# Air Quality and Indoor Environment of Compost Bedded Dairy Barns in Ohio

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# Overview

- Background of the study
- Study methods
- Indoor thermal environment
- Air quality in bedded pack dairy facilities
- Conclusions and suggestions

# Backgrounds of the Study

- The positive impacts for cow comfort and milk production as well as the ability to handle manure as a dry material have resulted in increased interest in compost bedded pack systems in Ohio .
- Manure composting process releases ammonia, odorous gases,  and heat.
- Ohio NRCS had air quality and safety concerns.
- This study is to comprehensive evaluate the effectiveness of the compost dairy barns.

# Objectives

- Evaluate air quality of compost bedded pack systems in Ohio
- Evaluate indoor environment of the compost bedded pack systems in Ohio
- Develop recommended design and management guidelines for dairy bedded pack systems.

# Methodology

- 4 study farms, 4 visits, 1 in each season
- Air quality (6-10 locations, before/after stirring)
  - Carbon dioxide ($CO_2$)
  - Hydrogen sulfide ($H_2S$)
  - Ammonia ($NH_3$)
- Thermal environment—T and RH

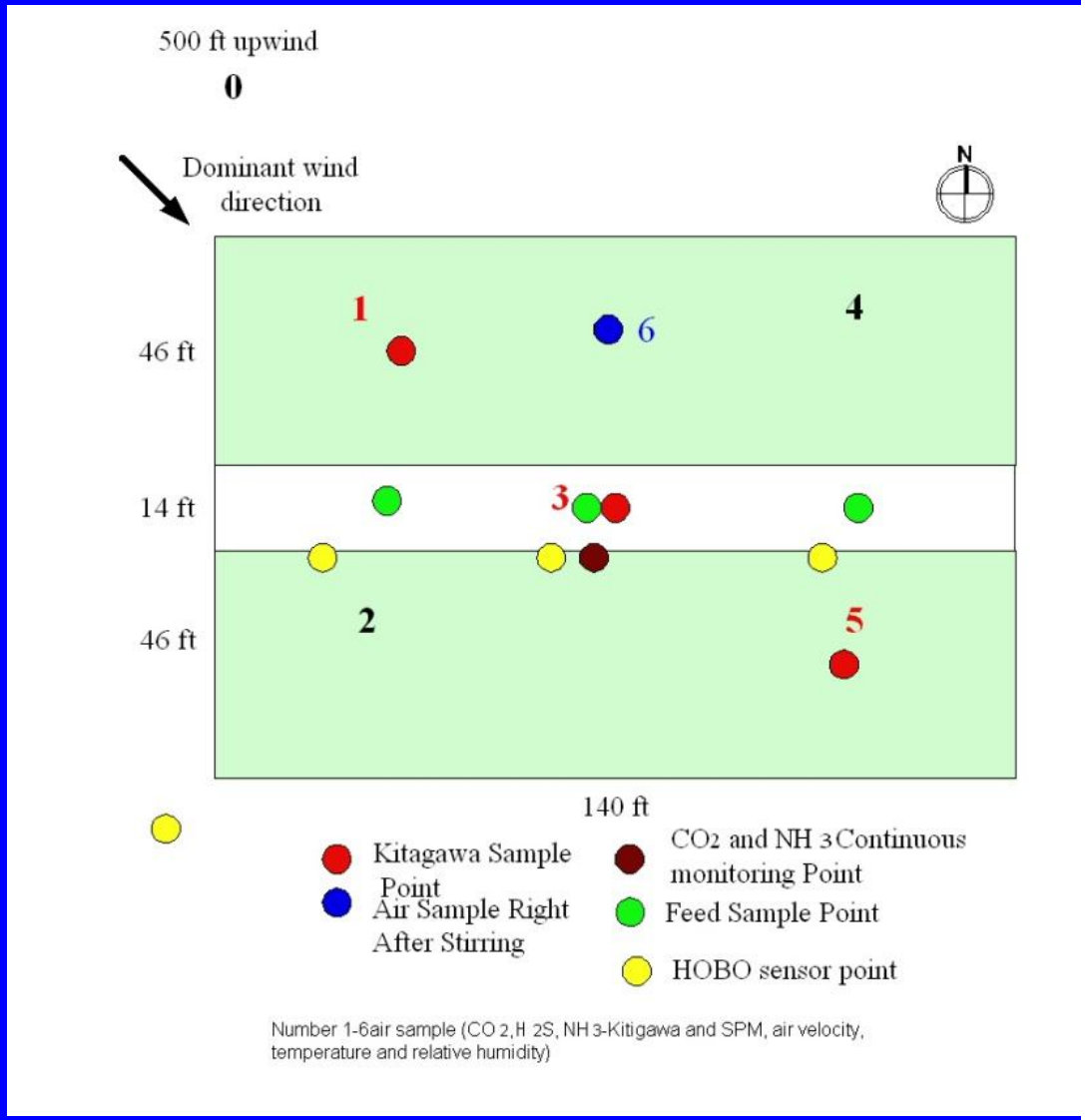
(6 short term seasonal measurement locations, 3 long term continuous measurement locations, 1 outdoor location for weather condition)

# Barn D-1, Zanesville, OH

- Compost barn began operations May 2006
- 160-170 heifers
- Cow spacing: 75 sq ft/cow
- Bedded area adjacent to feed alley

# Sampling Plan for Barn D-1

- 4 points for continuous T and RH measurement
- 5 points for gas concentration
- 3 points for verification of gas concentration
- 6 random points for compost bedding sampling

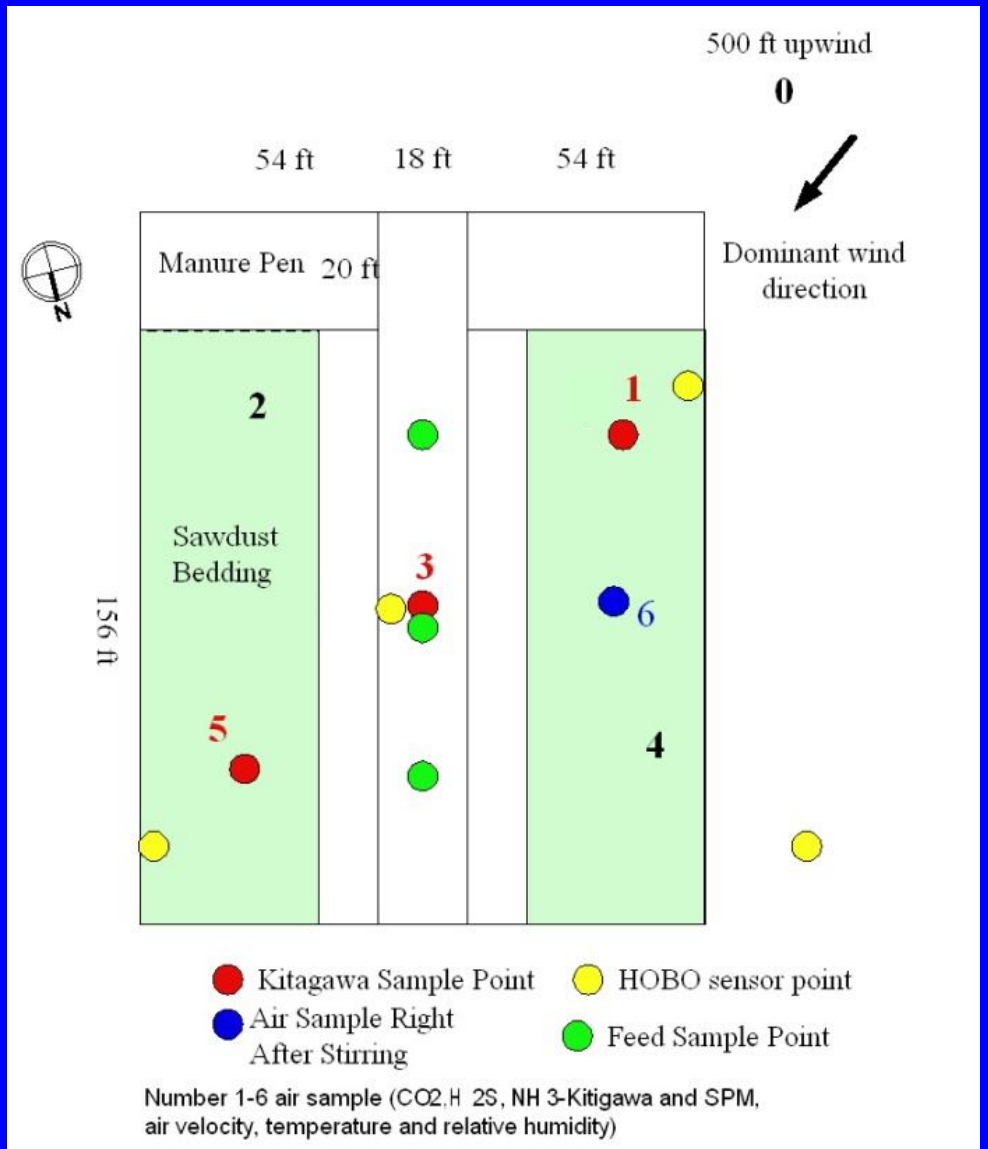


# Barn D-2, Millersburg, OH

- Operation started in Jan. 2008
- 150-160 Jerseys (on pasture spring-fall)
- Cow spacing: 88 sq ft/cow
- Feed alley and manure storage at the end of building

# Sampling Plan for Barn D-2

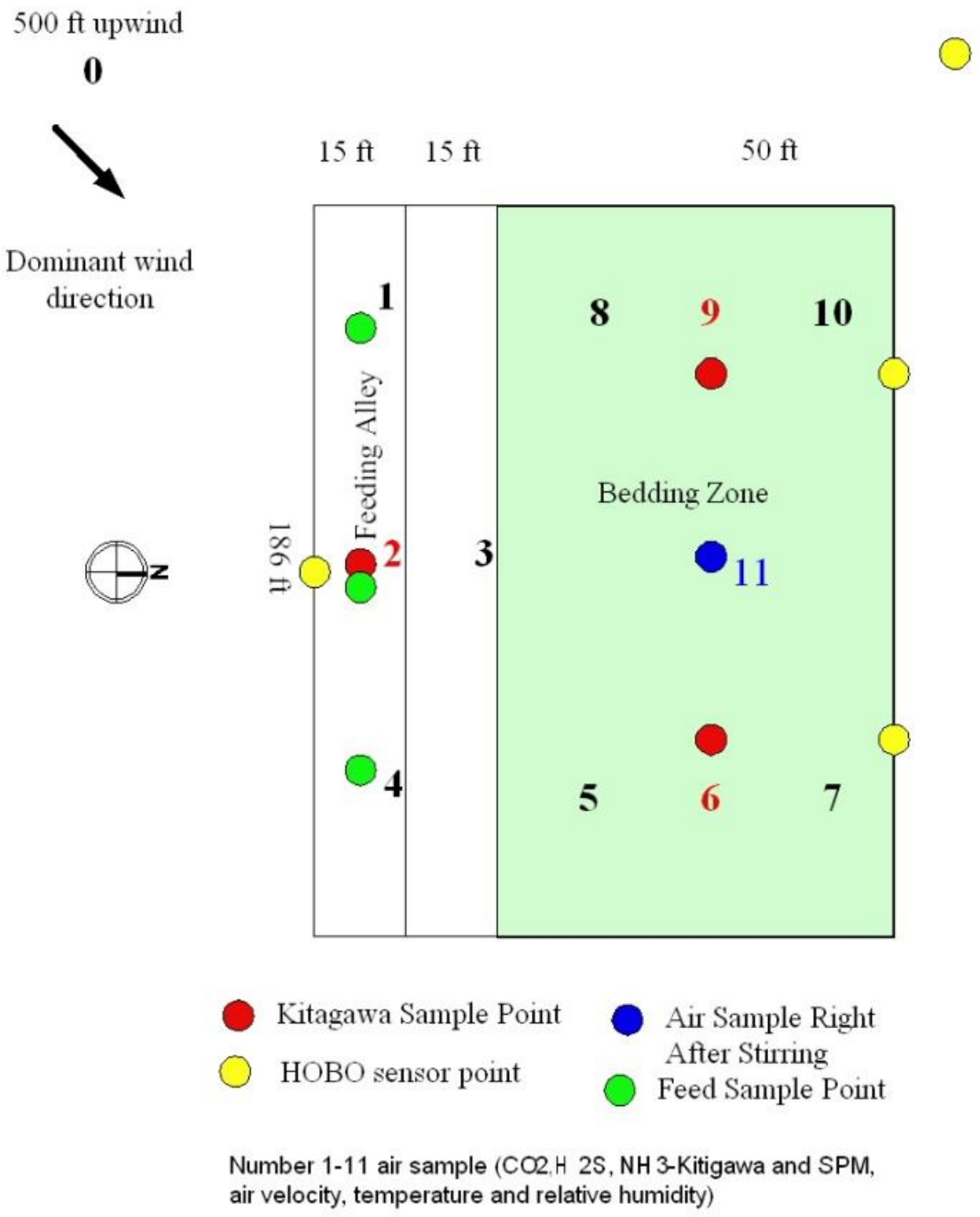
- 4 points for continuous T and RH measurement
- 5 points for gas concentration
- 3 points for verification of gas concentration
- 6 random points for compost bedding sampling



# Barn D-3, Lodi, OH

- Operation started in Nov. 2008
- 60-65 Holsteins
- Cow spacing: 90 sq ft/cow

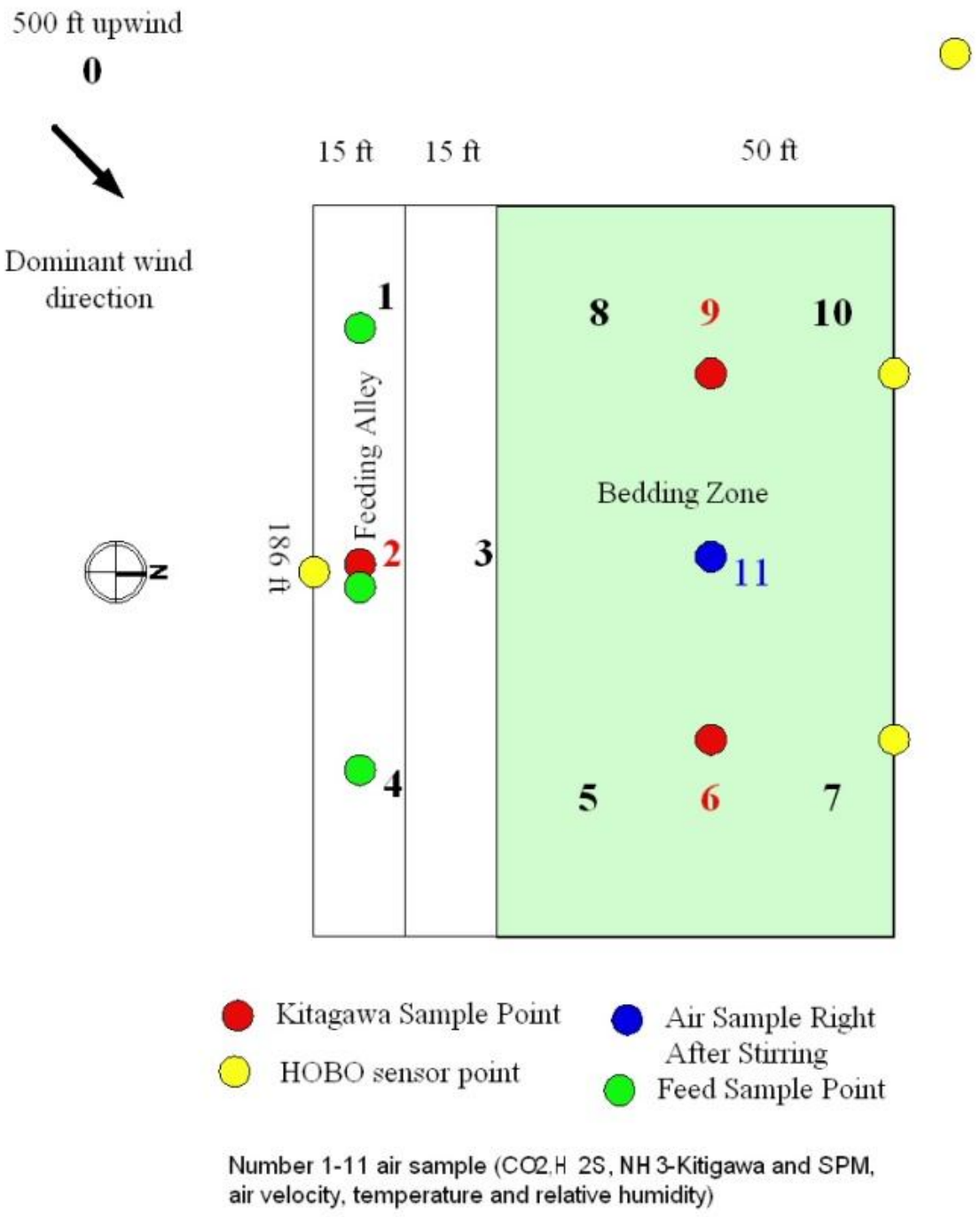
# Sampling Plan for Barn D-3



# Barn D-4, Mantua, OH

- Operation started in Dec. 2007
- 80-90 Holsteins-Jersey & Holstein-Jersey-Normandy crosses (on pasture spring-fall)
- Cow spacing: 80 sq ft/cow

# Sampling Plan for Barn D-4



# Indoor environment measurement

- Air velocity– TSI VELOCICALC®
  - 0-9999 fpm
  - 3% error
- Temperature- TSI VELOCICALC®
  - Range:  0 to 60°C (32 to 140°F)
  - Accuracy: ±0.6°C (±1.0°F)
  - Resolution: 0.1°C (0.1°F)
- Humidity- TSI VELOCICALC®
  - Range: 5% to 95% RH
  - Accuracy:  ±2.0% RH
  - Resolution: 0.1% RH
- Hobo Outdoor Air Sensors
  - Range of -35°C to 80°C
  - and 0 to 100% RH

Model 8386

# $CO_2$ measurement

- TSI-IAQ meter:
  - 0-5000 ppm
  - ±50 ppm or ± 3% of reading
  - Resolution:1 ppm
- Matheson-tri-gas Kitagawa tubes
  - Accuracy: 5 to 15%

# Ammonia ($NH_3$) measurement

- SPM:
  - Range: 0-30 ppm
  - Resolution: 0.5 ppm
- Matheson-tri-gas Kitagawa tubes
  - Accuracy: 5 to 15%


# Hydrogen sulfide ($H_2S$) measurement

- Jerome H2S analyzer 631-X
  - Range: 0.001 to 50 ppm
  - Resolution: 0.003 ppm
  - Accuracy:
    ±0.003 ppm at 0.05 ppm
    ±0.03 ppm at 0.5 ppm
    ±0.3 ppm at 5 ppm
    ±2 ppm at 25 ppm
- Matheson-tri-gas Kitagawa tubes
  - Accuracy: 5 to 15%

# OT-21 Temperature and $O_2$ Probe for Bedded Pack

- Oxygen measurement range is 0-22%
- Temperature range is -18 ºC - +100 ºC
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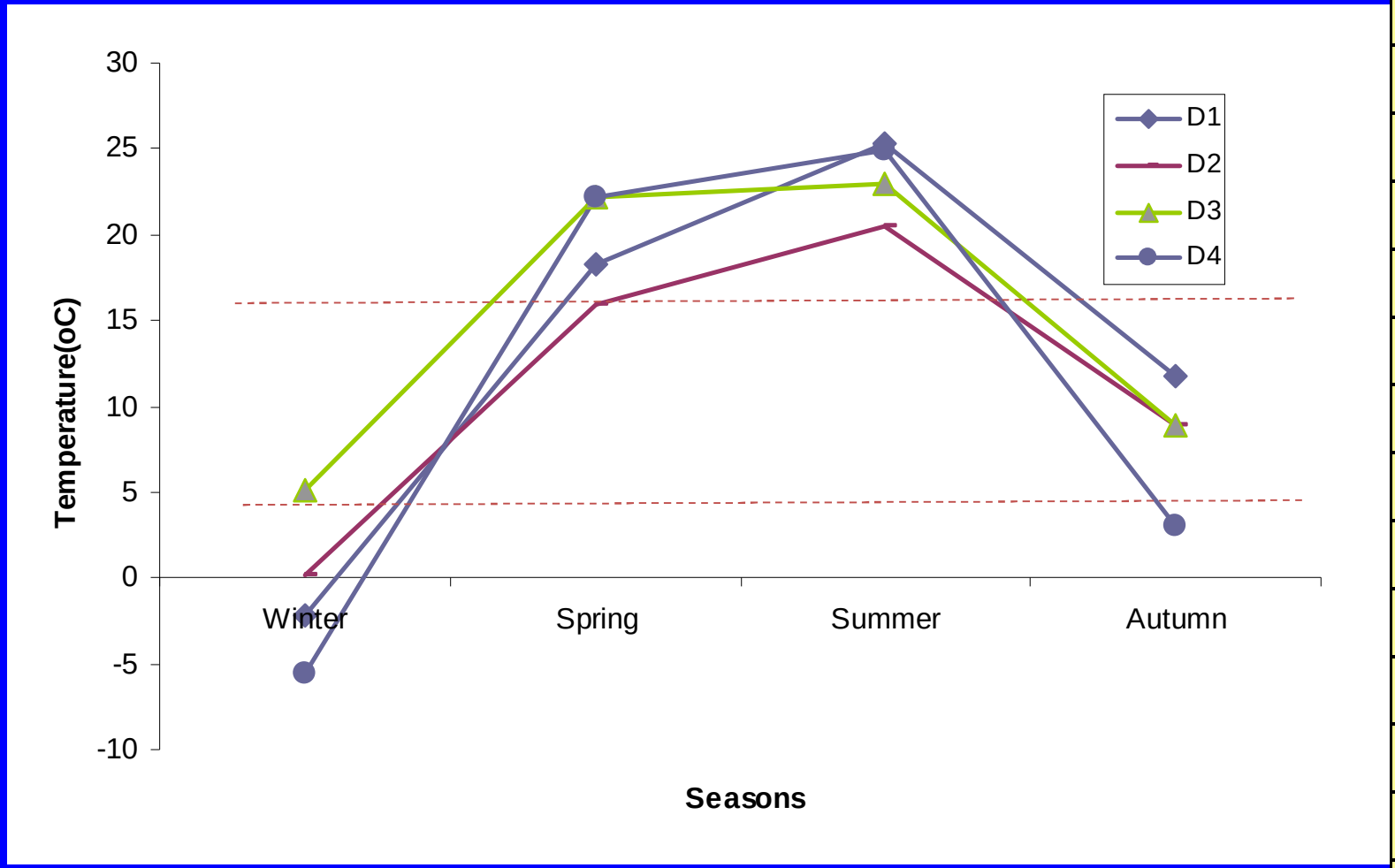
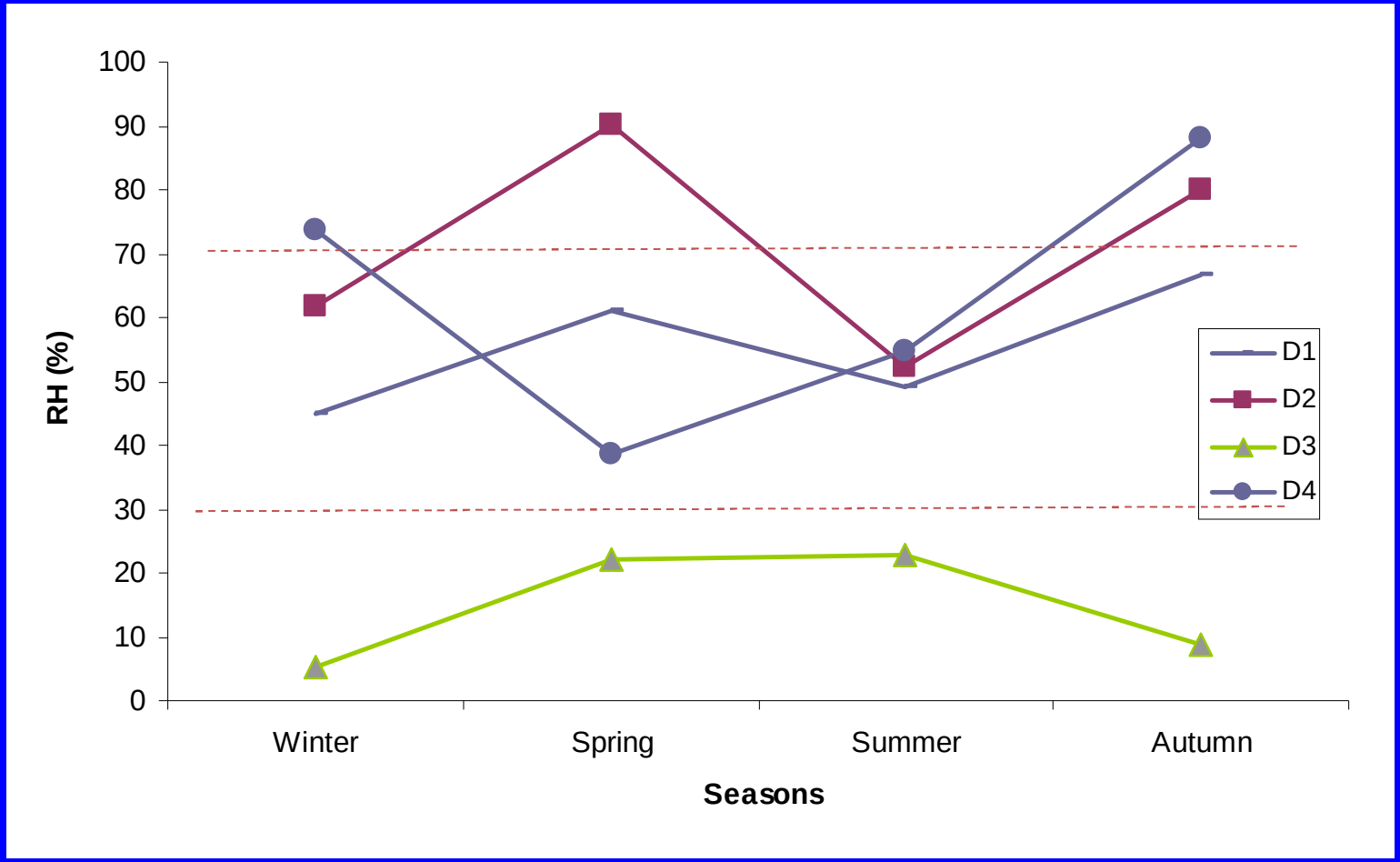
# Temperatures in the Barns

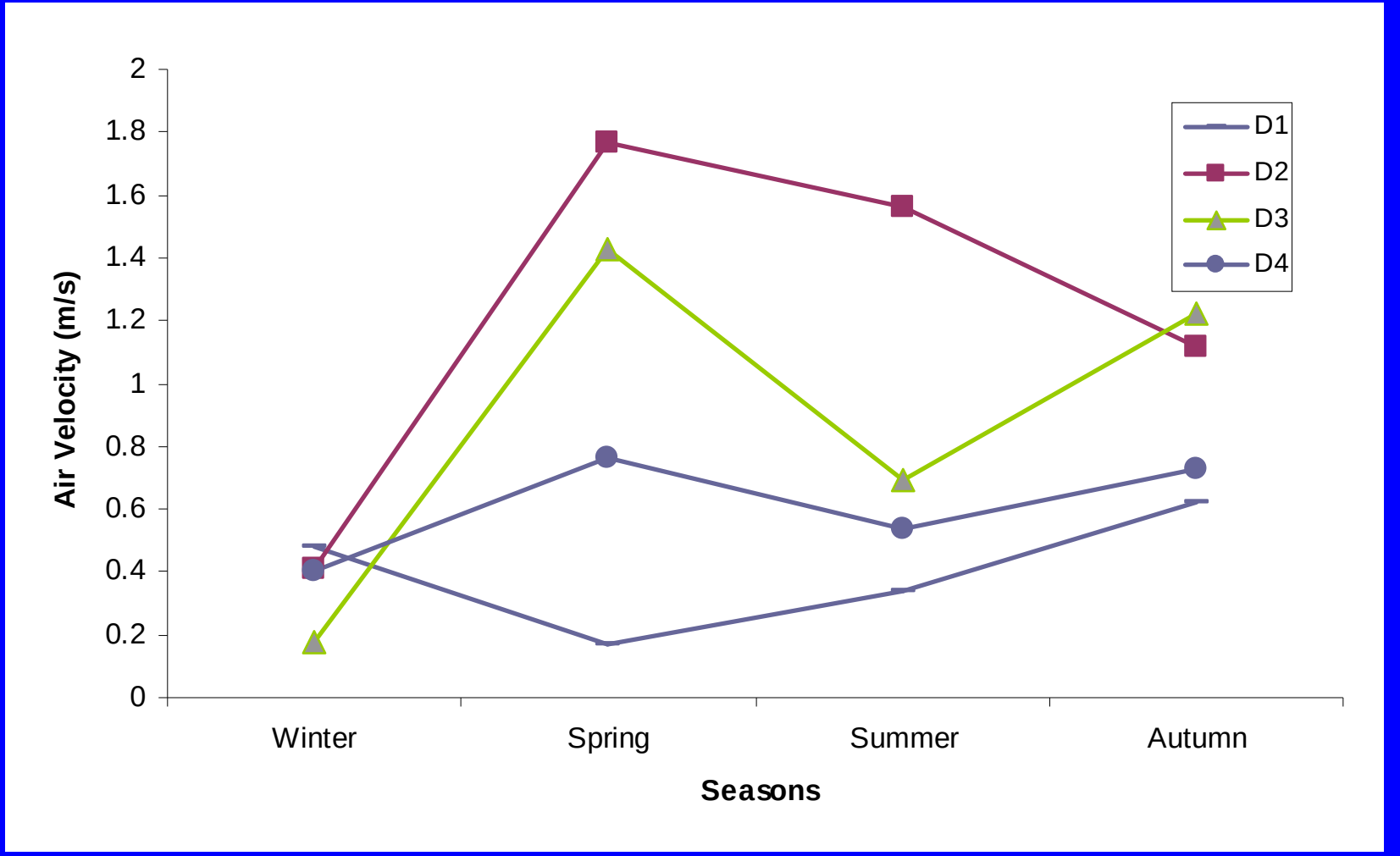



| °F | °C |
|---|---|
| 79 | 26.1 |
| 77 | 25.0 |
| 75 | 23.9 |
| 73 | 22.8 |
| 71 | 21.7 |
| 69 | 20.6 |
| 67 | 19.4 |
| 65 | 18.3 |
| 63 | 17.2 |
| 61 | 16.1 |
| 59 | 15.0 |
| 57 | 13.9 |
| 55 | 12.8 |
| 53 | 11.7 |
| 51 | 10.6 |
| 49 | 9.4 |
| 47 | 8.3 |
| 45 | 7.2 |

# Relative Humidity (RH) in the Barns



# Air Velocity in the Barns

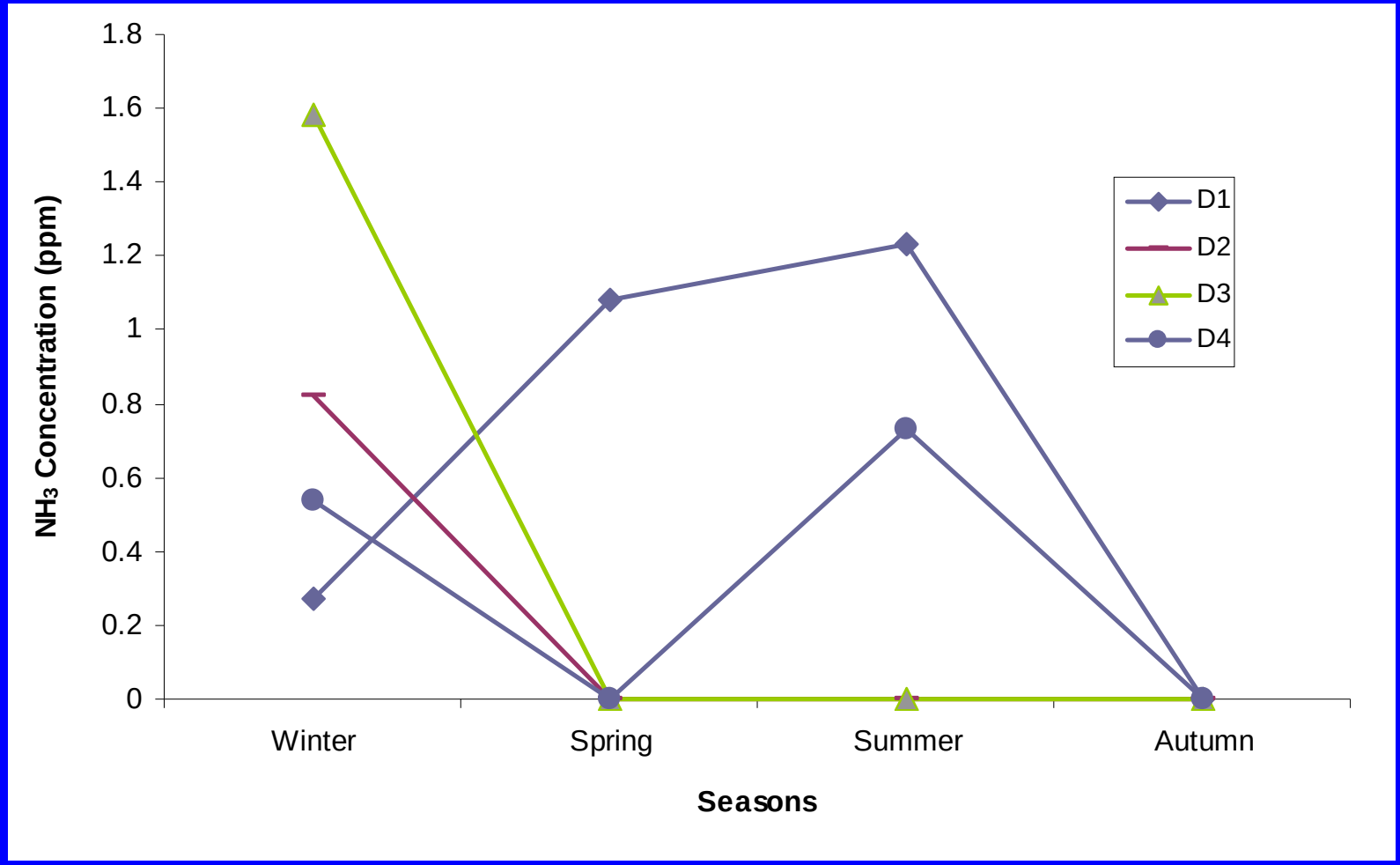


# Thermal Environment in the Barns

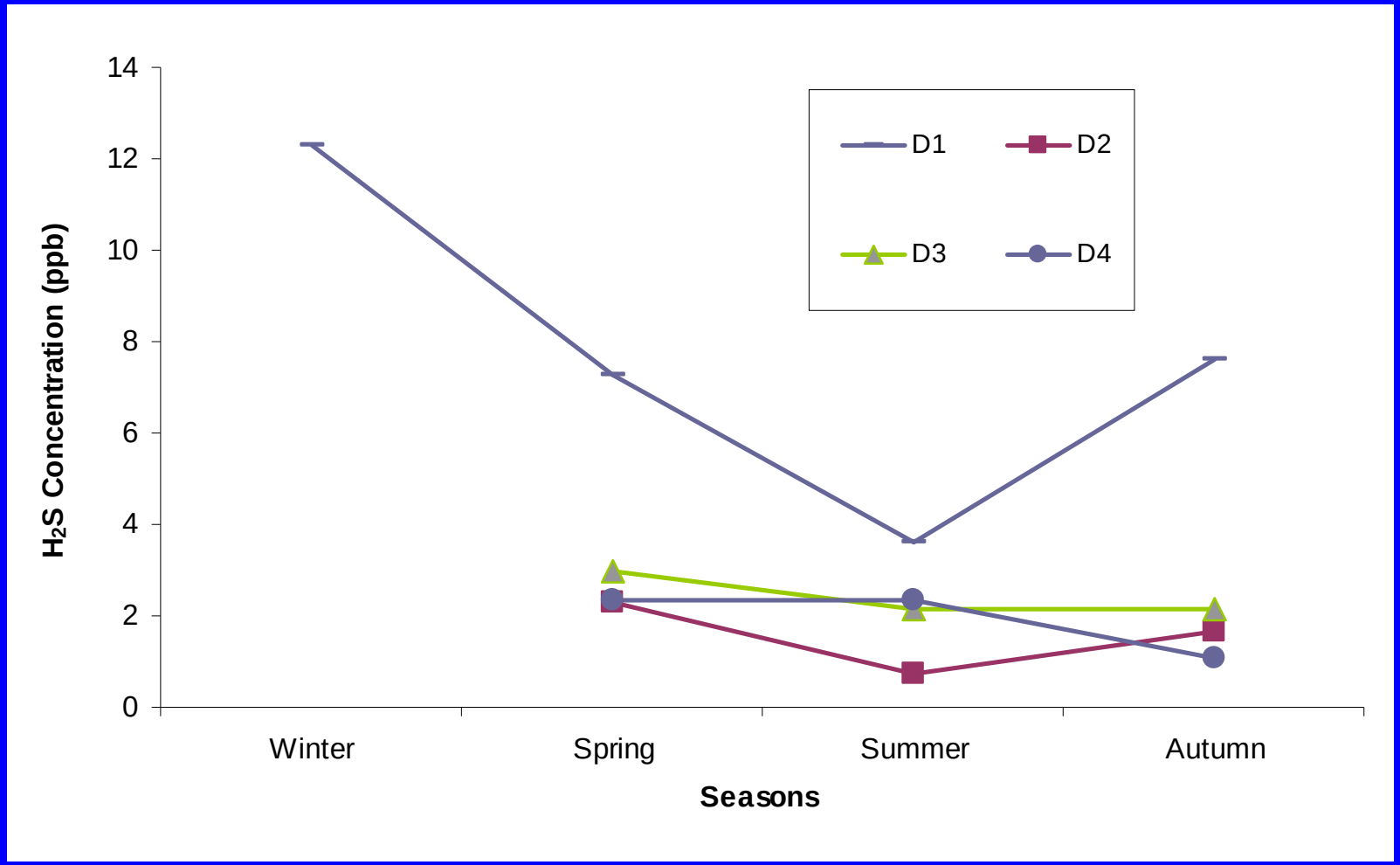
| Parameters | Values | Cow Comfort Zone |
|---|---|---|
| Temperature (mean) | 28 – 78 °F (-2-26 °C) | 40-60 °F (4-16 °C) |
| Relative humidity (mean) | 35 – 90% | 30-70% |
| Air velocity (mean) | 0.2 – 1.8 m/s | n/a |

- Temperatures in naturally ventilated dairy barns follow weather changes
- In cold winter, the barn temperature is below the cow comfort zone
- In hot summer, the temperature is above the cow comfort zone, cooling fans are needed.

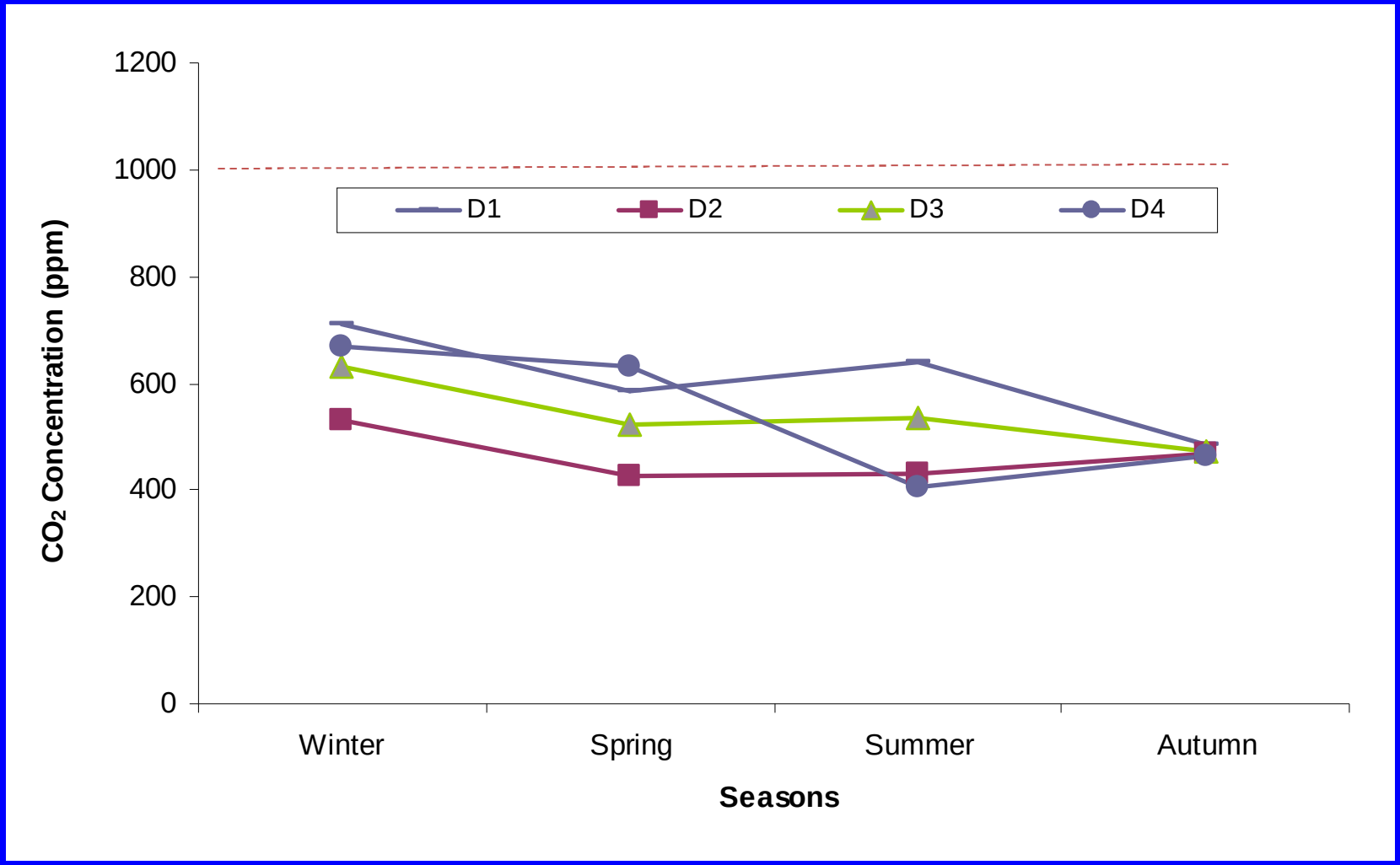
# $NH_3$ Concentrations in the Barns



# $H_2S$ Concentrations in the Barns



# $CO_2$ Concentrations in the Barns



# Summary of Air Quality in the Barns

| Air Quality Parameters | Values | OSHA | NIOSH |
|---|---|---|---|
| Carbon dioxide | 400 – 700 ppm | 5000 ppm | 5000ppm |
| Ammonia | 0 – 1.6 ppm | 50 ppm | 25 ppm |
| Hydrogen sulfide | 1 – 12 ppb | 20 ppm | 10ppm |

- No air quality concerns.
- The nature ventilation is adequate for dairy barn air quality control.

# Indoor air quality and environment of a free-stall dairy barn with liquid manure management system

| | March | | June | | August | | Annual average |
|---|---|---|---|---|---|---|---|
| | Ave. | Std. | Ave. | Std. | Ave. | Std. | |
| Odor ($OU/m^3$) | 105 | 20 | 79 | 16 | 117 | 27 | 100 |
| $CO_2$(ppm) | 465 | 85 | 449 | 55 | 513 | 104 | 476 |
| $NH_3$ (ppm) | 2.1 | 0.5 | 3.0 | 1.3 | 1.4 | 1.0 | 2.2 |
| $H_2S$ (ppm) | 0.004 | 0.007 | 0.012 | 0.011 | 0.031 | 0.030 | 0.016 |
| PM Mass ($mg/m^3$) | 0.910 | 0.010 | 0.755 | 0.044 | 1.527 | 0.117 | 1.064 |
| T ($^oF$) | 53 | 1.6 | 78.3 | 1.0 | 85.5 | 1.0 | 72 |
| RH (%) | 79.3 | 5.4 | 54.3 | 1.707 | 56.6 | 3.7 | 63 |
| Air Velocity (m/s) | 0.44 | 0.36 | 1.40 | 0.65 | 1.12 | 0.66 | 0.99 |

# Conclusions and Suggestions

- The air quality in the compost bedded pack diary barns was good.
- Because of natural ventilation, the indoor environment of the dairy barn are out of the cow comfort zone in Winter and Summer.
- Cooling fans are need in warm months.
- The indoor air quality and thermal environment of the compost bedded dairy barns are comparable with that of the free-stall dairy barns with liquid manure management systems.

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# Thank you.
# Any questions?


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