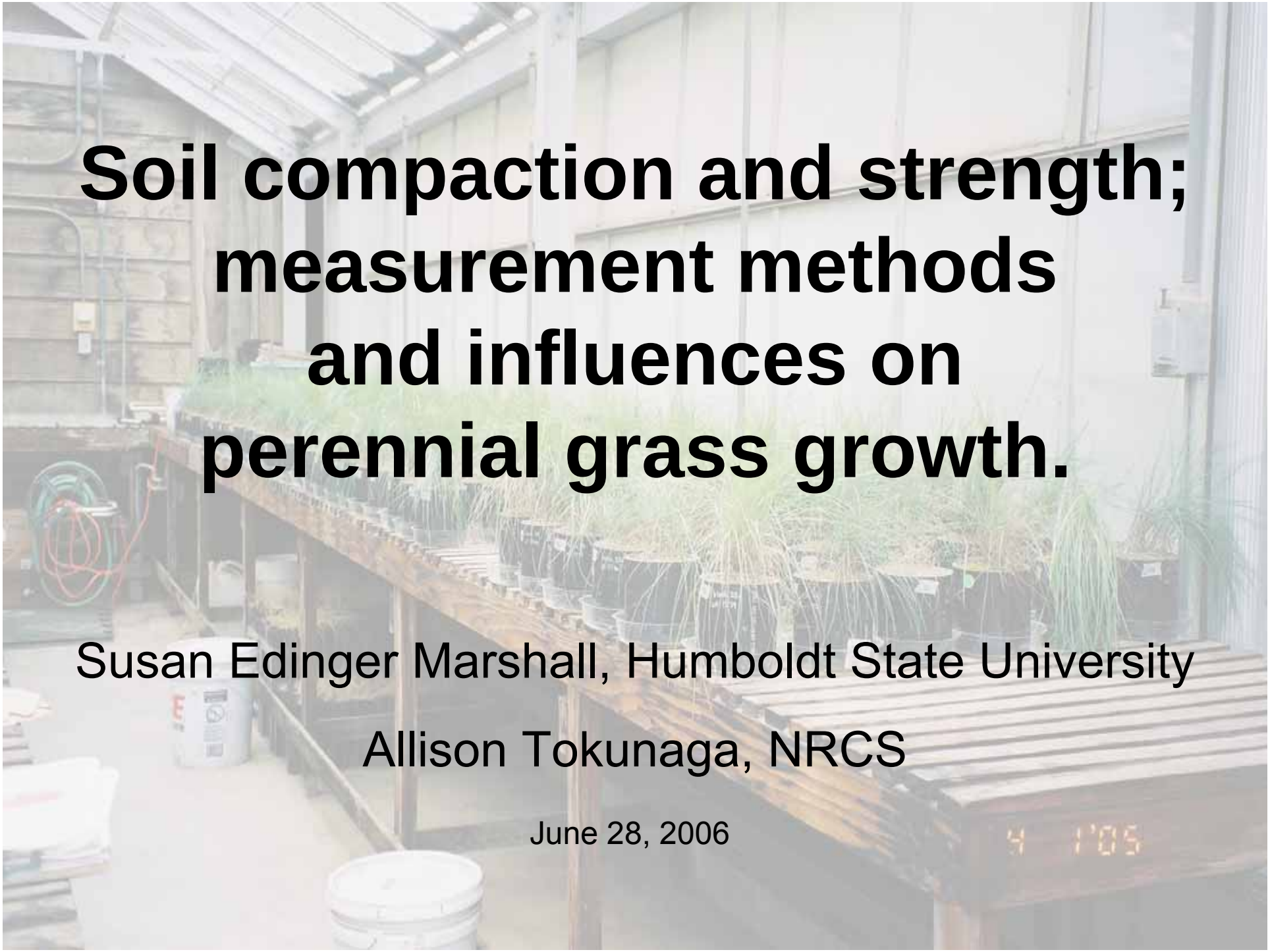

Soil compaction and strength; measurement methods and influences on perennial grass growth.

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Outline

- Definitions
- Limits to plant growth
- Tokunaga's study; Methods &Results
- Discussion

Source: USDA-NRCS Plant Materials Program

Soil Compaction

- Increasing the soil bulk density, and concomitantly decreasing the soil porosity, by the application of mechanical forces to the soil. (SSSA)
- Commonly expressed as g/cm^3 (or lbs/ft^3)

Direct measure of soil compaction - Bulk Density (Db)

- The mass of dry soil per unit volume
- <2 mm fraction of soil, no coarse fragments

Soil Strength
Penetration Resistance (PR)

- Capacity of a soil to resist a force without rupture, fragmentation, or flow
- Resistance to penetration by roots
- Affected by several factors, including soil moisture (lubrication)

Limits to plant growth

Root limiting bulk densities…

- Compaction studied most often in agriculture
- Taproot species or C_4 (warm-season) grasses
- Root-limiting bulk densities…
  - 1.5 g cm^{-3} fine textures
  - 1.9 g cm^{-3} coarse textures
  - No single critical bulk density apparent in literature

Limits to plant growth, cont.

Root-limiting soil strength…

- 2.5 to 3 MPa (363 to 435 psi)
- 6 to 7 MPa (coarse soils)
- Strength varies with both bulk density and water content – in rangelands it may vary with season
  e.g., denser and drier = increased strength

Limits to plant growth, cont.

Besides physical root impedance, compaction can lead to…

- Decreased infiltration
- Slower water and gas movement
- Typically the uppermost 10 cm tend to be compacted by grazing animals (compared to deeper seated compaction by heavy equipment, glaciers,etc.)

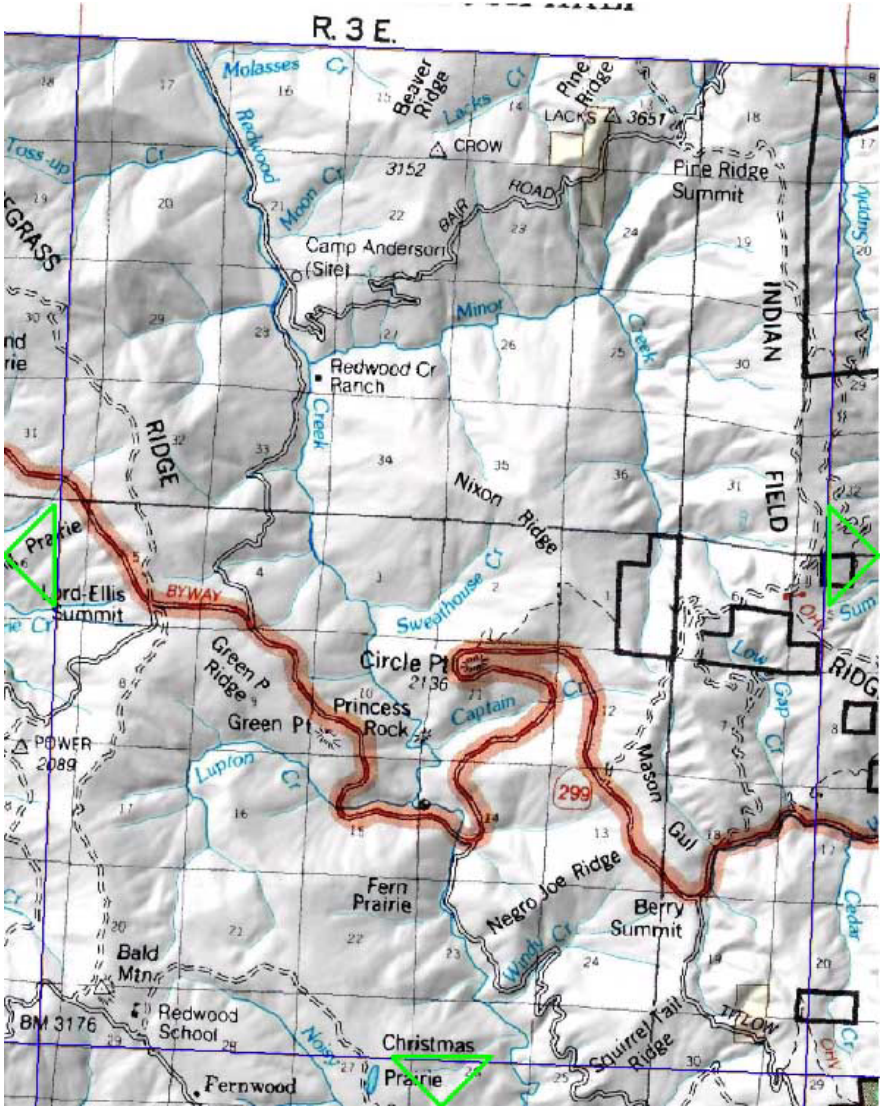
Tokunaga's Research Questions (M.S. thesis at HSU)

- How does root and shoot biomass production vary over a range of bulk density and soil strength?

- Is there a threshold bulk density and/or soil strength that limits biomass production of roots and/or shoots?

Study Site

- Nixon Ridge
- Annual vegetation
- Blue wildrye
- Oak woodland
- Grazed



Greenhouse Methods

- Surface soil collected from Nixon Ridge and sieved to <2 mm
- 3 bulk densities
  - "loose" = 1.00 g cm^{-3} (gopher mounds and/or high litter content)
  - "medium" = 1.25 g cm^{-3}
  - "dense" = 1.55 g cm^{-3} (previous studies)
  - Compacted using ASTM protocols

Greenhouse Methods cont.

- 3 water potentials
  - “wet” = -33 kPa (field capacity)
  - “moist” = -500 kPa (moderate water stress)
  - “dry” = -1500 kPa (permanent wilting point)
  - Maintained 3 days a week

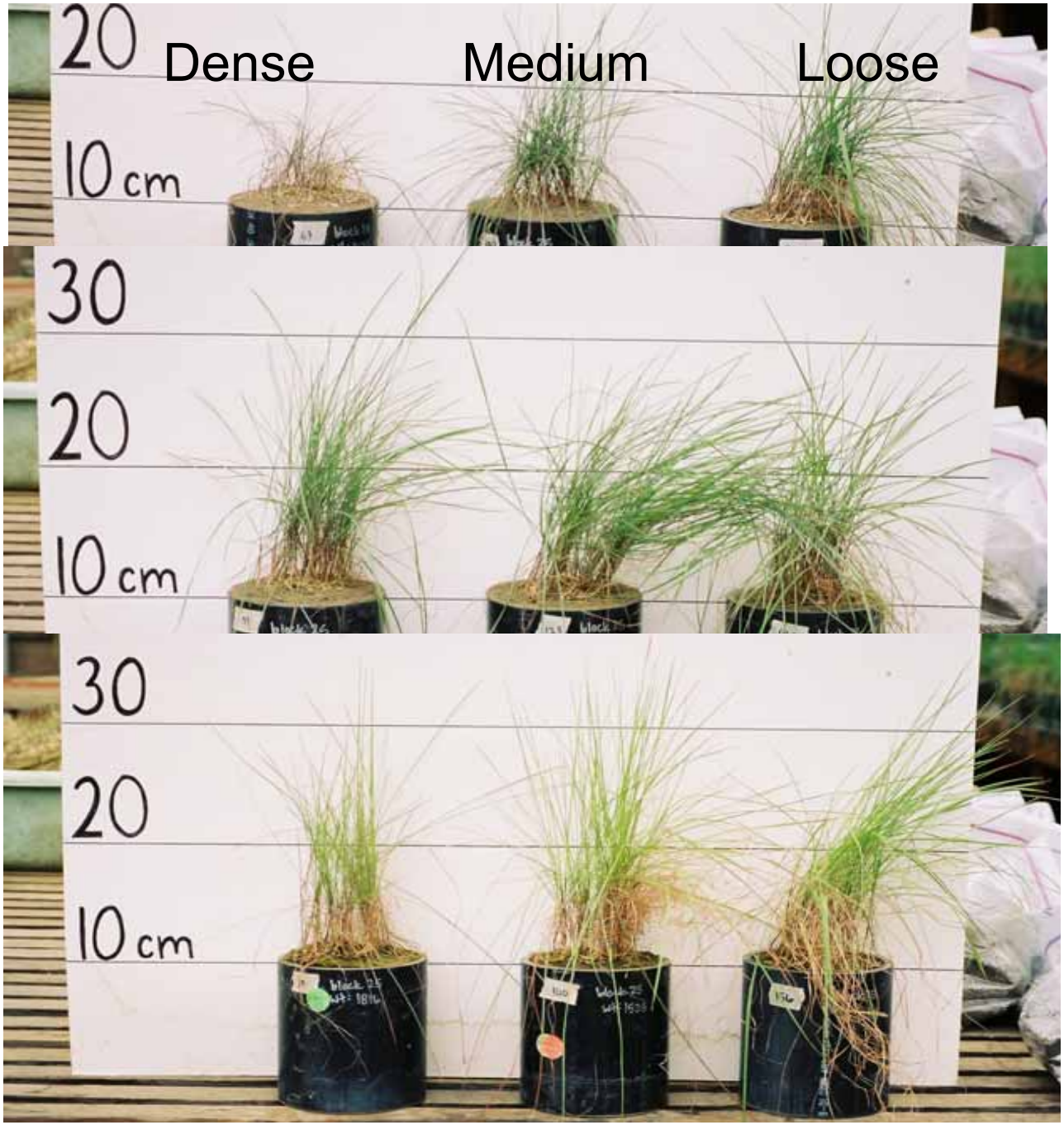
Greenhouse set-up

about 4 months growth of Blue Wildrye (perennial, cool season),
rotated and watered 3x week, randomized weekly
n=25 for each Db/moisture combination

Dry

Moist

Wet



Greenhouse Variables

- Shoot biomass→ clipped and dried
- Root biomass→ washed and dried
- Soil strength→ penetrometer

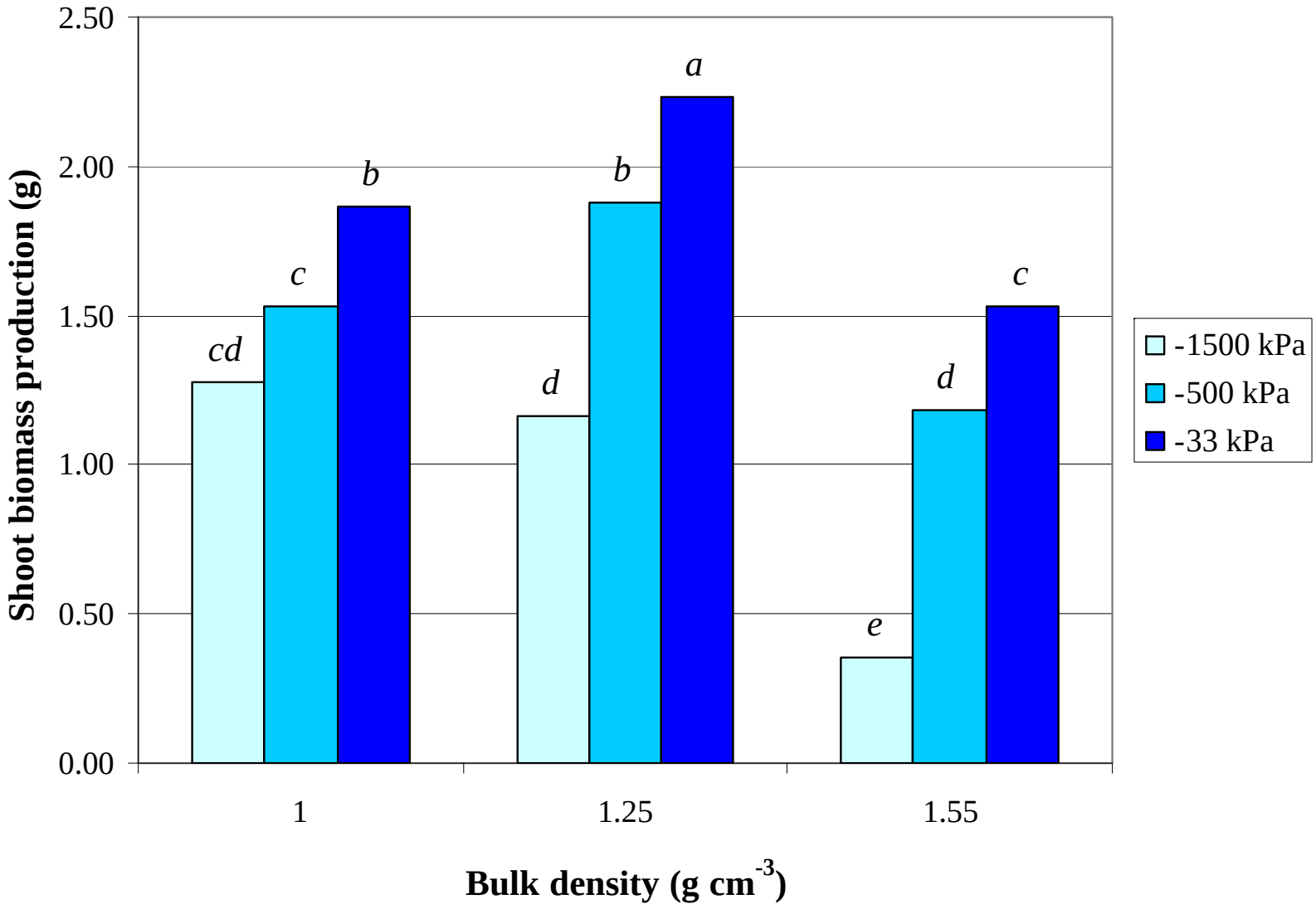
  hydraulic press
- Root depth→ split core

RESULTS

- Different letters (a, b, c) indicate significant differences at p=0.05 using Analysis of Variance

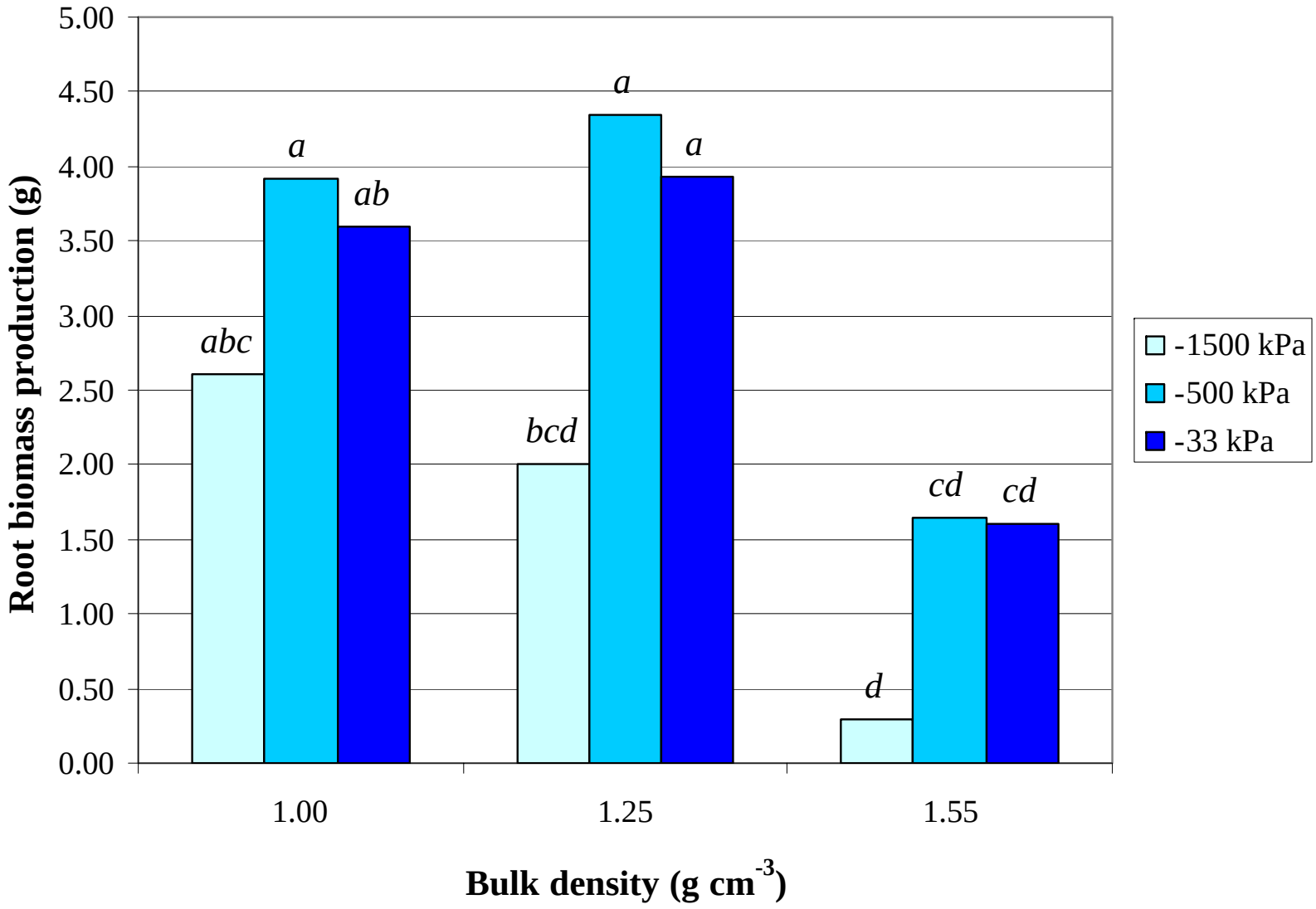
Shoot Biomass

n = 25

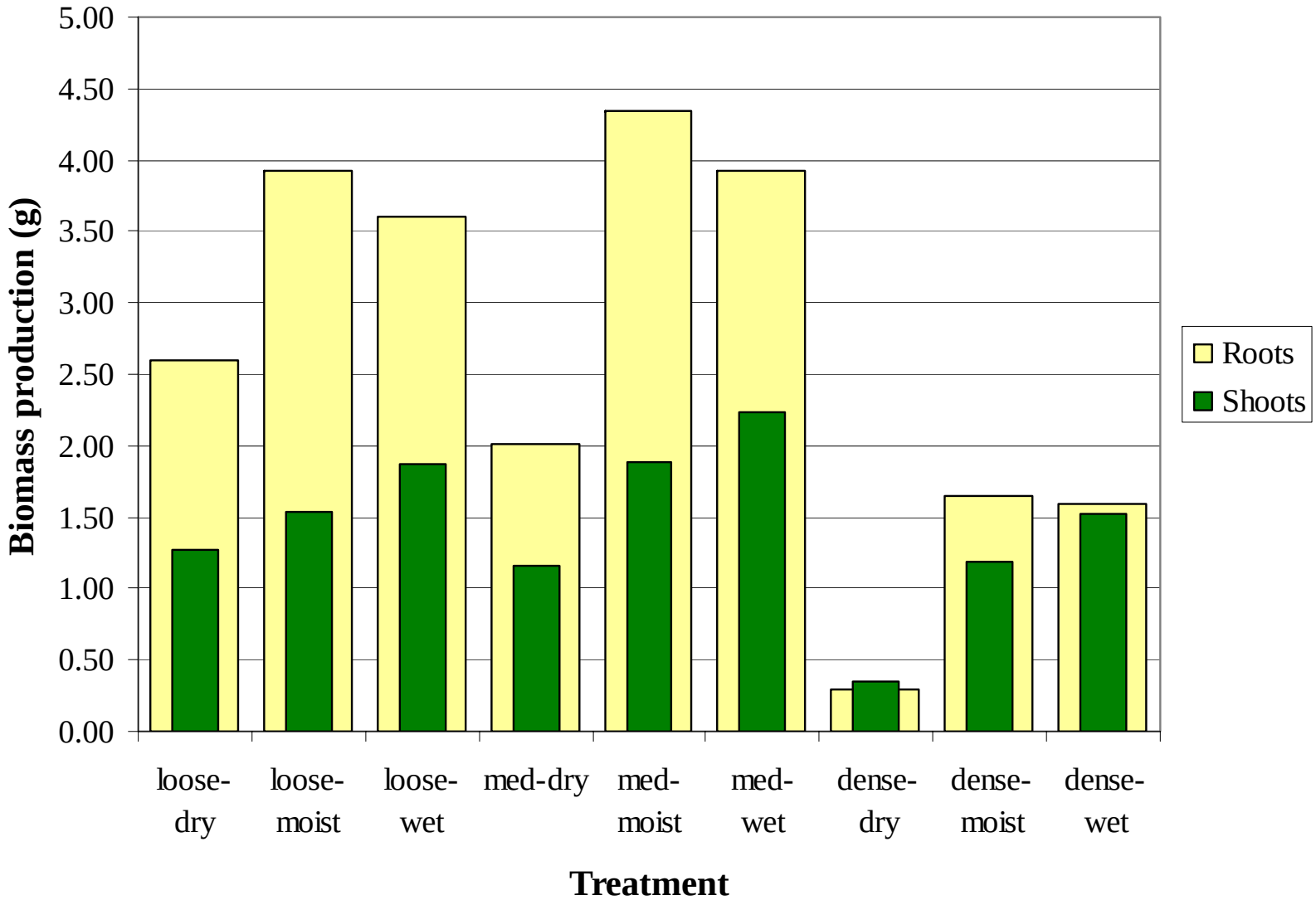


Root Biomass

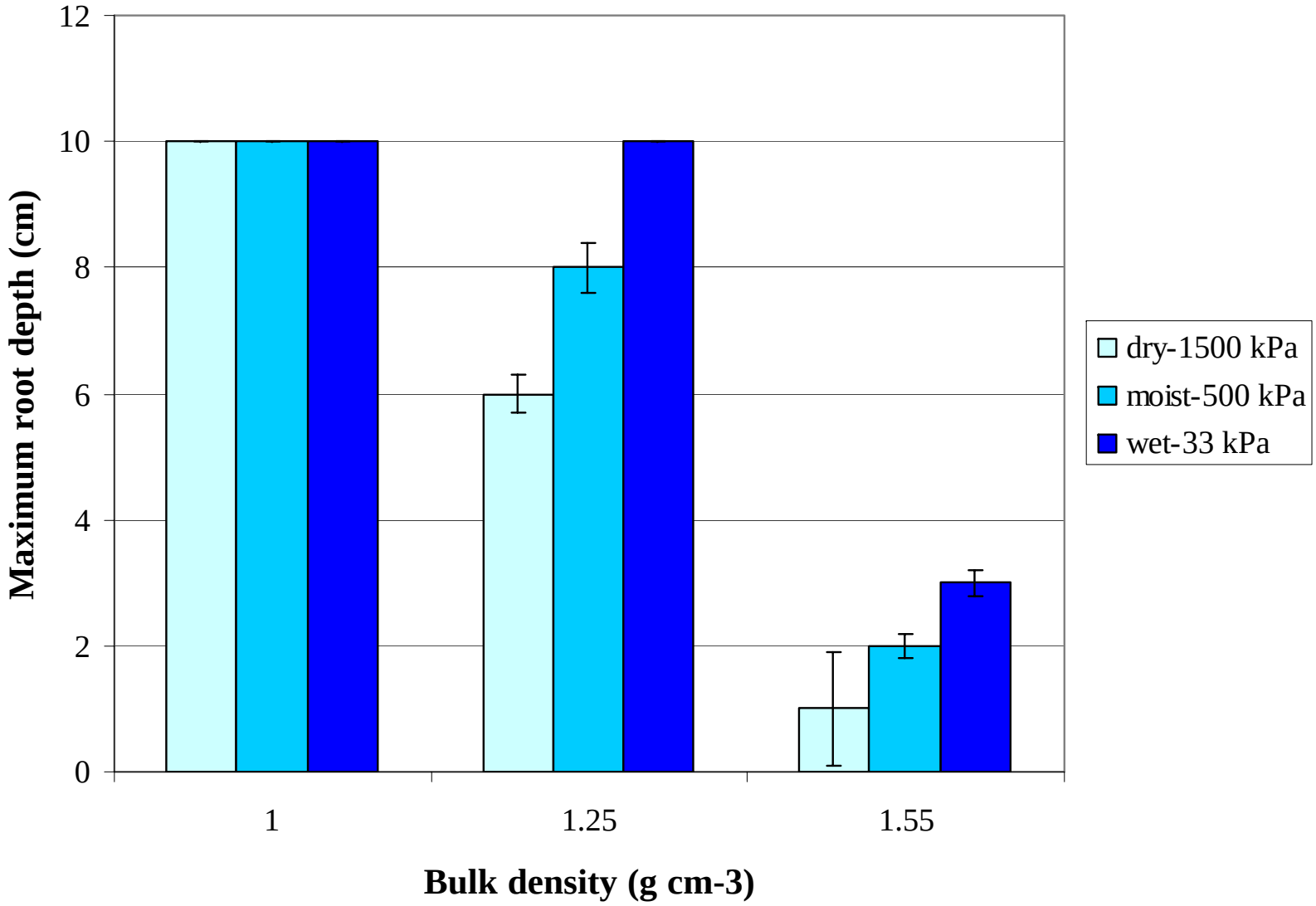
n = 9



Roots and Shoots

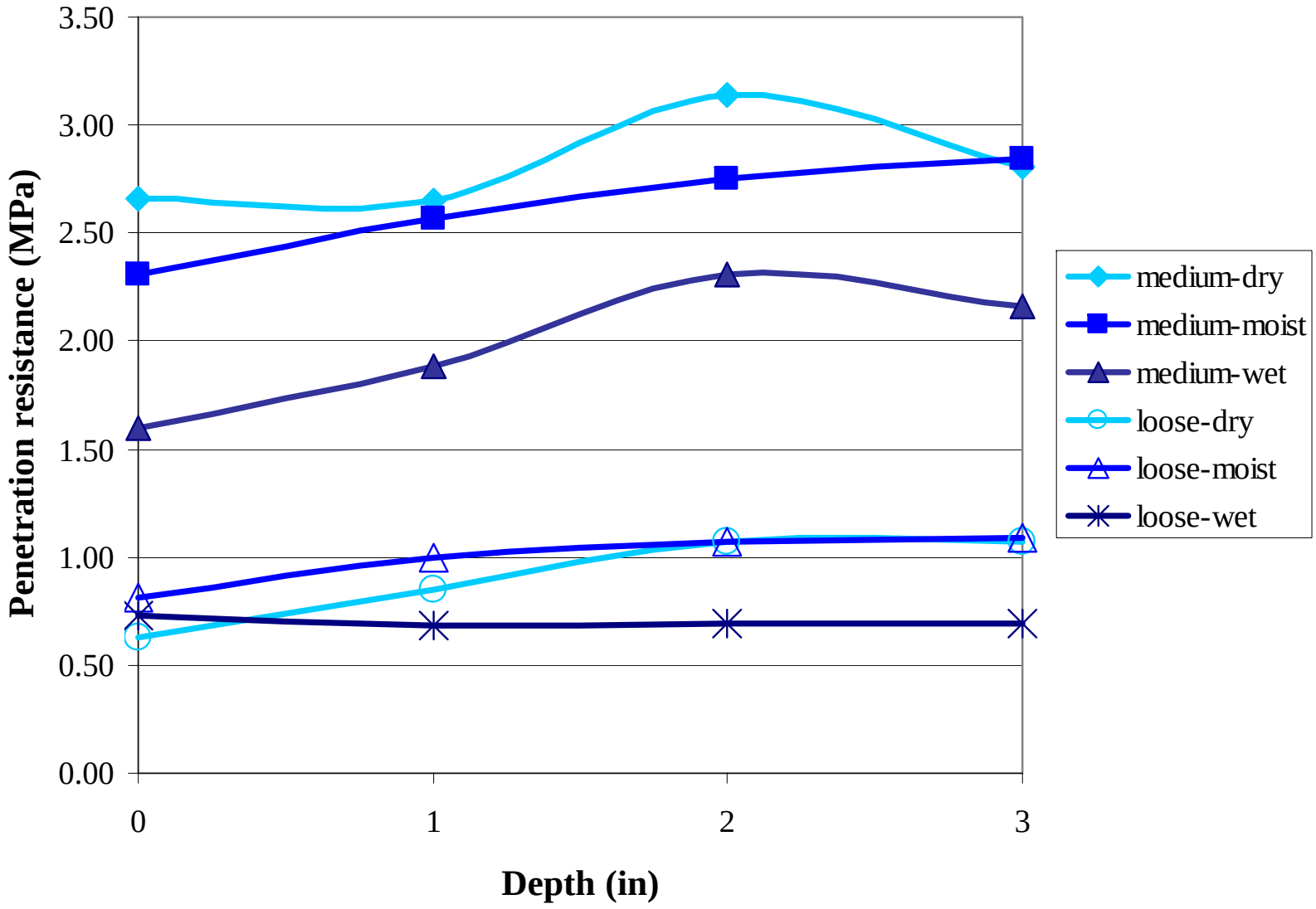


Maximum Root Depth



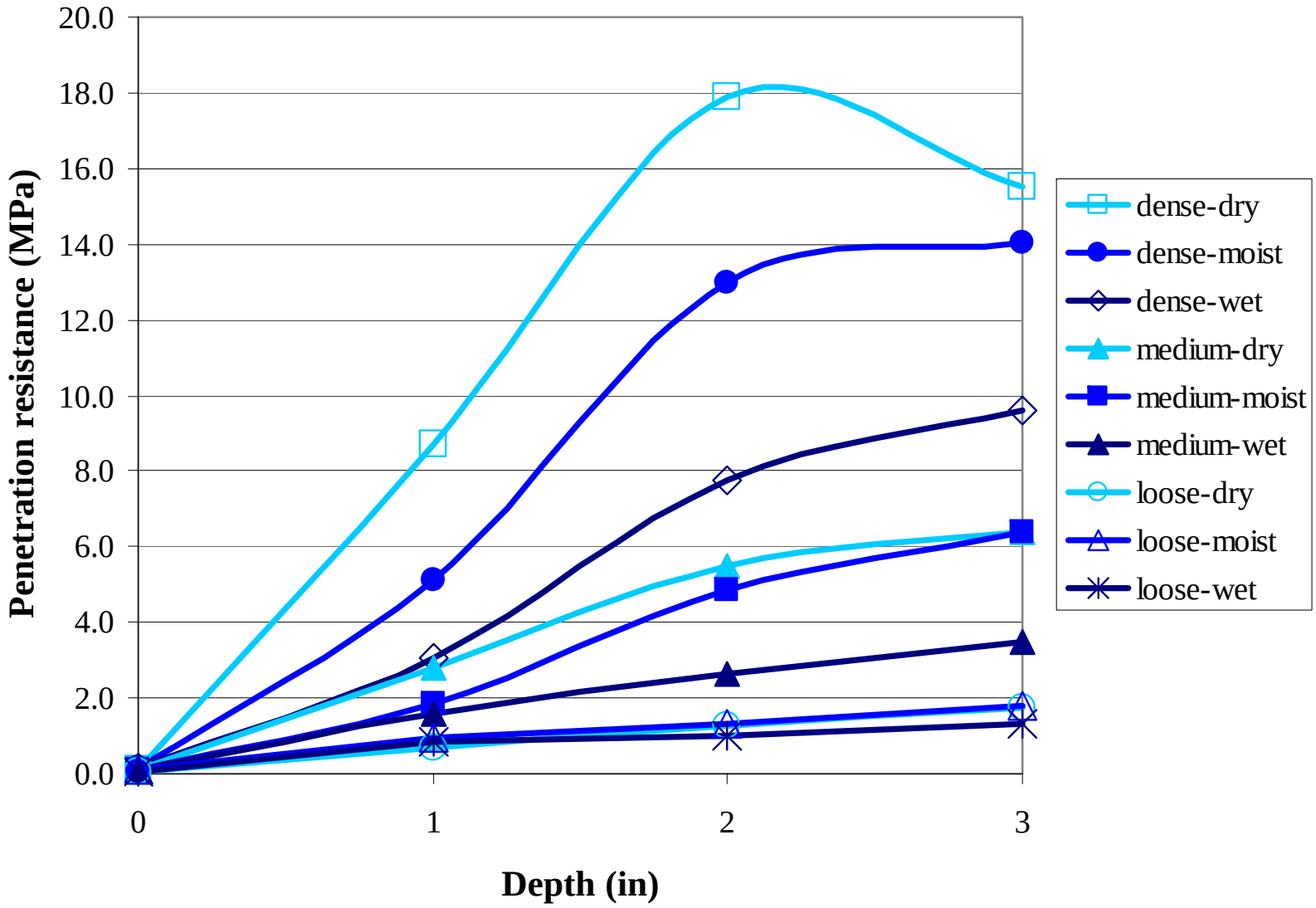
PR—Penetrometer

n = 21



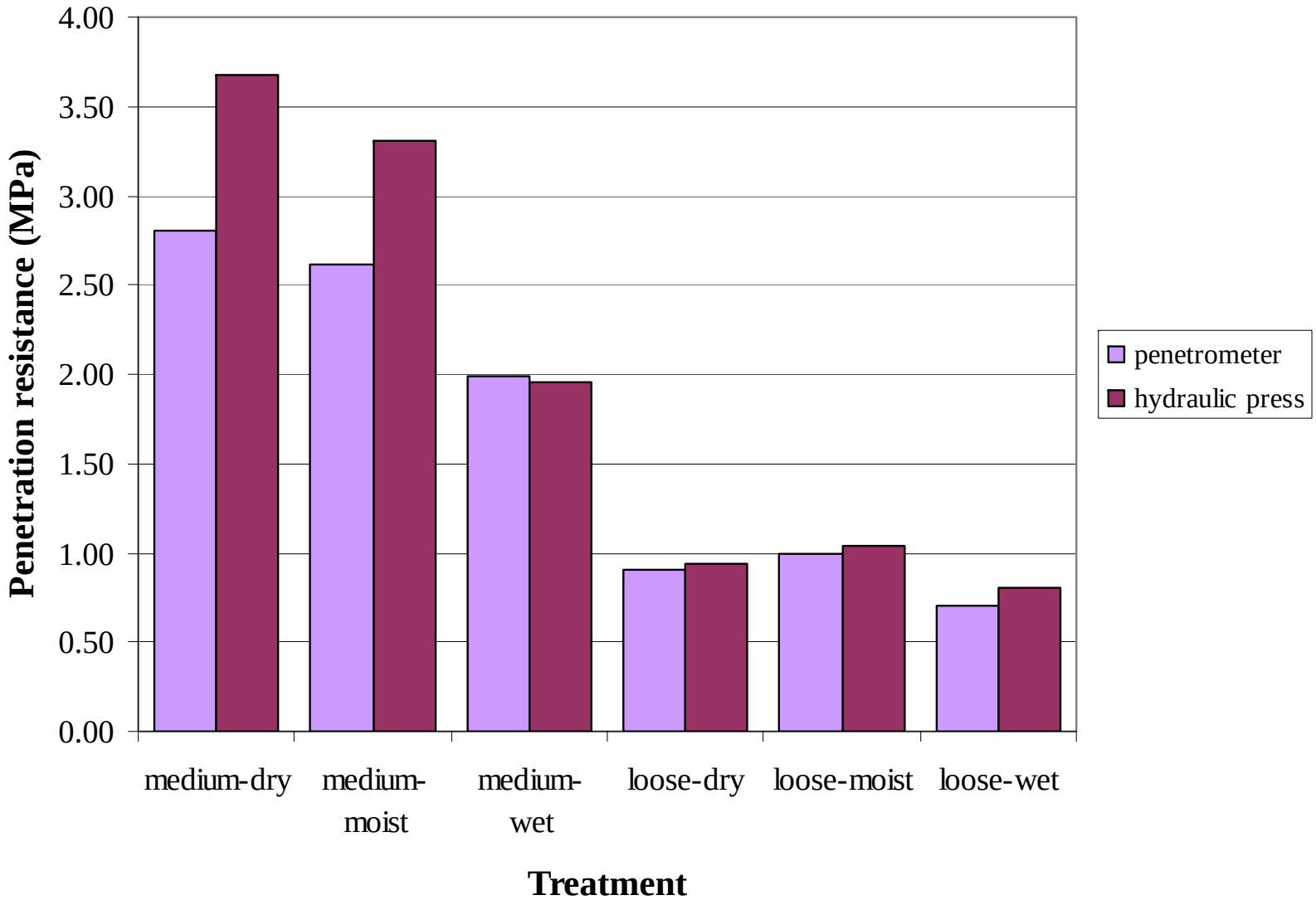
PR—Hydraulic Press

n = 4

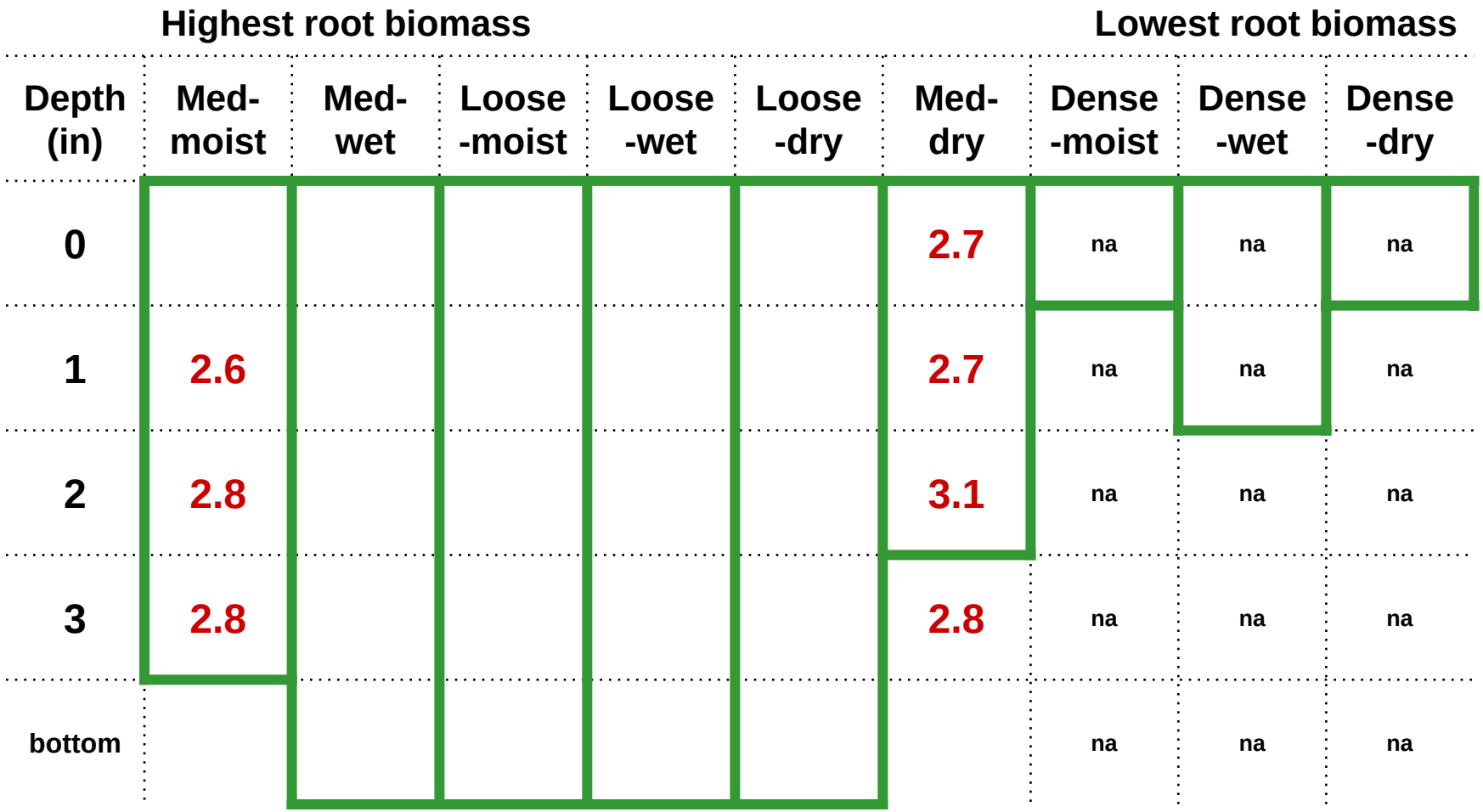


Discussion

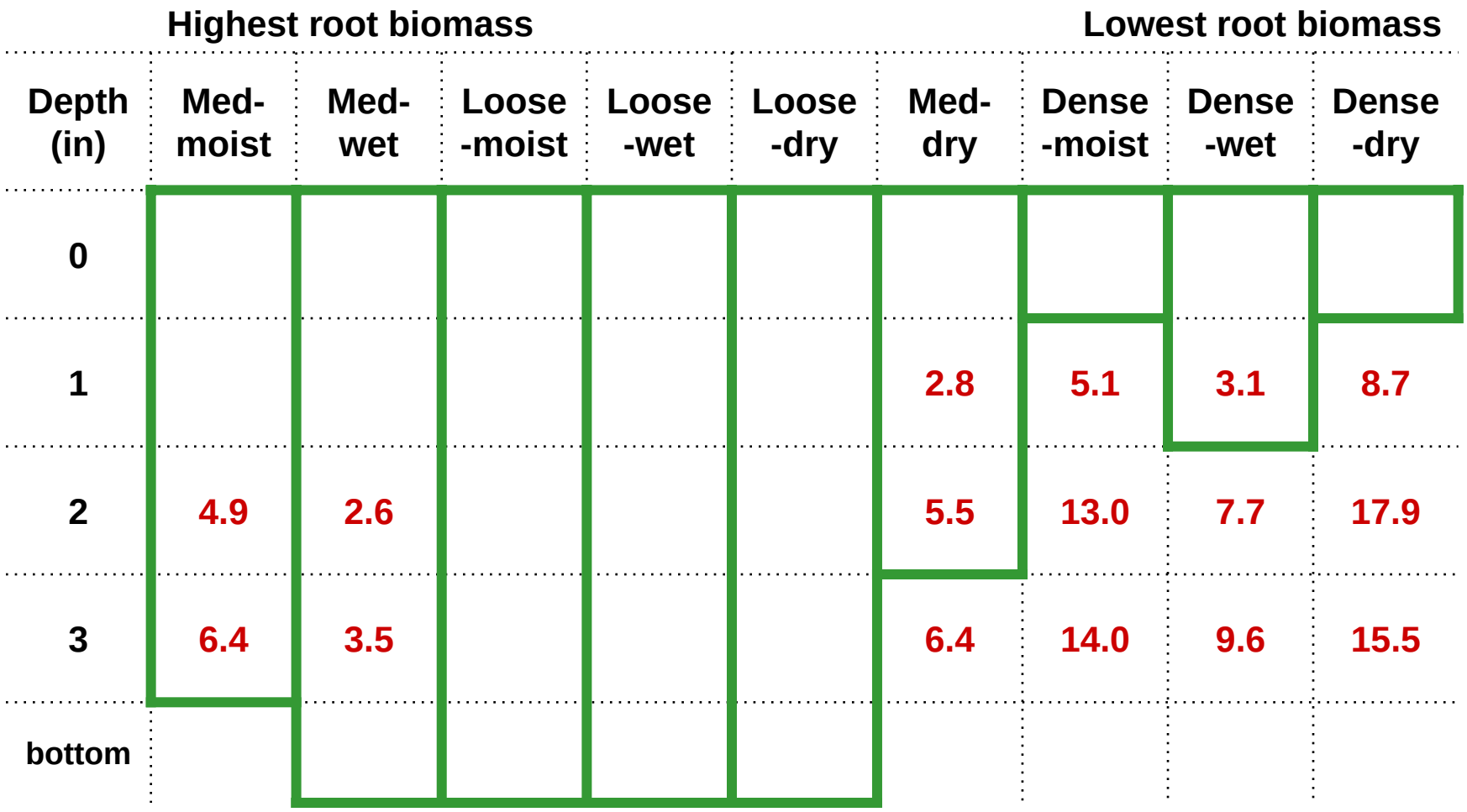
Soil Strength Methods



PR and Roots—Penetrometer



PR and Roots—Hydraulic Press



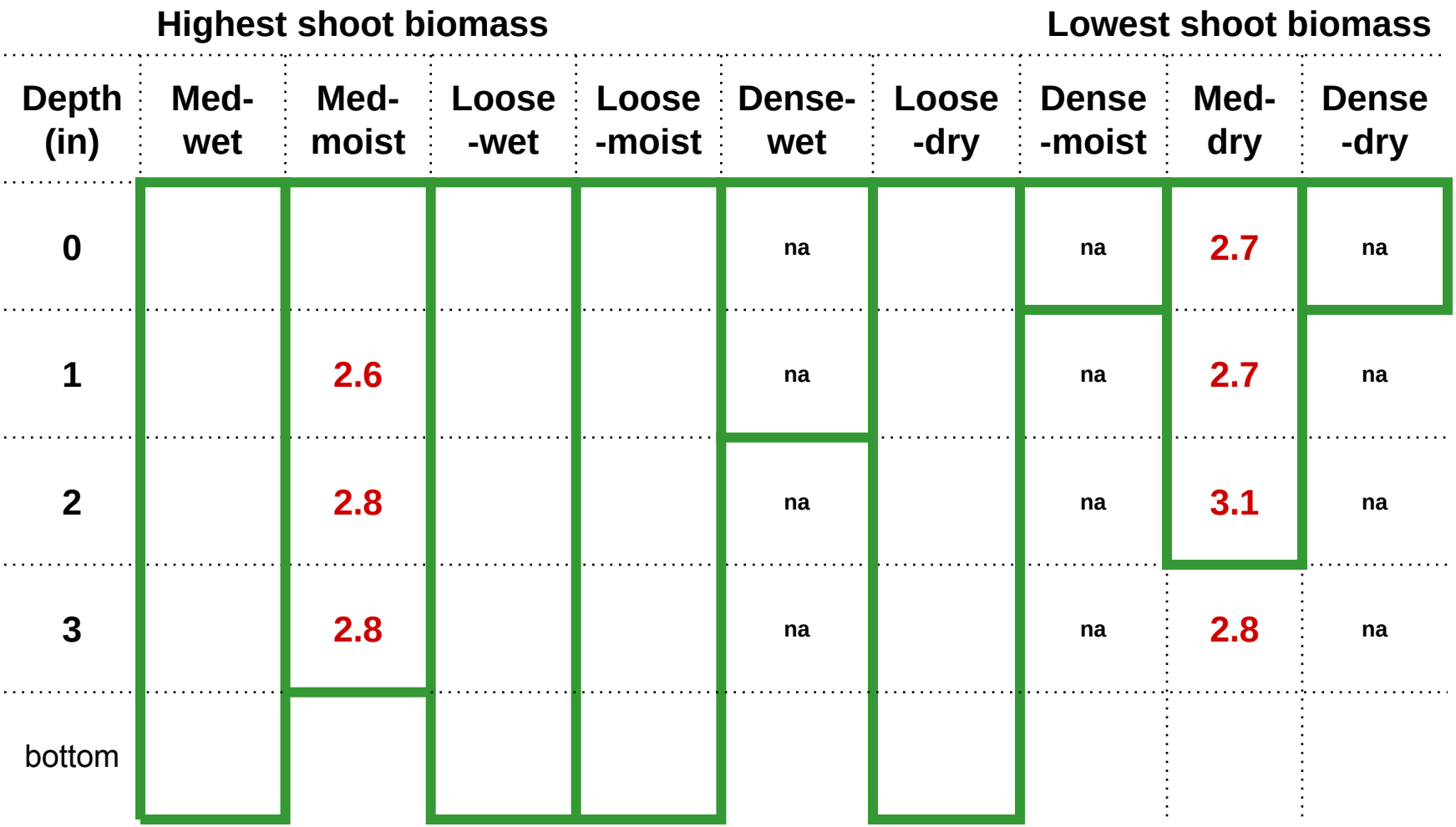
Summary—Roots

- Lower root biomass production :
  - Higher bulk density
  - Higher soil strength
  - Shallower root depth
- Higher root biomass production:
  - Lower water stress
  - Can have higher soil strength

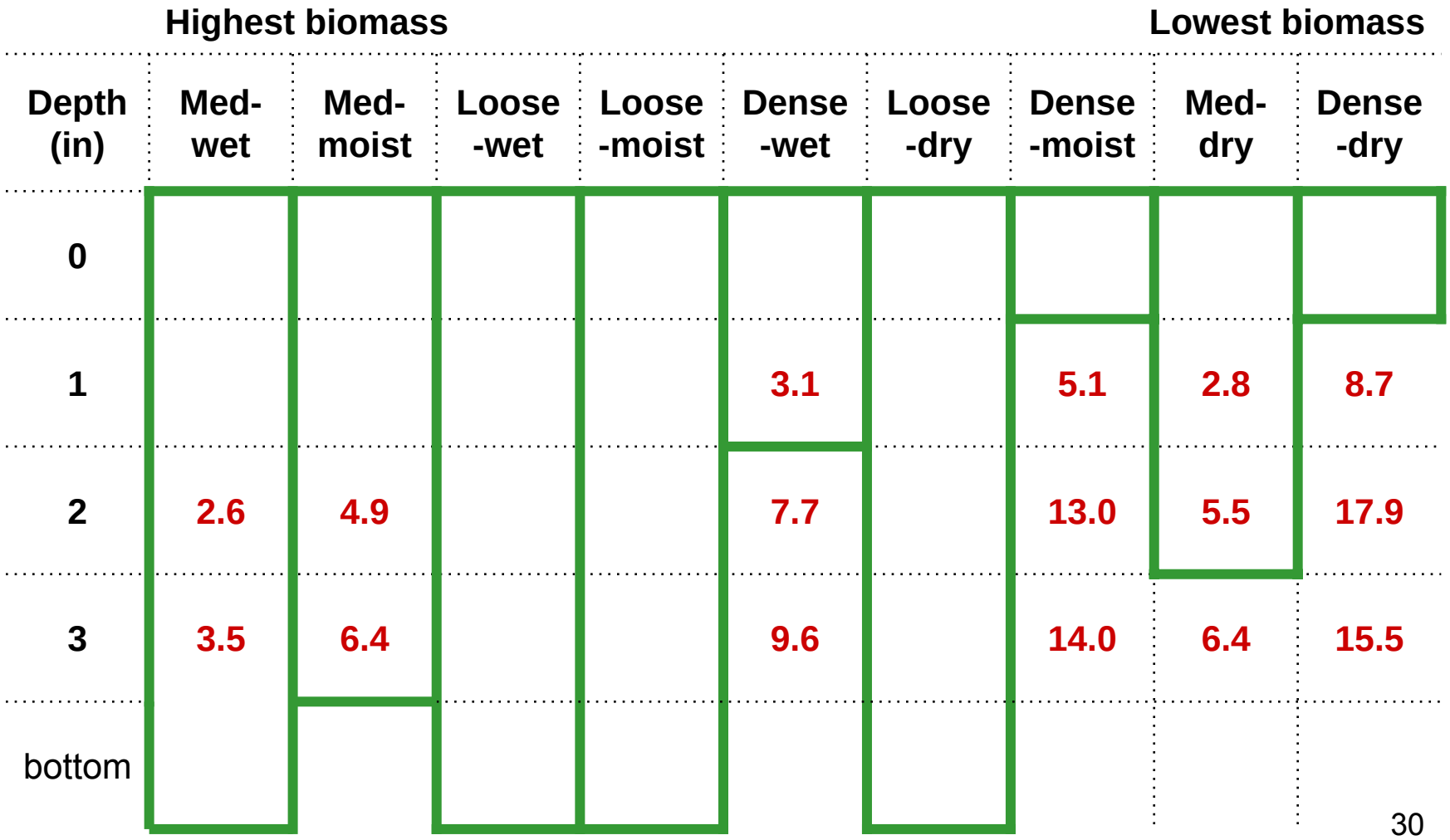
Summary—Roots

- Roots penetration and biomass production can potentially be high over a wide range of soil strength above 2.5 MPa

PR and Shoots—Penetrometer



PR and Shoots—Hydraulic Press



Summary—Shoots

- Higher shoot biomass production:
  - Lower water stress
  - Deeper root depth
  - Can have higher soil strength
- Similar shoot production occurs under contrasting belowground conditions

Field Relevance and Conclusions

General trend in biomass production:

- Increasing bulk density and soil strength decreases biomass production and root penetration
- High production and deep root penetration can occur in soils that exceed 2.5 MPa
- Effects possibly moderated by water availability

Field Relevance and Conclusions

- Is there a threshold bulk density or soil strength?
- Similar production can occur across a range of bulk densities.
- A wide range of soil strength data were obtained using different instruments - provides a range of soil strengths associated with lower production.

Field Relevance and Conclusions

- Physical difficulty in obtaining quantitative data on very compacted and strong soils (and these didn't have rocks!)
- Penetrometer
    - Useful under agricultural conditions
    - Less useful on rangeland conditions
- Hydraulic press
    - For dense and strong soils
    - Of little field value
- Wide range of measurements

Final Thoughts

- Tate et al. (2004) REM 57(4):411-417 took 1,489 bulk density samples at SJER to tease out the effects of grazing management, RDM and other site factors.

- The interactions of bulk density, strength and moisture status are important for annual plants that ‘regerminate’ and grow annually.

Final Thoughts

These same interactions influence perennial grasses differently…

- High Db and strength can limit soil volume exploited by roots for water and nutrients (critical for year-to-year survival).
- As long as water is available, grass roots penetrate beyond what has been recorded for many agricultural crops.
- High bulk density may be more important in terms of water infiltration and deep percolation compared to physical impedance to root growth in field settings.