Breeding for improved heat tolerance: methods, challenges, and progress

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ADSA Mtg, West Palm Beach, June 16-19, 2024

Heat tolerant cow and genetics

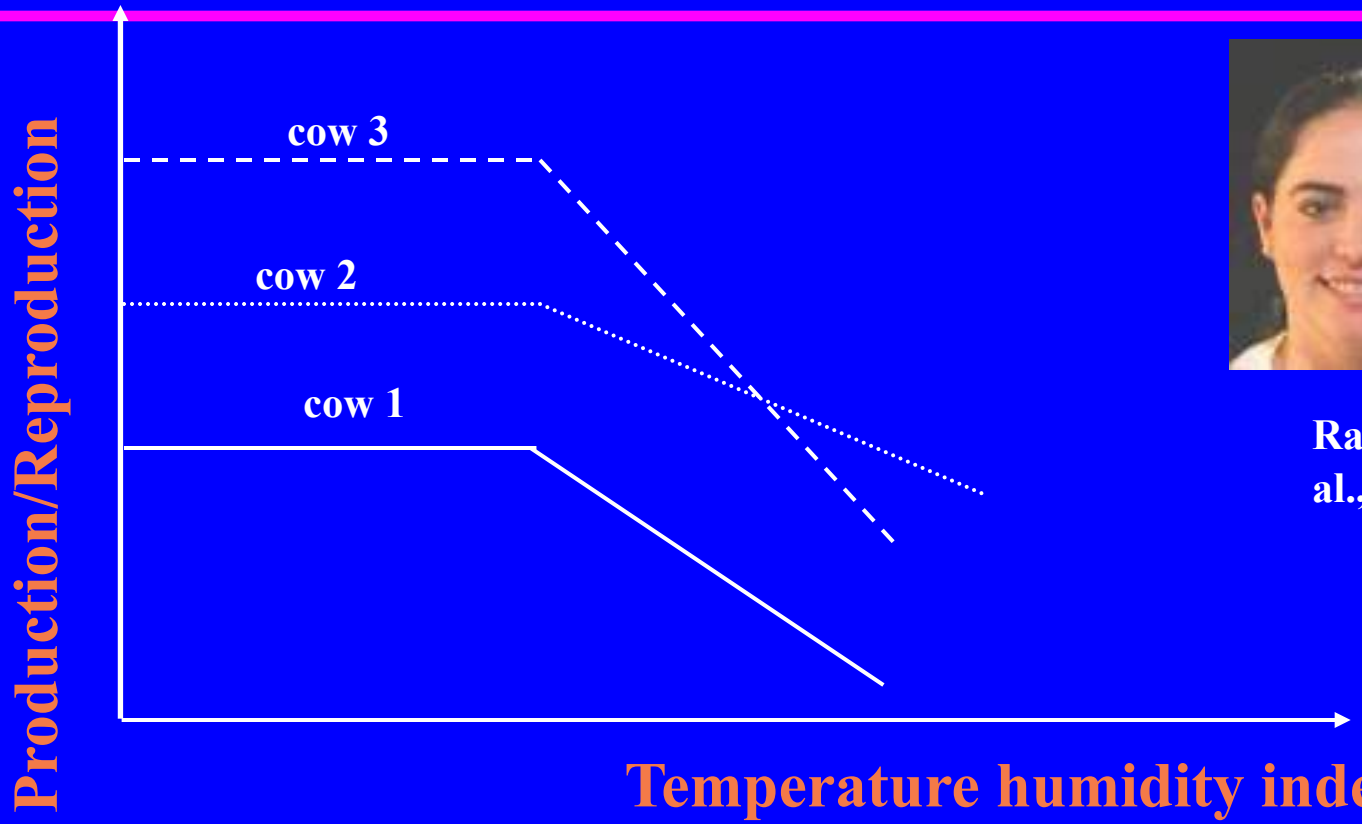
- Under heat stress, cow should:
  - keep milk flowing
  - reproduce
  - keep healthy
  - do not die
- Constantly improving management available under heat stress
- Does it make sense to select for heat stress?

Studies on heat stress

- Measurements on individual cows (e.g., Hansen lab, Collier lab)
  - Rectal temperatures
  - Respiration rates
  - Production and reproduction

- Use of public weather stations for test days etc. (Ravagnolo et al., 2001)

Assumption for heat stress model

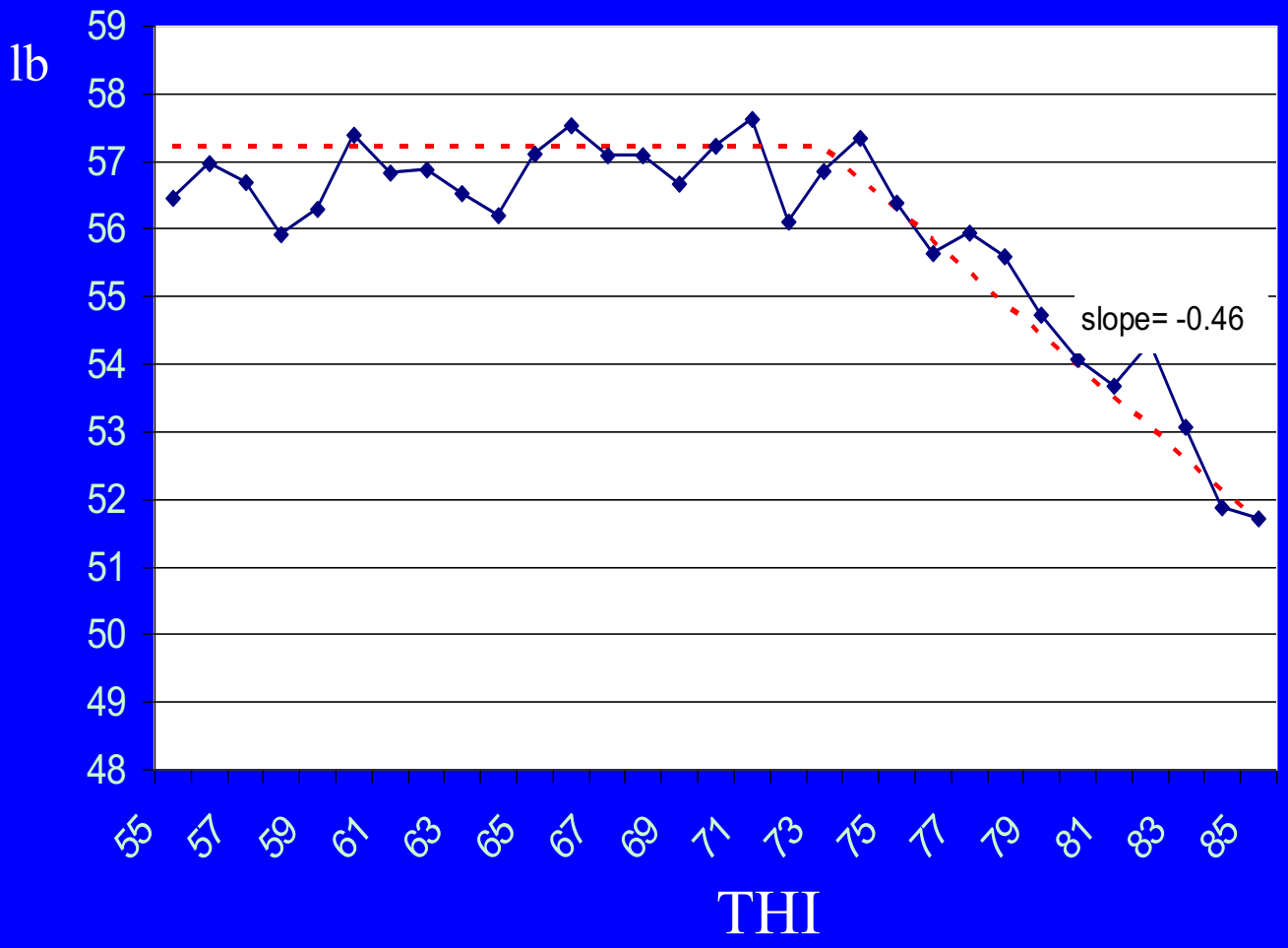


Ravagnolo et al., 2001

Breeding value: $BV = a + f(THI)*v$

a – regular breeding value v – heat-tolerance breeding value
f(THI) – function of temperature humidity index

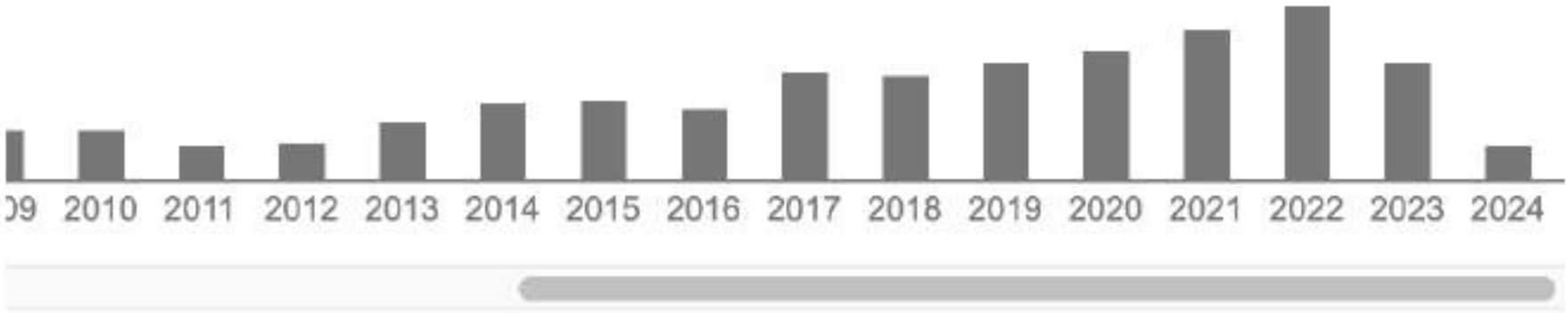
Effect of THI on daily milk production



Genetics results - 2002

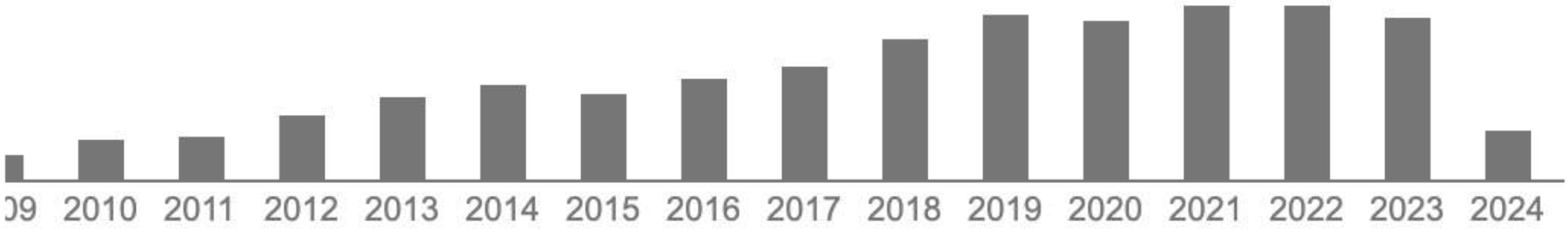
- Heat stress begins at about 72F THI (22 C at 100% humidity)
- Genetic variability for heat tolerance present but not big
- Relationship between regular and heat tolerance genetics antagonistic at ~ -0.4

Cited by 707



Genetic component of heat stress in dairy cattle, development of heat index function
O Ravagnolo, I Misztal, G Hoogenboom - Journal of dairy science, 2000

Cited by 969



Temperature-humidity indices as indicators of milk production losses due to heat stress
J Bohmanova, I Misztal, JB Cole - Journal of dairy science, 2007

Heat stress across USA

- Variation in heat tolerance across USA
- Genetic evaluation for heat stress with national data
  - Profile of heat tolerant bull
  - Can one identify heat-tolerant sires?
  - What are they?

Bohmanova et al. (2005 and 2006)

Differences between most 100 and least 100 heat tolerant sires

Milk	-1100kg
Fat%	+0.2%
Pro%	+0.1%
Dairy Form	-1.4
Udder	+0.7
Longevity	+0.90
Fertility	+1.6
Index	+36

- Less milk
- Better fitness and conformation traits
- Low accuracy of active sires for heat stress

National evaluation of U.S. Holsteins (Aguilar et al, 2010)

- Holstein U.S. test days
- 3 parities
- Random regression model
- Heat stress effect

Variances for three-parity test-day repeatability model

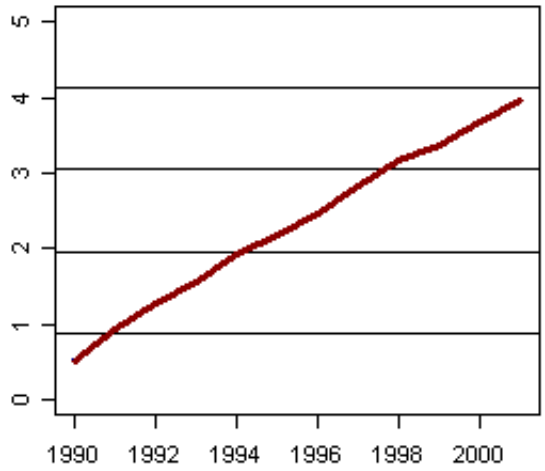
	Milk			Fat (kg*100)			Protein (kg*100)		
	1	2	3	1	2	3	1	2	3
Regular	5.6	7.5	6.5	74	94	109	43	57	52.2
Heat(+5^{0}C)	4.0	7.0	9.0	37	75	142	22	48	108
Corr	-0.46	-0.38	-0.47	-0.39	-0.39	-0.30	-0.43	-0.36	-0.50

Genetic variance for heat stress strongly increases with parity

More production ➔ more heat to dissipate

Genetic trends of daily milk yield for 3 parities – regular effect

First



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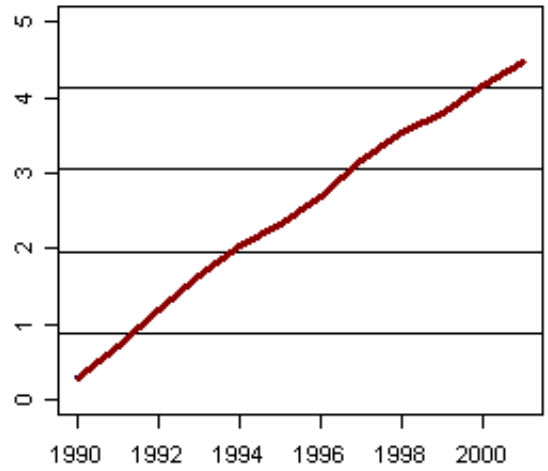
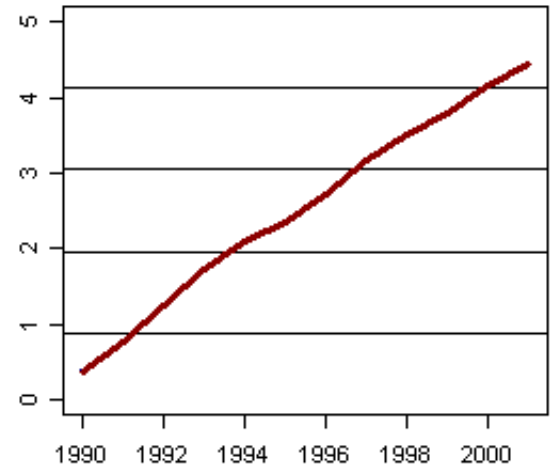
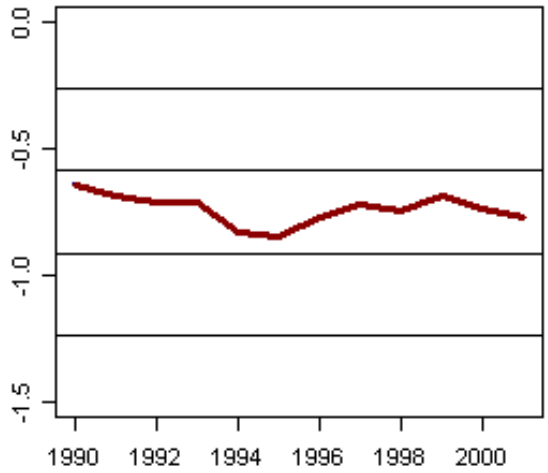


Third



Genetic trends for heat stress effect at 5.5° C over the threshold

First



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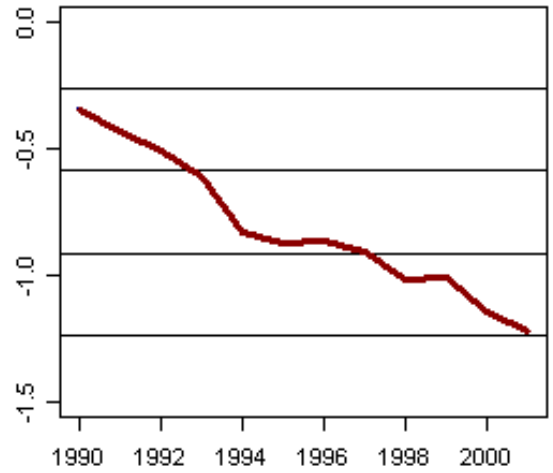

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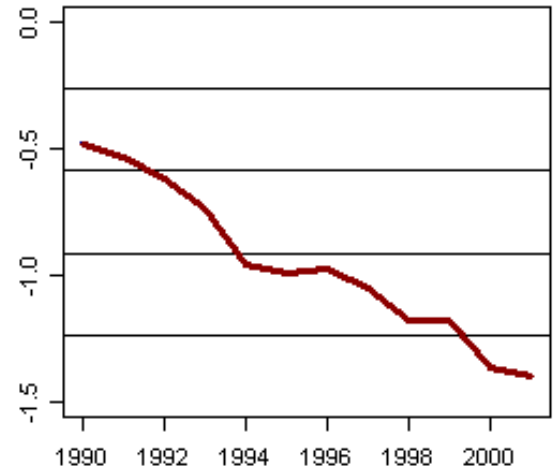
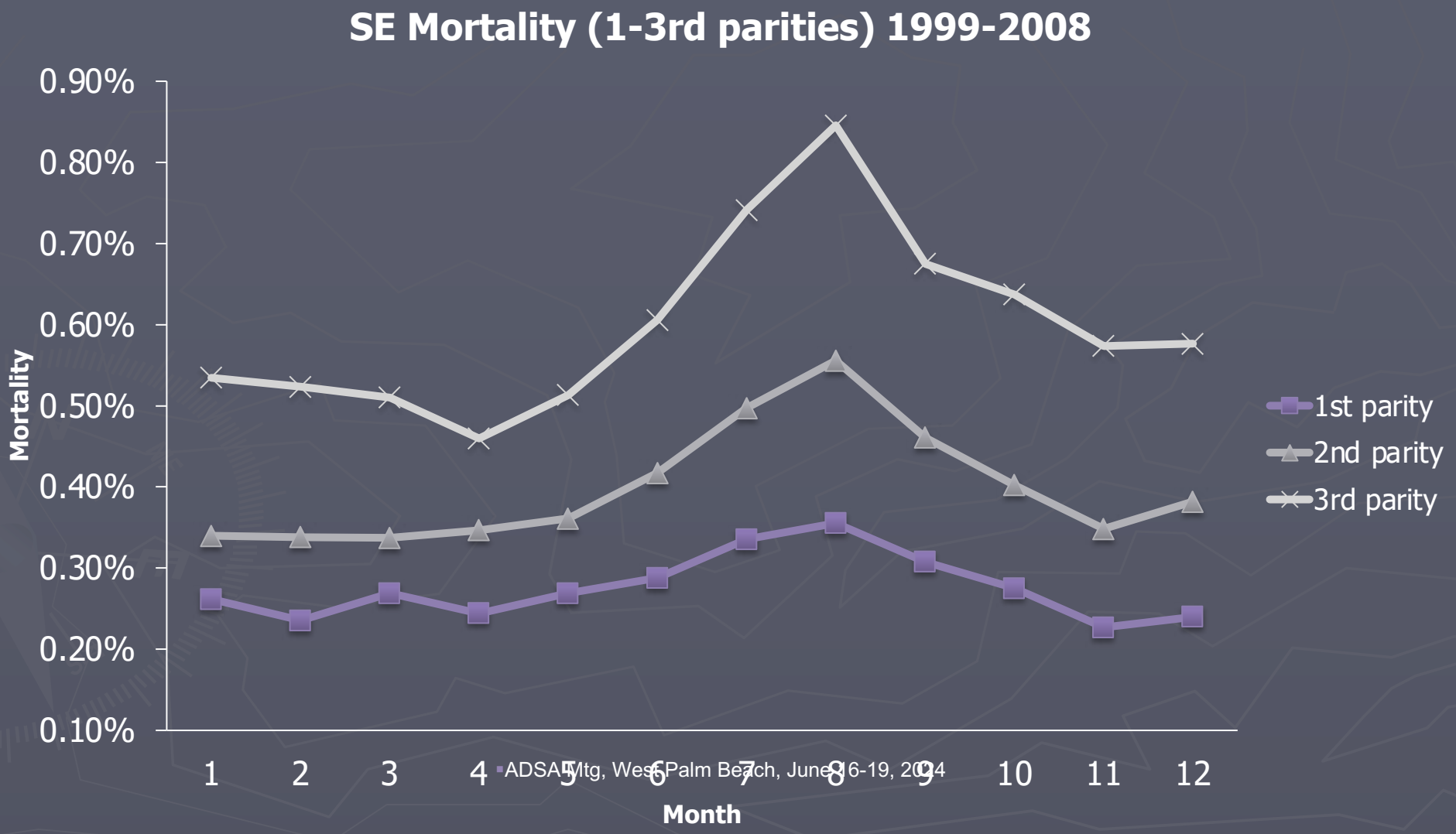


Mortality in SouthEast

Tokuhisa et al. (2011)



Heat stress and US Industry in 2010s

- Poor milk and fertility ➔ better sprinklers and fans
- Still poor fertility due to poor heat detection ➔ timed AI
- Low survival and not enough replacements ➔ sexed semen

Heat stress addressed by managemental modifications

Later developments

- Heat stress moving north
  - In Canada, threshold of heat stress 57 for protein (Campos et al., 2022)
- With genomics, high reliability, even for cows
- Genetic evaluation for heat stress in Australia (Nguyen et al., 2017)
- New interest by AI companies, e.g., Select Sires (McWhorter et al., 2022)

Heat tolerance work in Australia

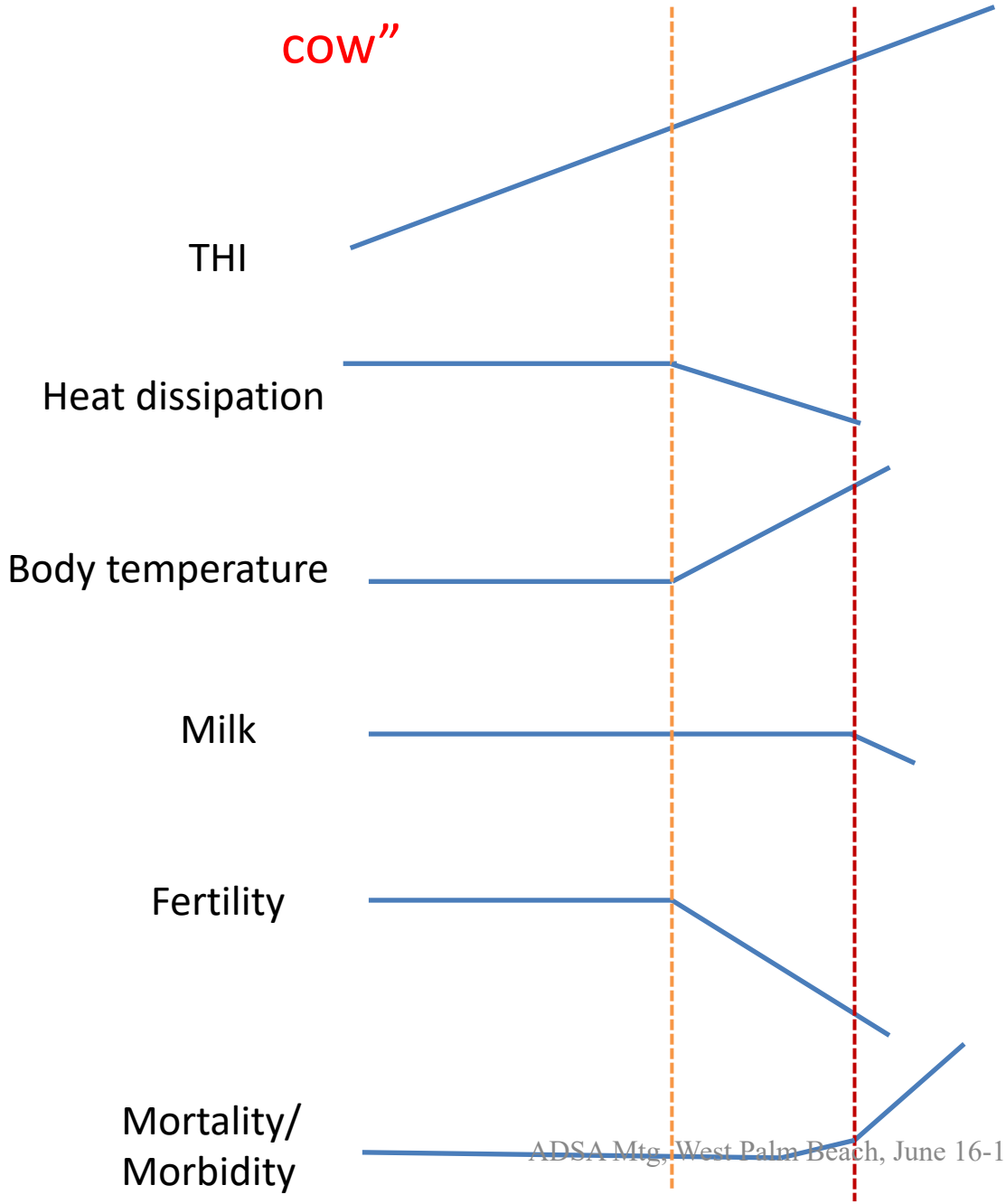
- Heat stress mostly in Queensland
- Threshold THI=60
- No extra variance in later parities
- No benefits from later parities

Nguyen et al., 2016
Doi:10.3168/jds.2015-9685

- Validation for heat-tolerant animals
  - Vaginal temperature 0.12 C lower
  - 5% less milk, 3% less fat, 2% less protein
  - DPR better 10% (summer) to 50%(winter)

Jensen et al., 2022
Doi:10.3168/jds.2021-21741

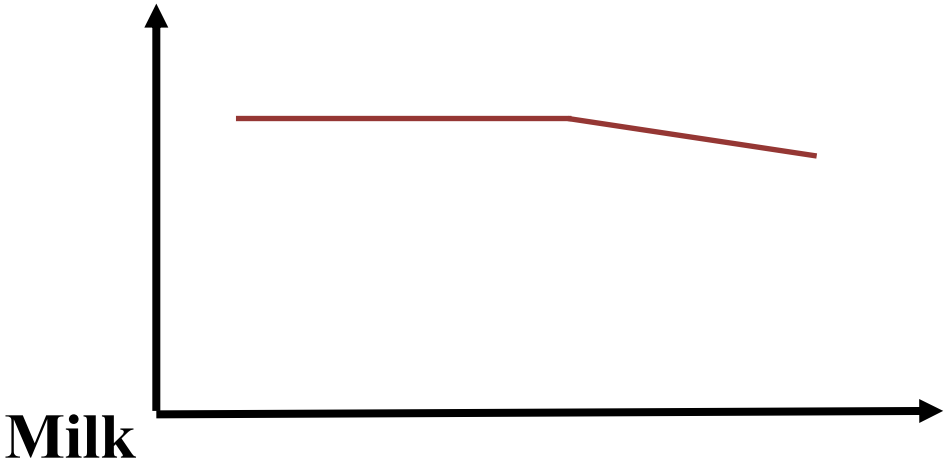
Profile of a "heat-tolerant cow"



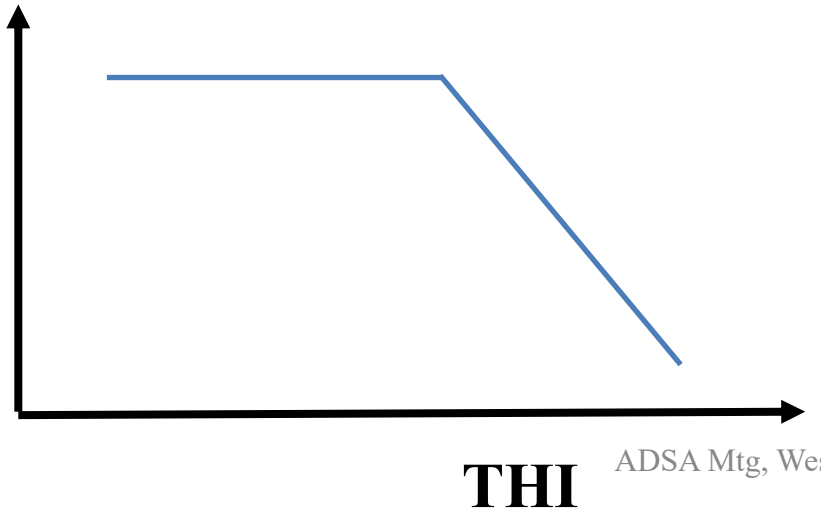
- "Heat tolerant" cow – workaholic
- Thresholds like in resource allocation studies (Waaij, 2004; Rauw, et al. 2008))

 Partially based on Dikmen et al. (2012)

Which is a desirable cow?

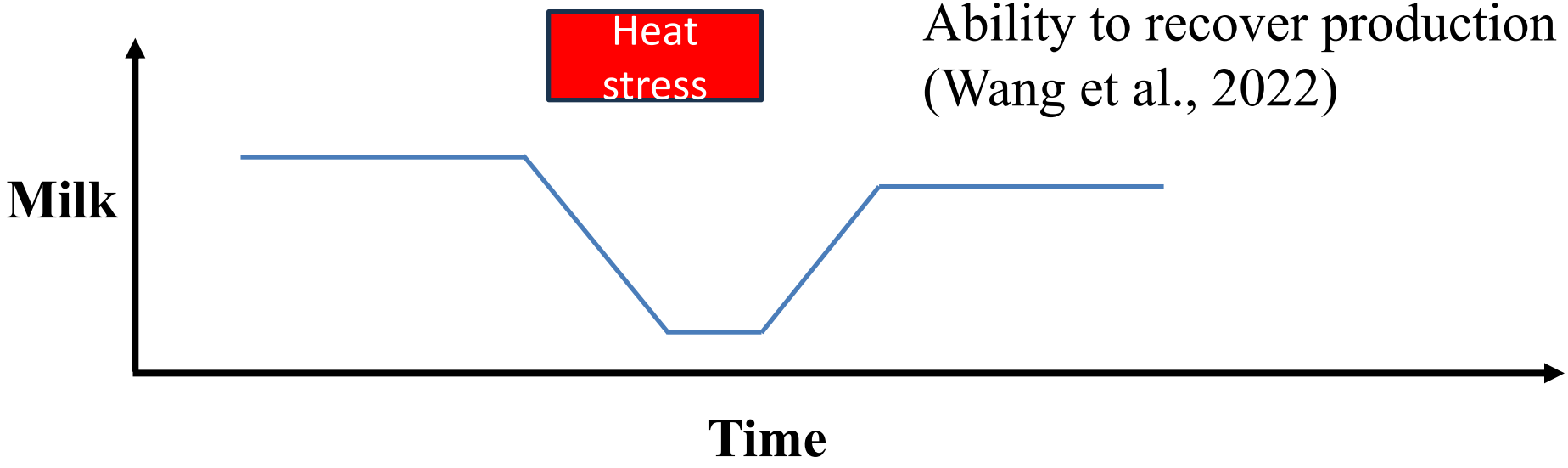


Heat tolerant
High risk for death and morbidity

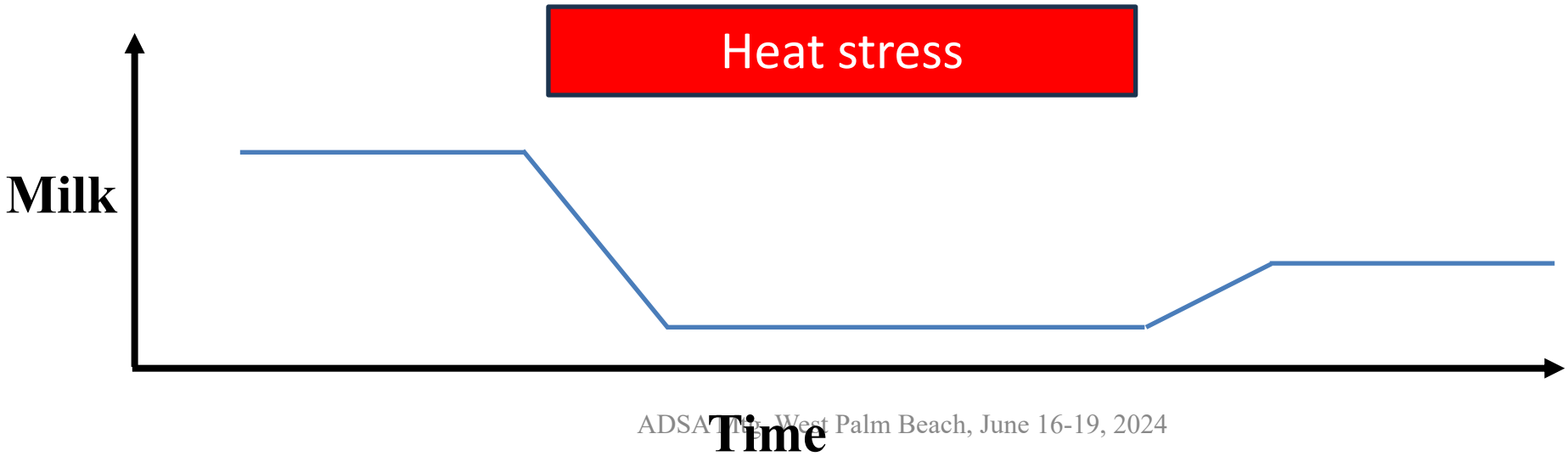


Resilient, not heat tolerant
Lower risk for death and morbidity

Recovery after heat stress event



Ability to recover production after stress (Wang et al., 2022)



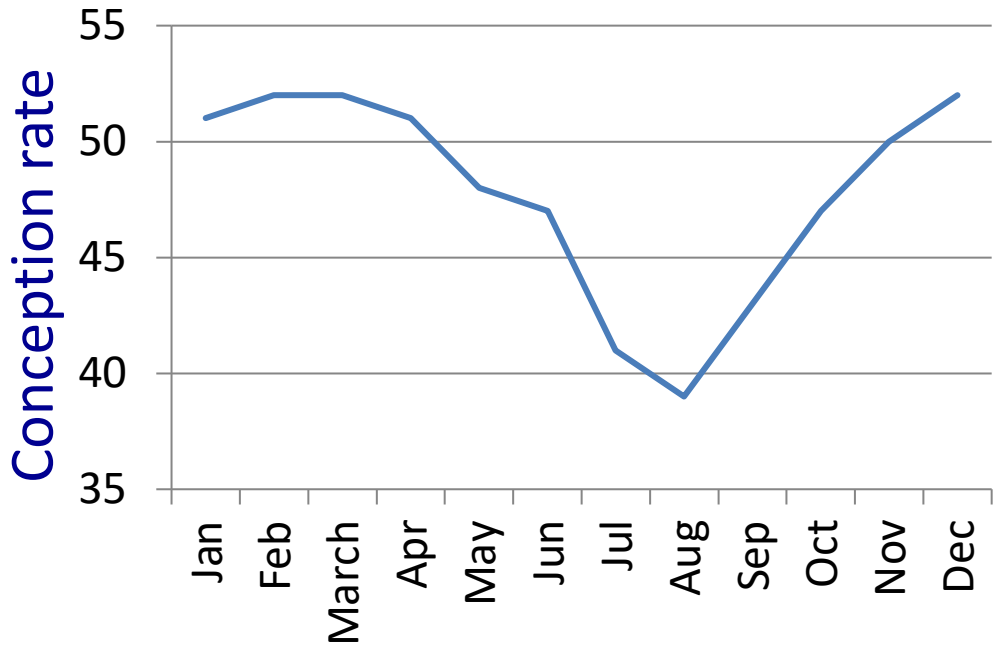
Questions about herd environment

- Is heat stress long, short or sporadic?
- Is management intensive of extensive?
- Is extension and vet care available?

- If high production – intensive management
- If investments limited - resilience

Is heat stress important in less intensive environments? - Iranian Holsteins

Small effect for milk



Mokhtar et al, 2012

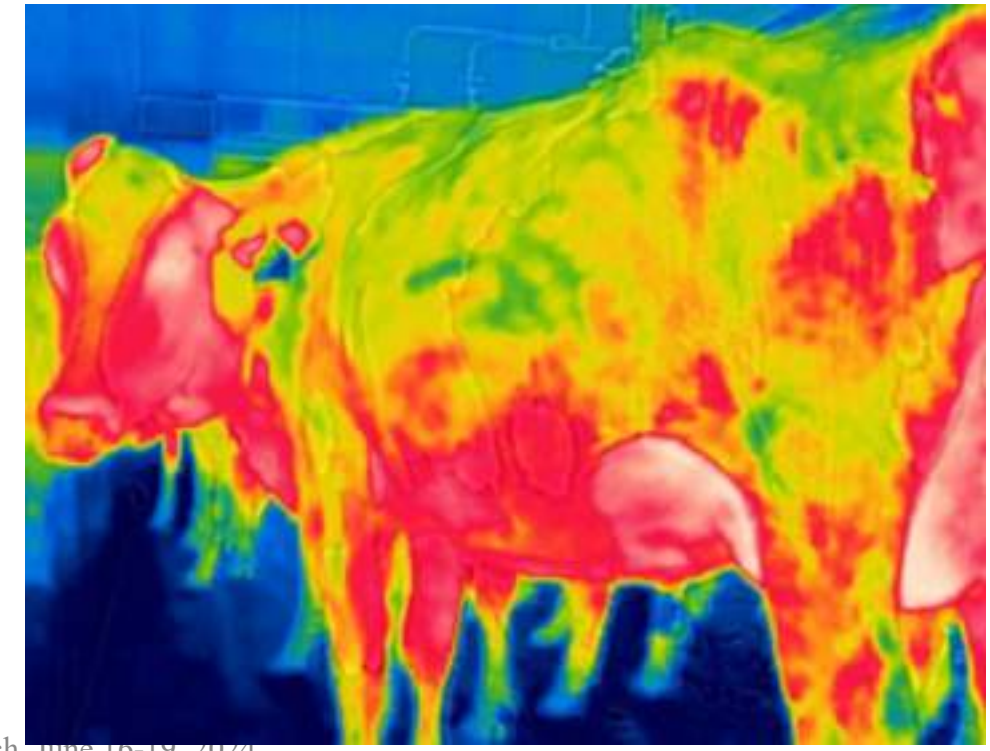

Thailand
Little change of milk seasonally


Ethiopia
One Jersey replaces 3 indigenous cows but requires extension

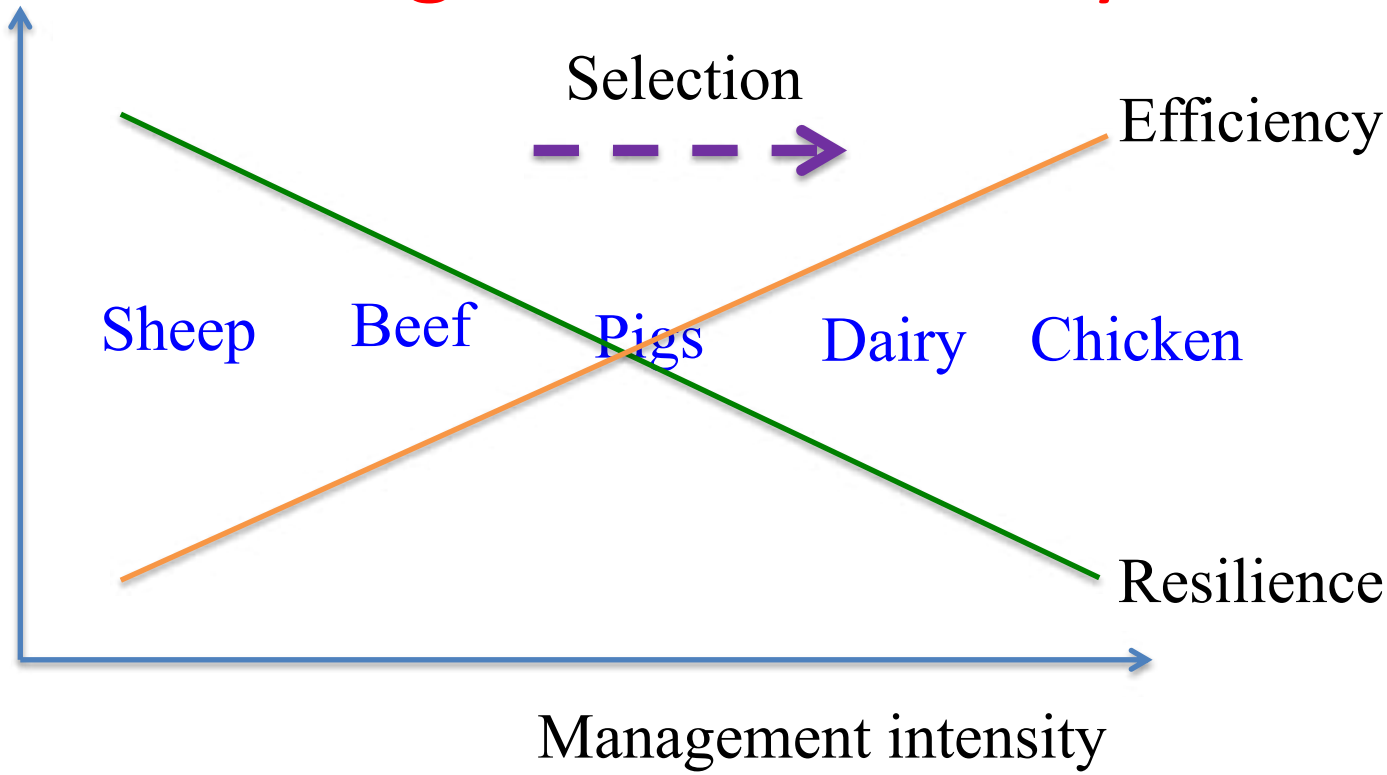

India
All kind of breeds and crosses - training and extension- NDDP

Heat resilience of beef cows

- Research by Don Spiers in beef cattle (Missouri)
  - 3 days in heat chamber without water
  - Cows stopped eating
  - Recovery after a few days



Resilience (heat tolerance)/efficiency and management intensity



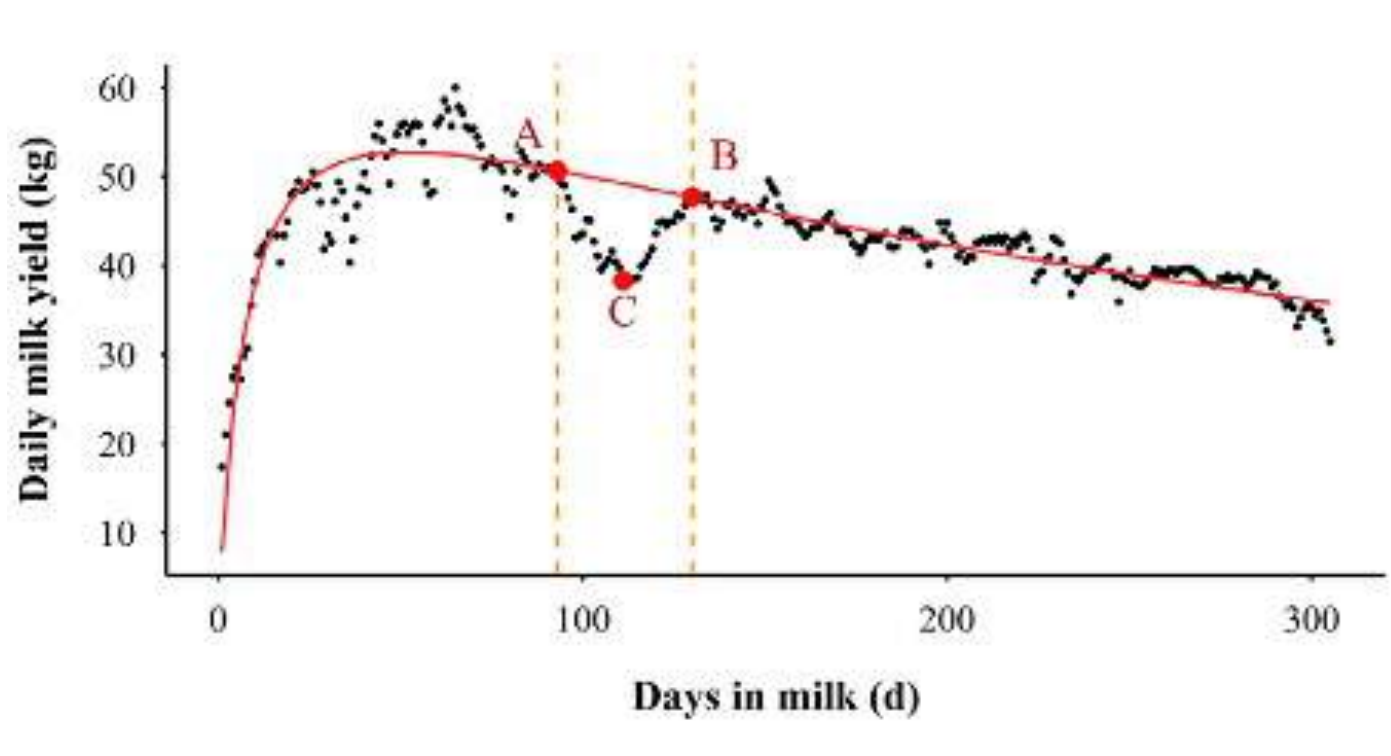
Is increasing production and resilience simultaneously possible?

Zefeh et al, 2023 https://doi.org/10.3389/fgene.2023.1127530

Canalization and resilience indicators

- Residual fluctuations influenced by genetics - canalization theory (Bodin et al., 2002, WCGALP)
- Larger residual variation associated with poor health status (Blasco et al., 2018)
- Resilience can be defined as small residual deviations (Colditz and Hine, 2016; Berghof et al., 2019)

How to evaluate resilience - minimize fluctuations

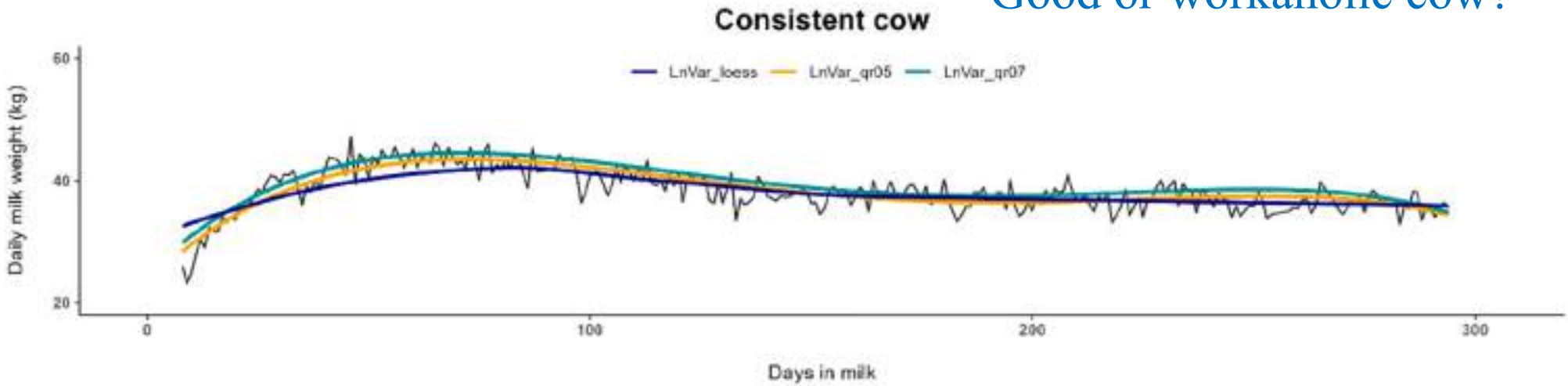


Fluctuations associated with lower milk, worse fertility and survival

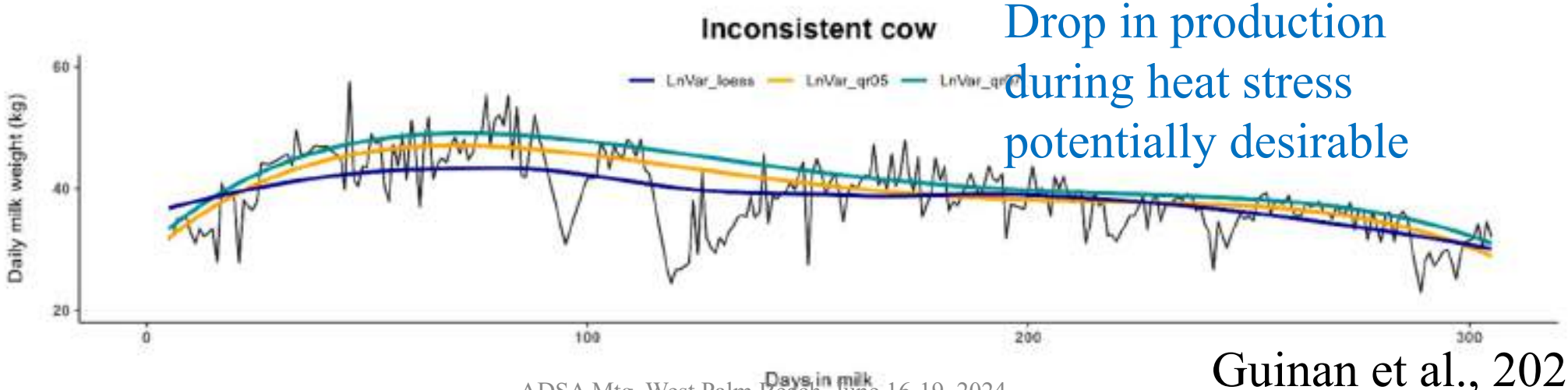
Wang et al., 2022
doi: 10.3389/fgene.2022.1031557

Deviation from averages

Good or workaholic cow?



Drop in production during heat stress potentially desirable



Guinan et al., 2024

What to do?

- Farmers do not want heat tolerant cows that milk less (Matin-Collado et al., 2023)

- Separate selection for more and for less heat-managed cows
  - More milk and less resilience with high management
  - More resilience with low management

- Is heat-stress trait different in farms with different level of heat management?

Do Holsteins have sufficient diversity for differential selection?

J. Dairy Sci. 106:2551–2572
https://doi.org/10.3168/jds.2022-21914

Nonparallel genome changes within subpopulations over time contributed to genetic diversity within the US Holstein population

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Is heat tolerance a different trait
In regions with different
management od heat stress?

J. Dairy Sci. 91:840–846
doi:10.3168/jds.2006-142

Short Communication: Genotype by Environment Interaction Due to Heat Stress

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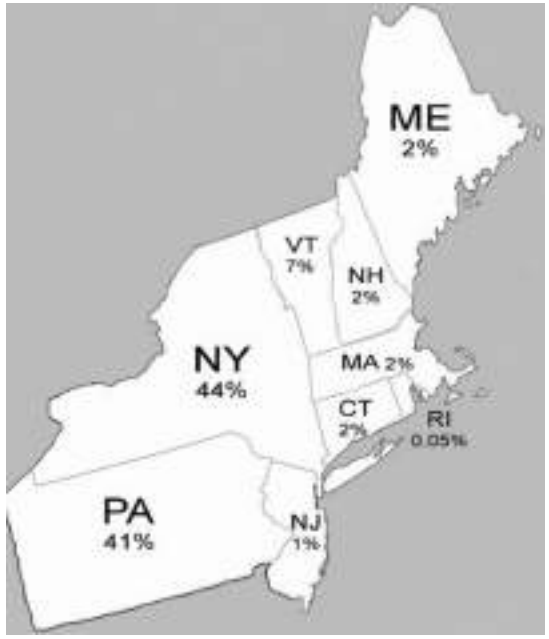
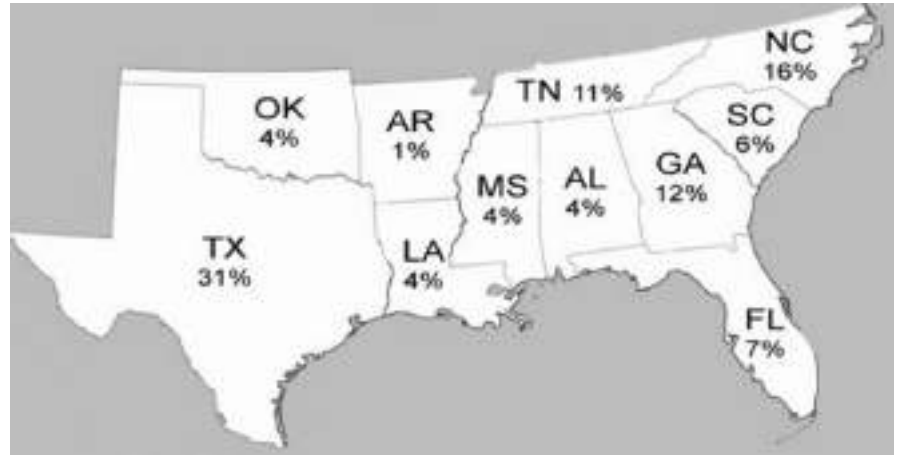


EBV_heat_northeast



EBV_heat_south

Correlation 0.8 for well proven bulls

Heat-stress same trait in regions -- different scale

Simple recommendations (old?)

- For high producing herds
  - Intensive management
  - More weight for secondary traits (fertility, mortality, morbidity, udder, feet and legs,…)
- For lower producing herds
  - Even more weight for secondary day traits
- For herds under short or sporadic heat stress
  - Short term management
  - Investigate resilience - ability to recover fast

Can genomic selection solve all problems?

JOURNAL ARTICLE ACCEPTED MANUSCRIPT

Potential negative effects of genomic selection

Ignacy Misztal ✉, Daniela Lourenco

Journal of Animal Science, skae155, https://doi.org/10.1093/jas/skae155

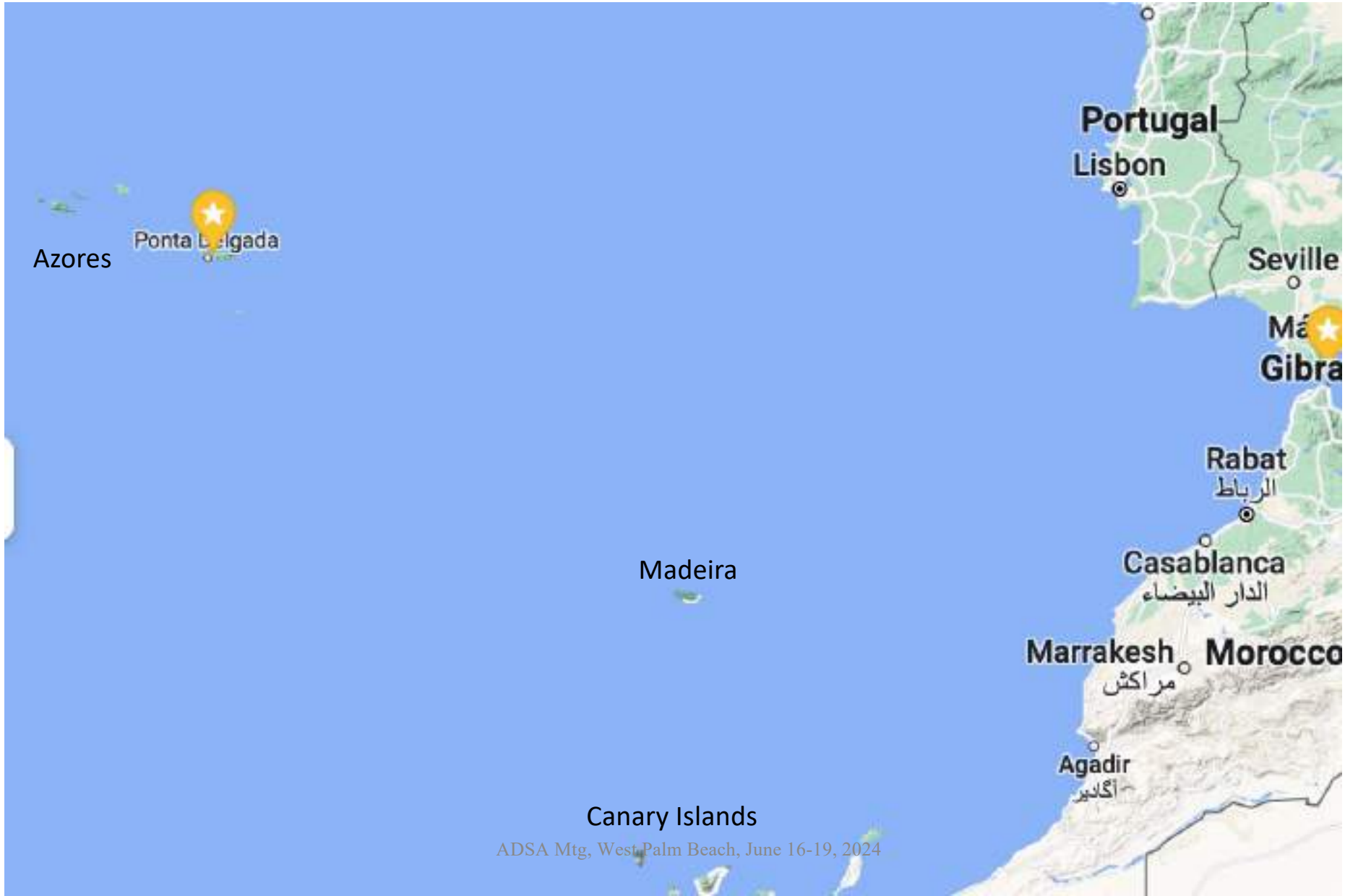
Published: 07 June 2024 **Article history** ▾

Additional issues

- How to estimate genetic parameters with large data?
  - Sample data – biases
  - No genomic – biases
  - All data – too expensive by REML or Bayesian

- How to understand genetic changes over time?
  - Resource allocation theories

Is there heaven for dairy cows?

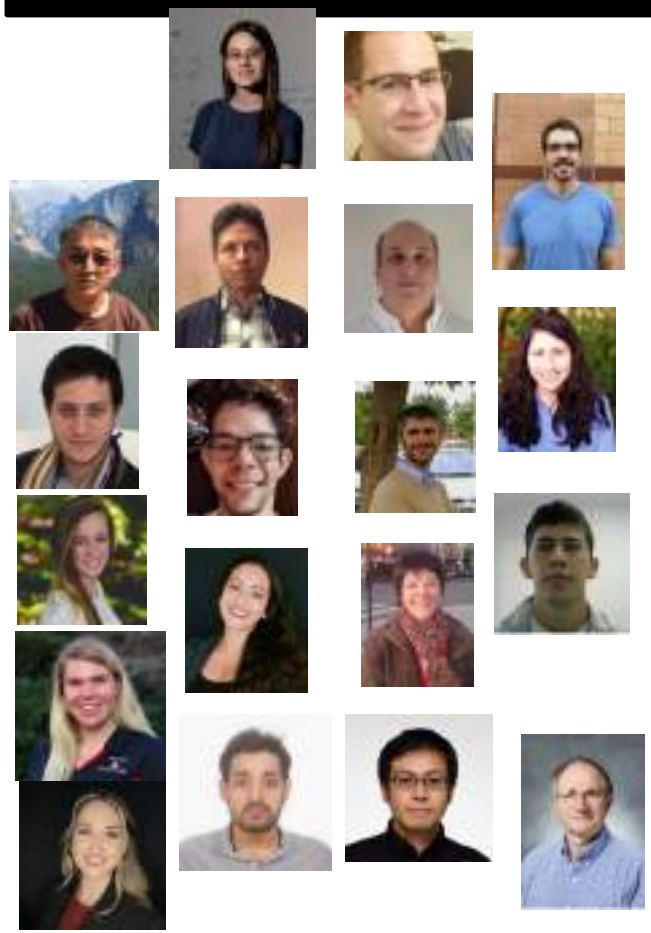



Sete Cidades
Ribeira Grande
Nordeste
Ilha de São Miguel
Furnas
Povoacao
Ponta Delgada
Vila Franca do Campo

Conclusions

- Heat tolerance and production antagonistic
- Current selection against heat tolerance
- Modern cow bred for sophisticated management
- Dilemma: high producing or resilient cow?

UGA AB&G team



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