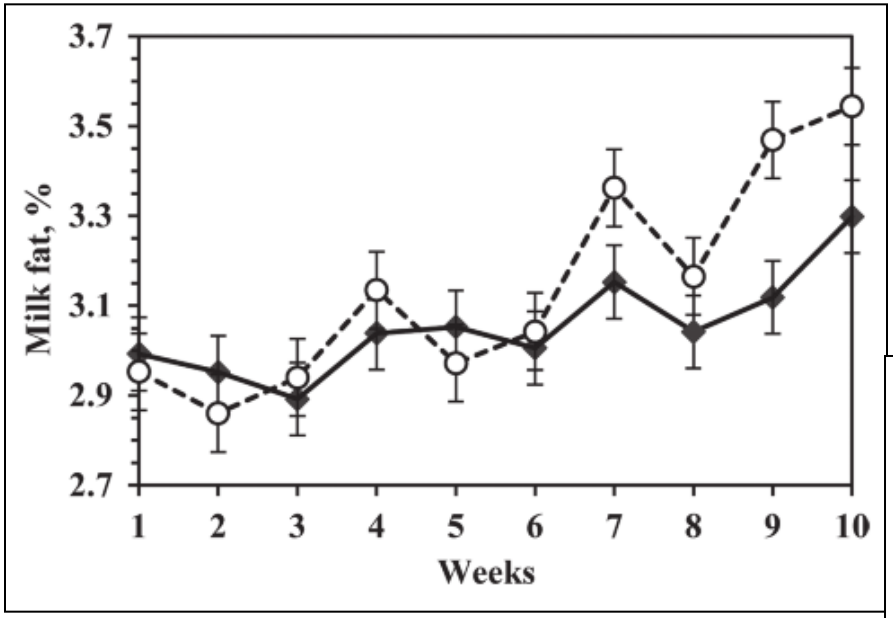


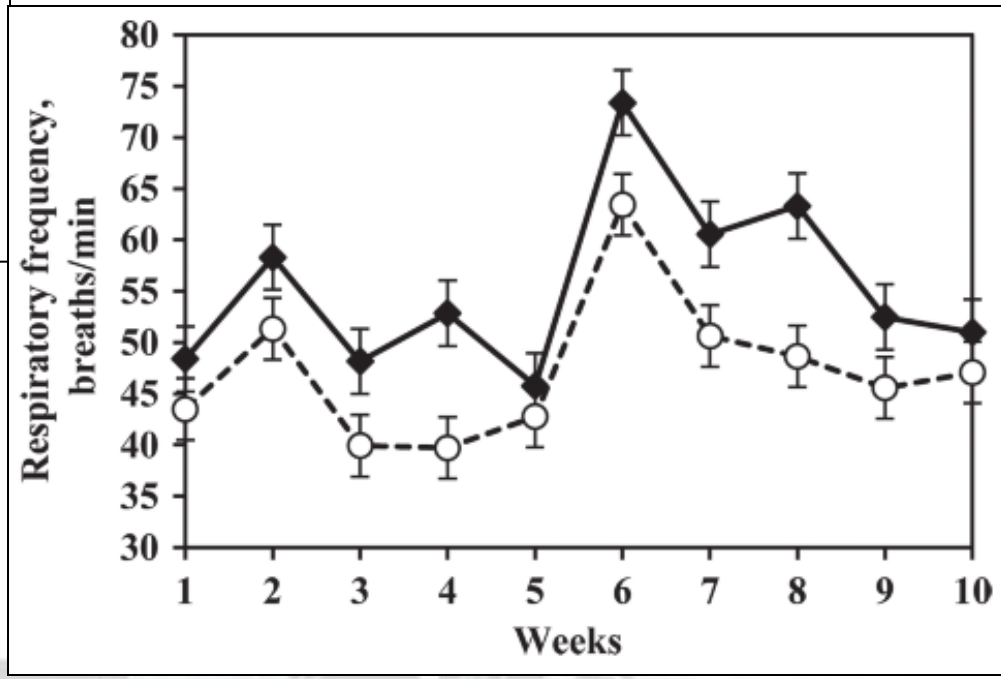


Control (♦) or yeast treatment (○)
(*P treatment = 0.03*)

(Salvati et al., 2015)

Response of lactating cows to live yeast supplementation during heat stress (summer – Brazil).





Control (♦) or yeast treatment (○)

(*P treatment; milkfat= 0.22; Respiratory frequency = .02)*

(Salvati et al., 2015)

Effect of Fungal Extracts on Milk production in HS-cows:

Early Lactation	A.0ryzae*	Control
Wallentine et al.,1986) 4% FCM	33.7	30.1
Gomez et al. 1988) 3.5% FCM	35.9	34.1
Gomez et al. 1990	40.4	38.7
Mid Lactation	**Improvement**	**6.90%**
Milk (Huber, 1985)	20.2	18.5
Milk (Huber et al., 1987)	23.6	22.6
Milk (Marcus et al. 1986) 3.5% FCM	30.7	29.0
Milk (Gomez et al., 1988) 3.5% FCM	21.4	20.5

Overall average **6.41%**

* Amaferm

* P < 0.05 ** P< 0.10

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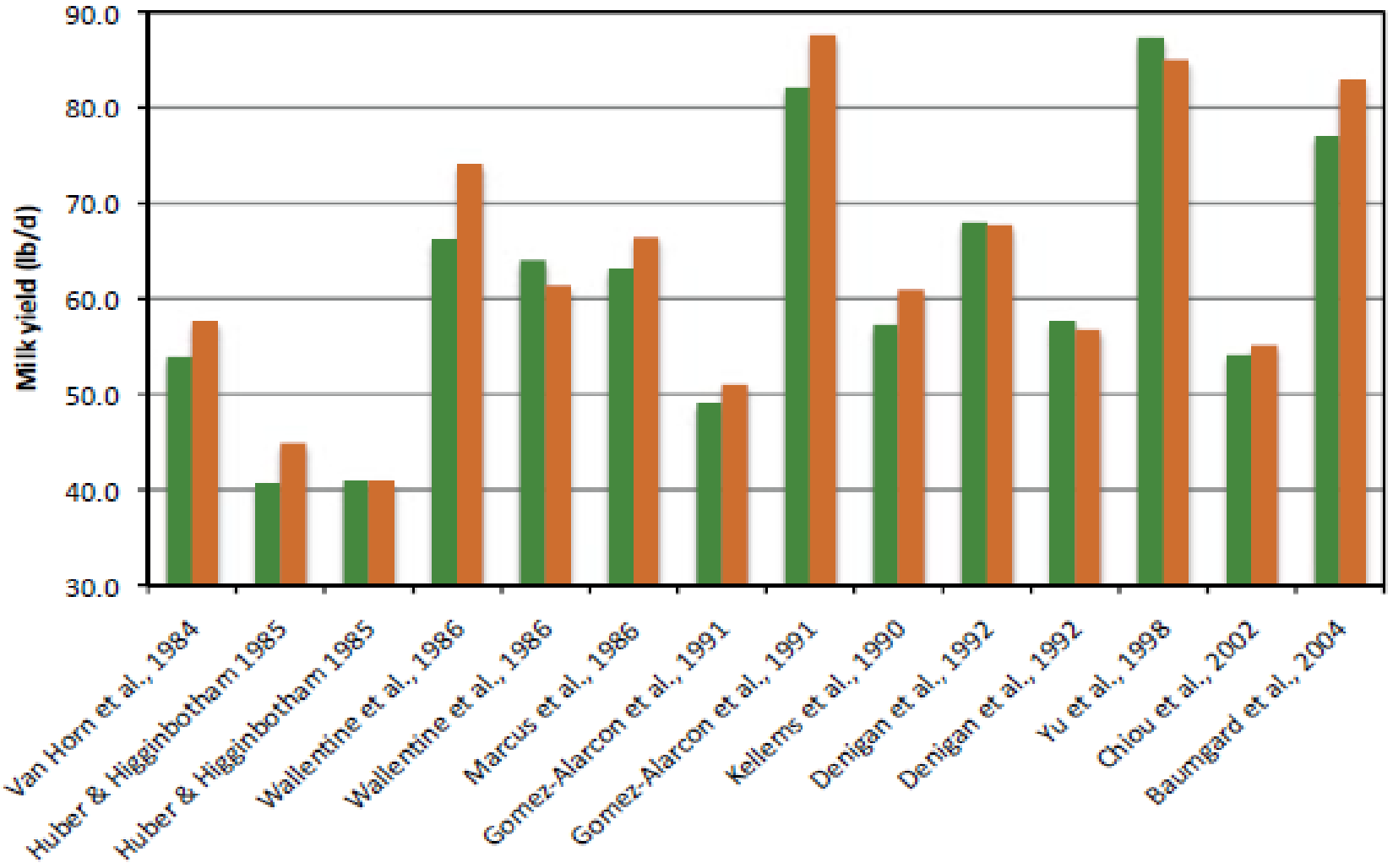
Milk Production in Heat stressed cows with A. oryzae extracts.



What can you do?

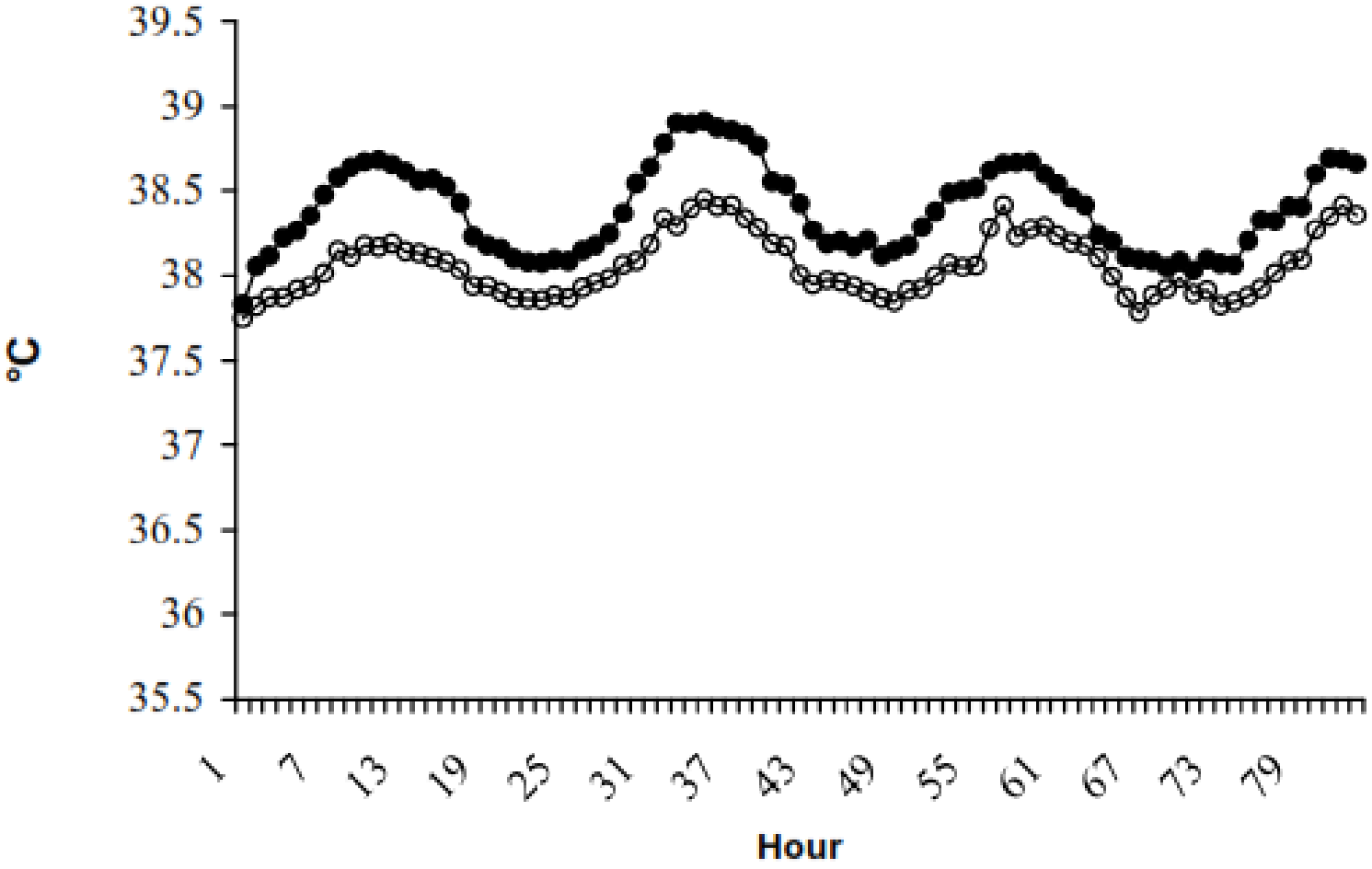
Mode of Action (MOA) DFM:

1. **Improved rumen fermentation of CHO:**
   - **Starch and sugars - Yeast**
   - **Fiber – A. oryzae**

2. **Enzymatic effect – lower GIT**
3. **Metabolic effects**
4. **Immune response**

What can you do?

Niacin; effect on Body core temperature*.



* from day 4 to day 7 period; (Zimbelman et al., 2008)

What can you do?

Niacin; effect on DMI, Water and MP (?).

	Period 1		Period 2		Trt		Period	
	C	Trt	C	Trt	SEM	P	SEM	P
DMI, kg/d	39.1	38.7	38.8	36.7	1.69	0.69	1.7	0.05
Water Intake, L/d	89.2	116.4	107.3	127.4	2.24	0.11	1.5	<0.01
Respiration Rate, bpm	30.6	32.5	50.8	54.5	1.78	0.14	2.1	<0.001
Rectal Temp. ^{o}C	38.01	38.06	38.34	38.17	0.06	0.05	0	<0.001
Milk Yield, kg/d	28.4	31.4	28.5	30.4				

(Zimbelman et al., 2008)

CTRL: 0g Niacin; Trt = Treatment (12g RP-N)

What can you do?

Effect of Herbal extracts on Milk production in HS-cows:

Number of publications in the J. Dairy Science: 0.

→ Questions:

1. **What is the real potential of plant extracts?**
2. **Situation in other spp.?**
3. **What chemical compounds are involved?**
4. **Can we identify and re-create?**
5. **How does it work?**

(et al., 2009)

Conclusions:

1. Heat stress in ruminant production is a natural phenomenon with enormous (incomplete understood) physiological and economic consequences
2. Seasonal heat stress is now also recognized as a problem in temperate areas.
3. Effects of heat stress can be reduced through:
   - Physical means
   - Management
   - Specific Nutritional

   } adaptations
4. Applications of the known means allows to remove the heat stress effects and reach production levels similar to temperate (THY<70) conditions.