# Bioavailability-Based Remediation of Lead Contaminated Soils Using Biochars

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Environmental Science Graduate Program, Co-Director

*Simon Power, PhD*

SCHOOL OF ENVIRONMENT & NATURAL RESOURCES
THE OHIO STATE UNIVERSITY

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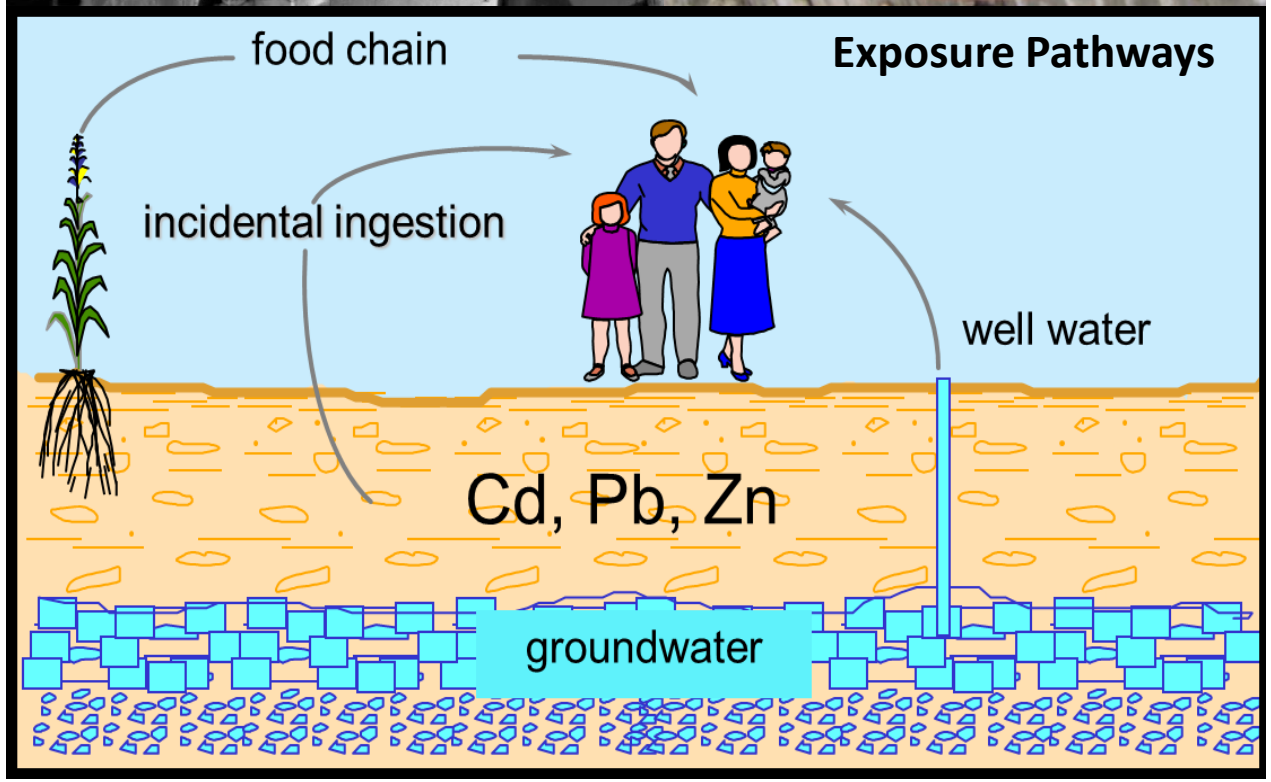

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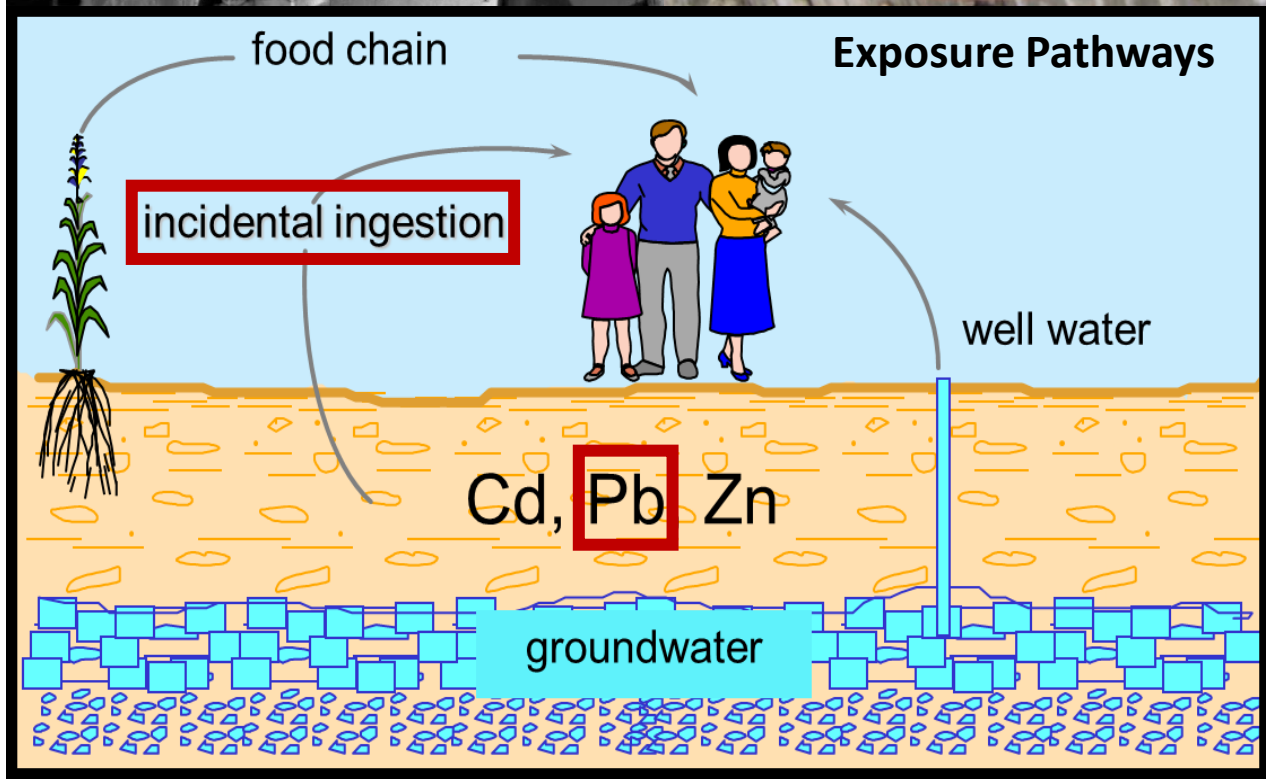

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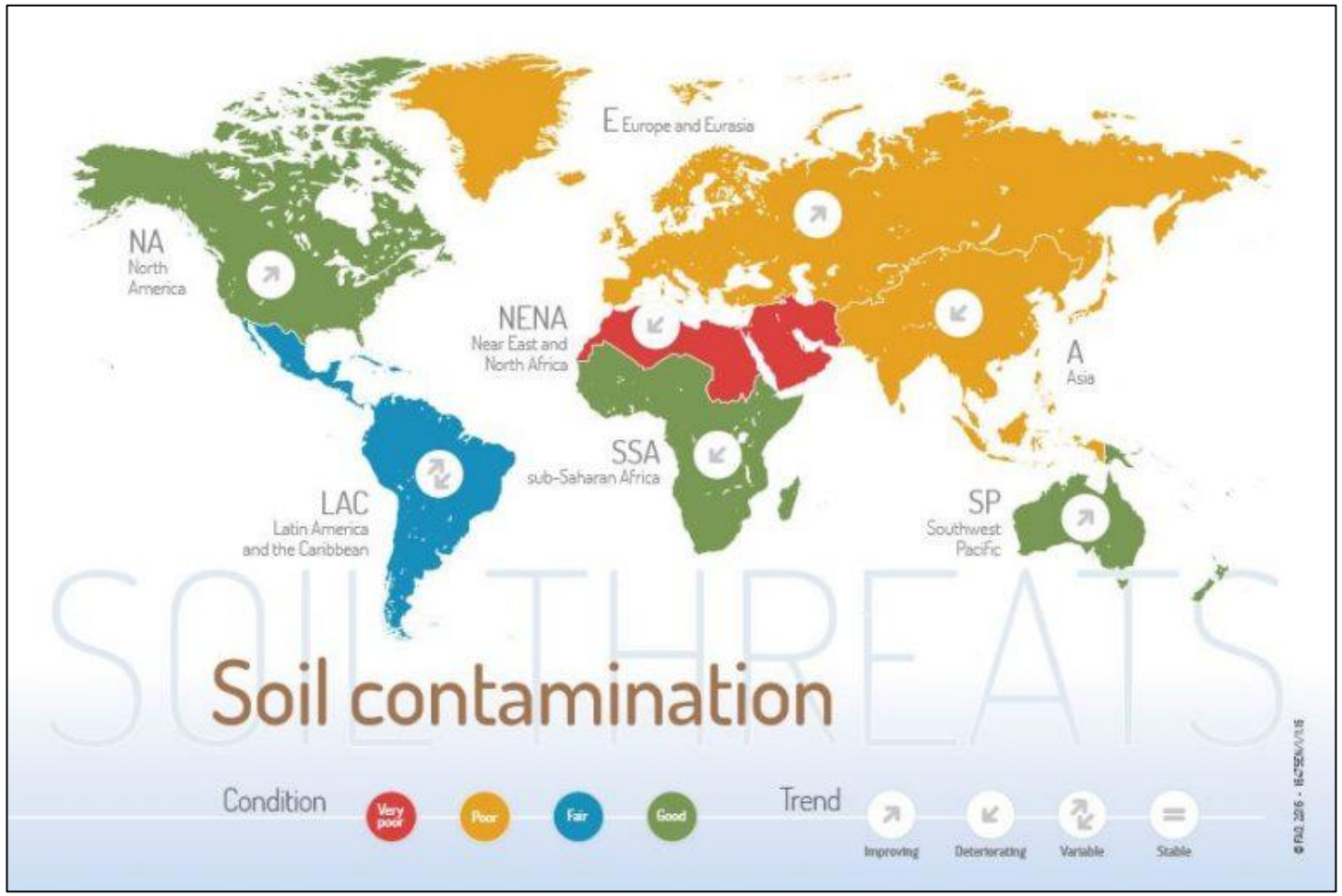


Hettiarachchi *et al.*, 2023.

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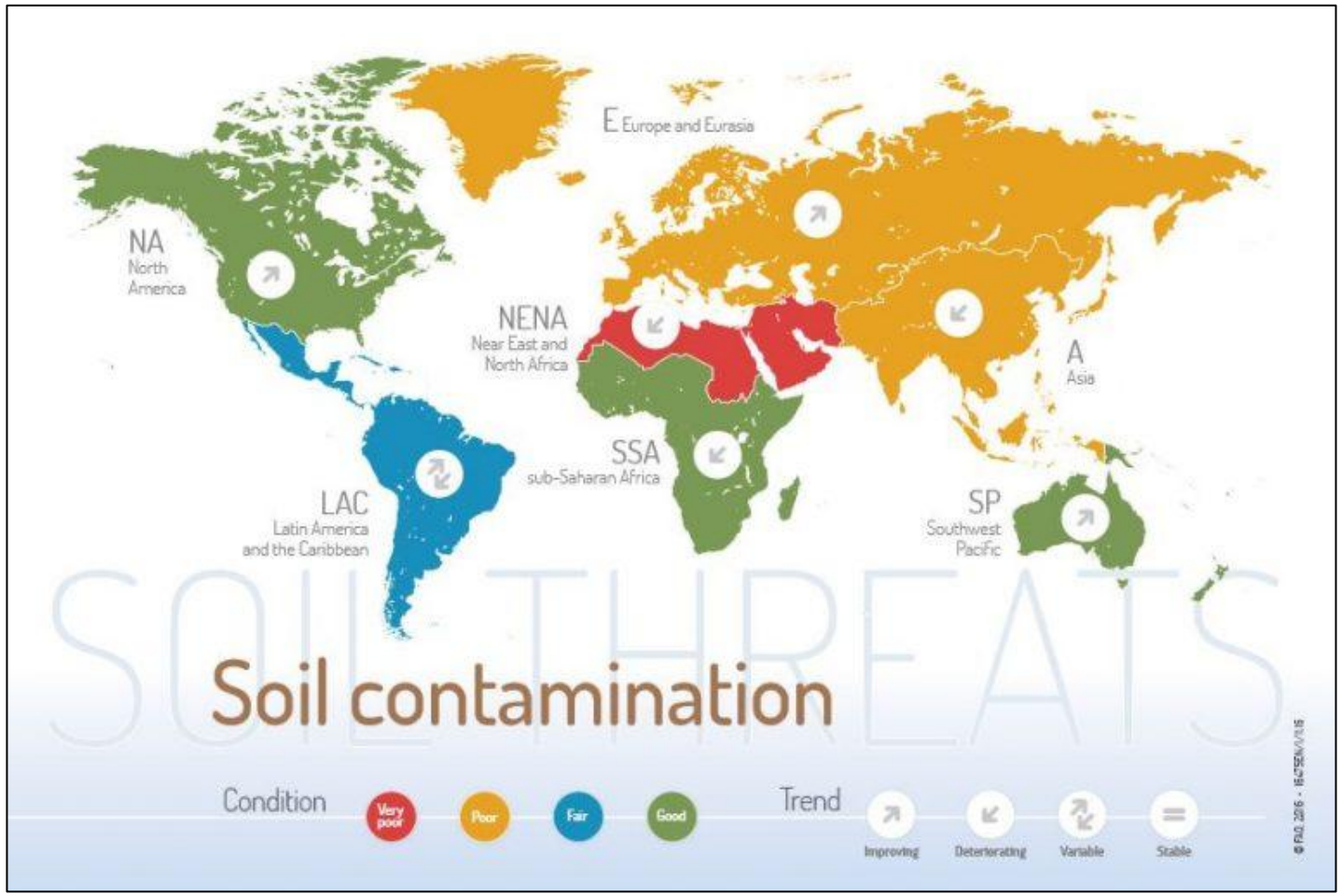


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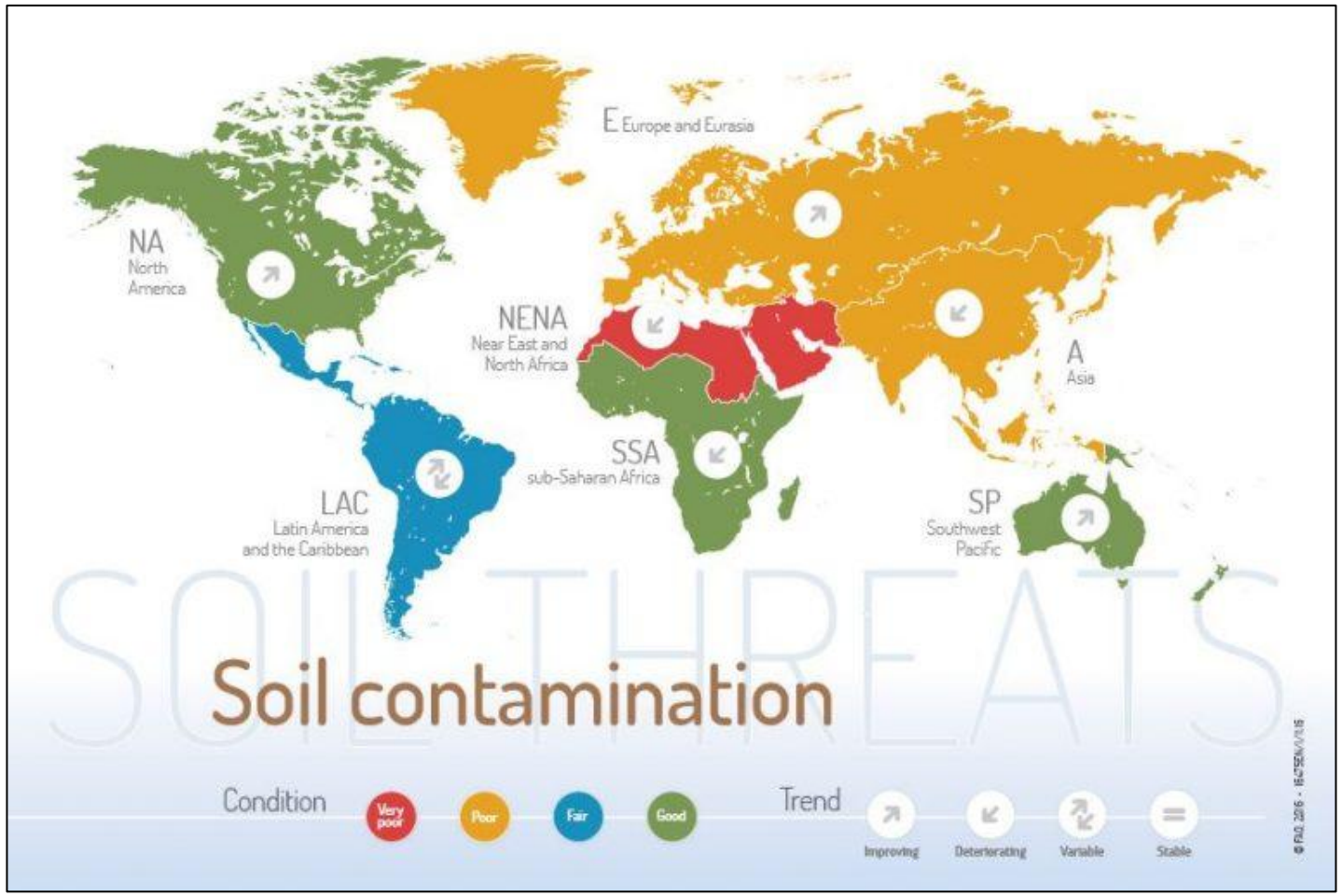


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US EPA Soil Screening levels

- ~~Old: 400 mg/kg~~
- Updated: 200 mg/kg
  - (100 mg/kg*)

# Pb Bioavailability Varies with Receptor and Exposure Pathway

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  - Soil pH 4 – 8.5

- Human stomach Environment
  - Stomach pH 1.5 – 2.5 (fasting)

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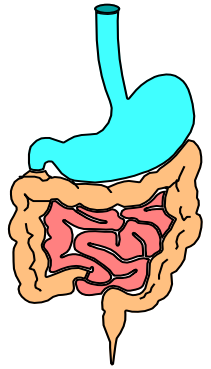

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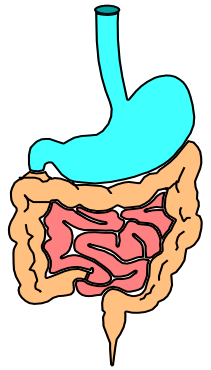

The GI environment is much more caustic to treated soil than the soil environment.

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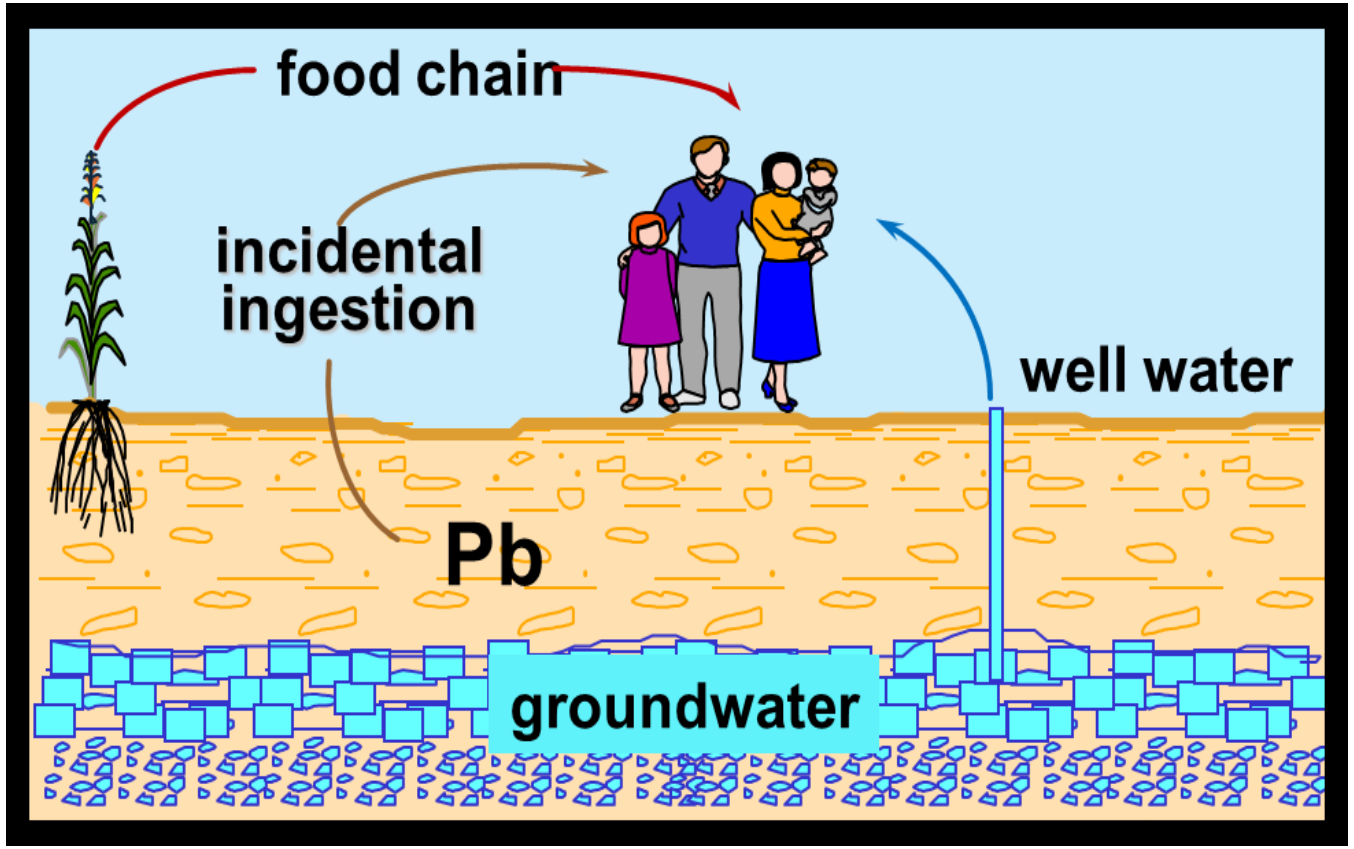

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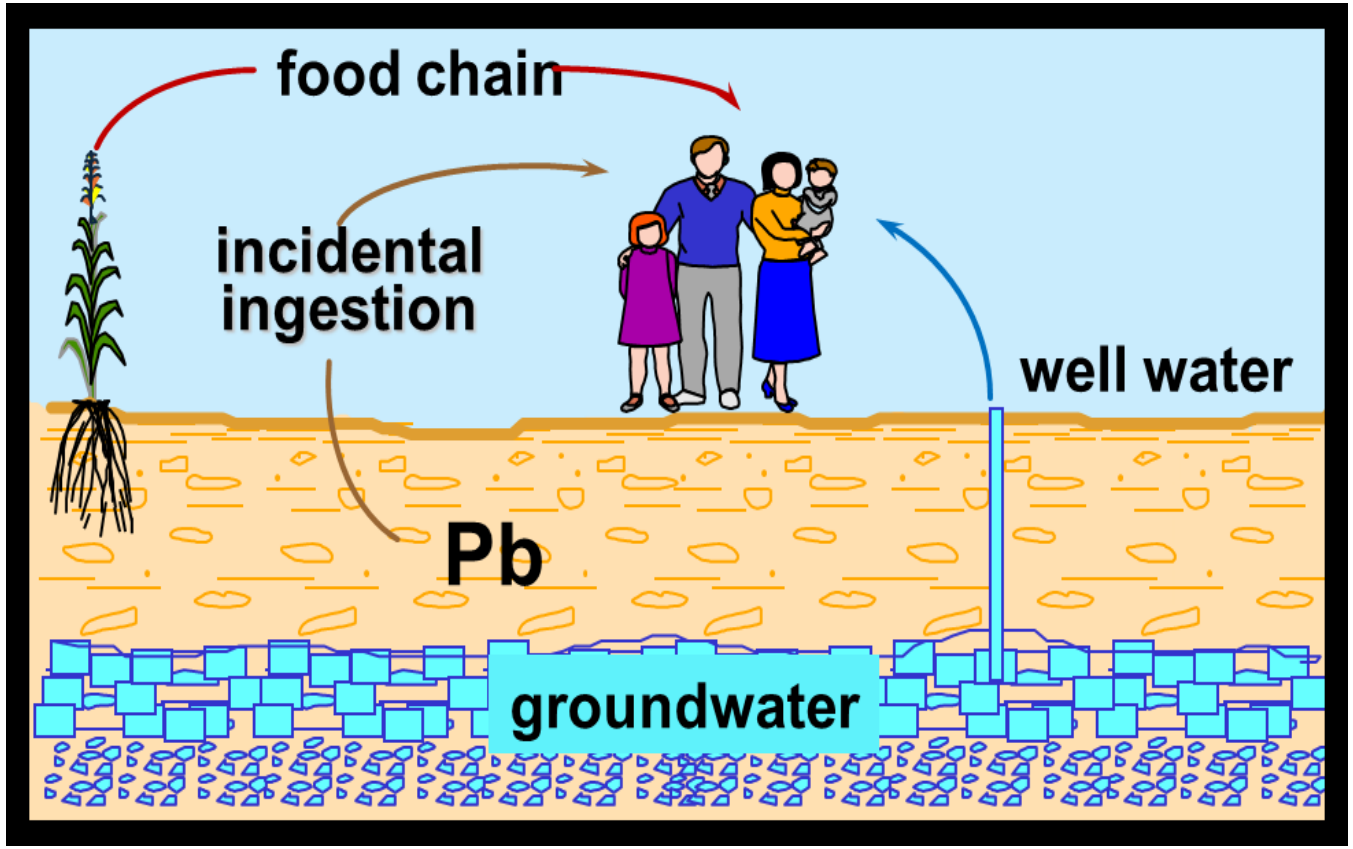


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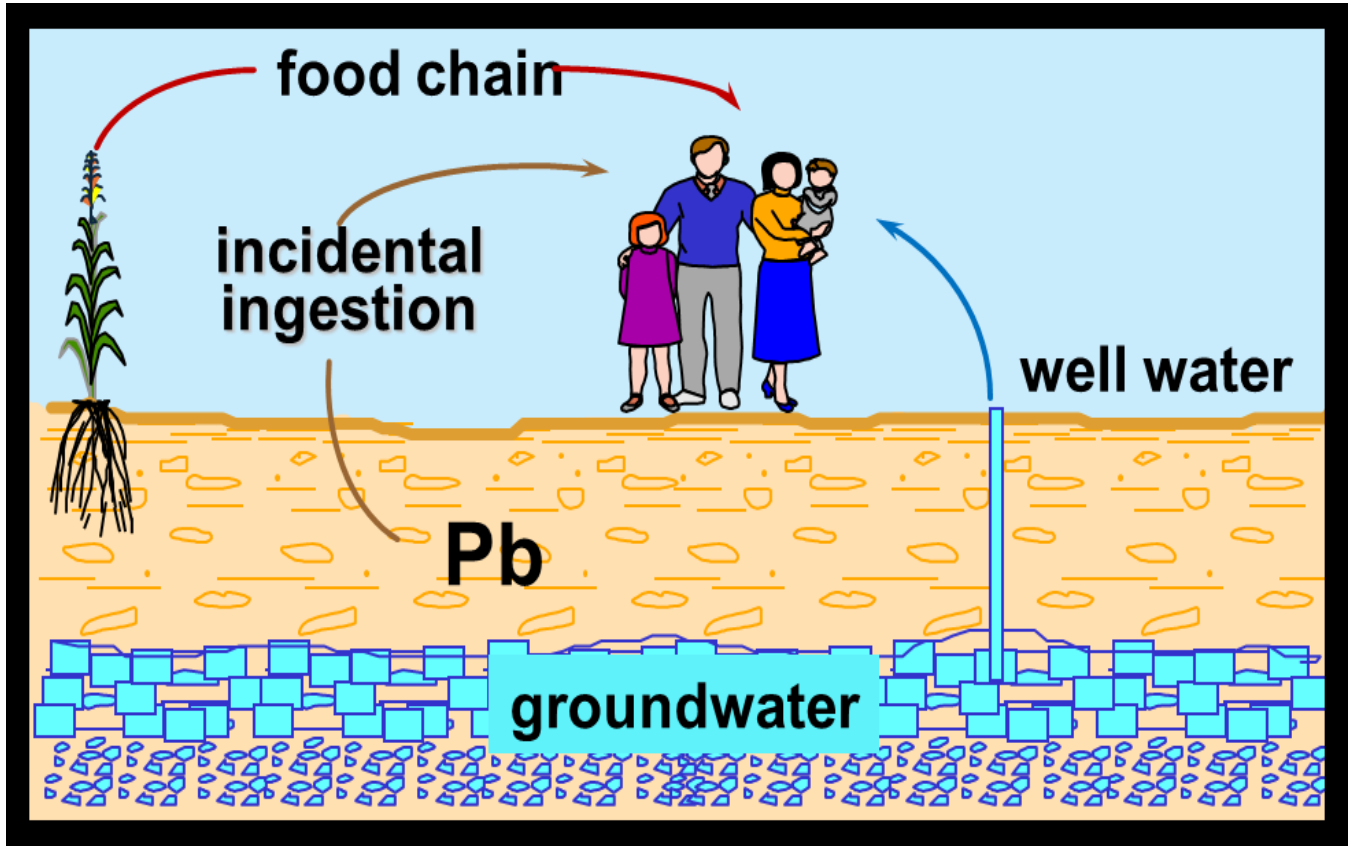


**Use soil amendments to reduce Pb:**

- Transmission to plants & soil invertebrates
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## Soil Amendments

- Yard/Wood waste
- Compost
- Biosoilds
- **Biochar**, and more.

# Biochar

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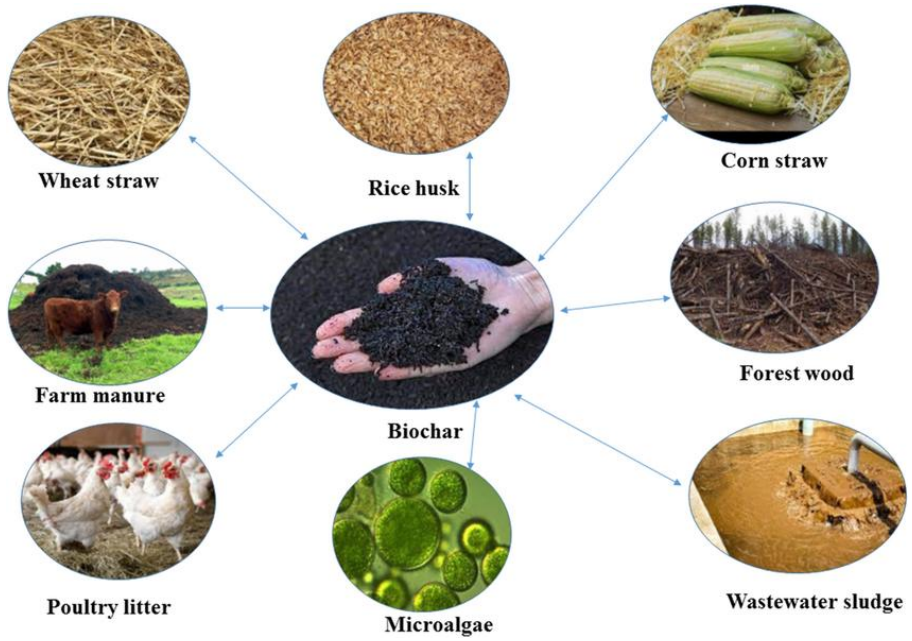

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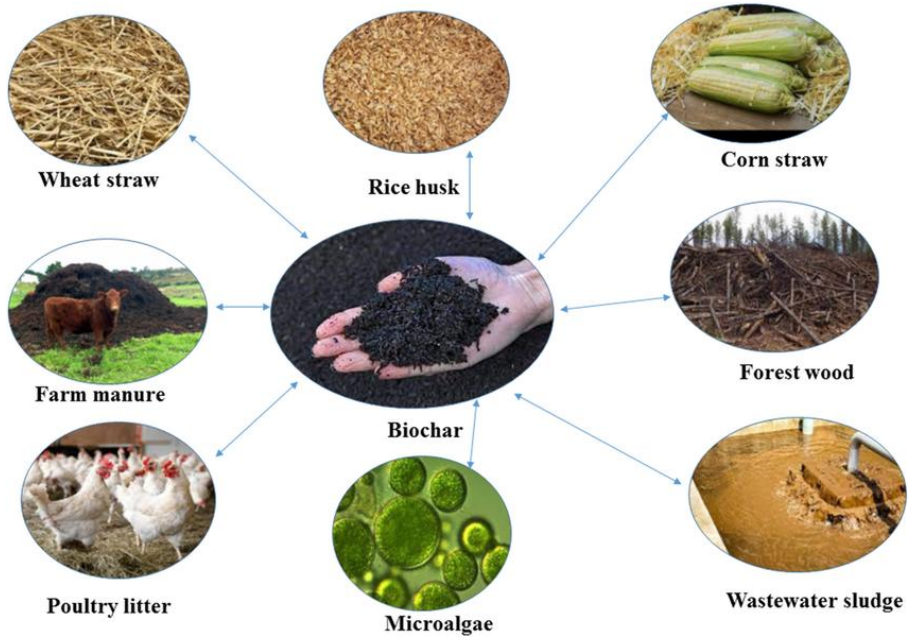


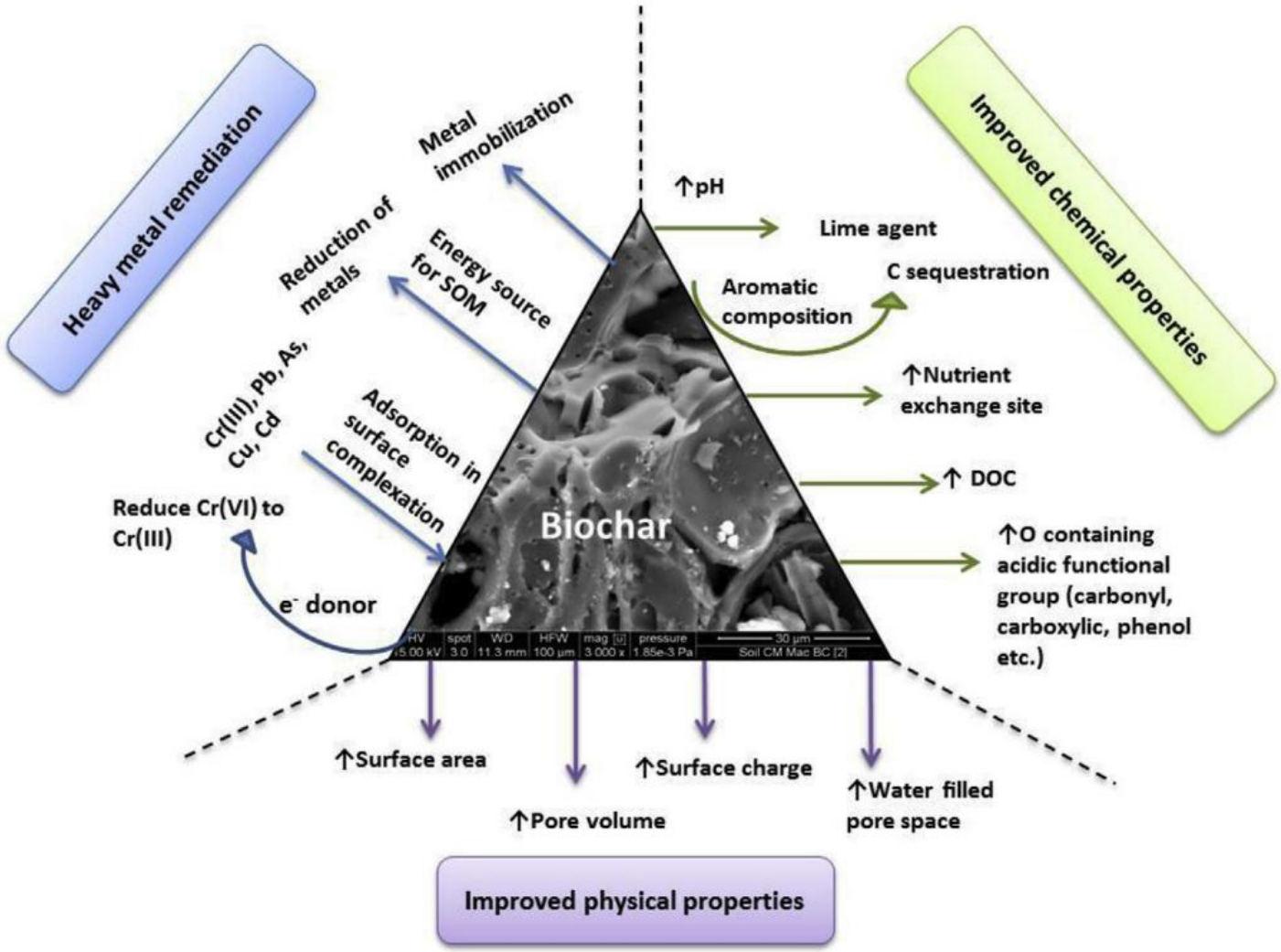


Li *et al.,* 2017; Rajapaksha *et al*., 2016.

# Ability of Biochar to reduce bioaccessible Pb from Soil Ingestion

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- Studies reported reductions in %IVBA Pb from biochar treatments (Netherway et al., 2020; Plunkett et al., 2022).
  - Specifically in P-rich biochars
- Limited research on the effect of BC reducing IVBA from incidental soil ingestion.

# Ability of Biochar to reduce bioaccessible Pb for Plants and Soil Invertebrates

Journal of Hazardous Materials Advances 6 (2022) 100086

Contents lists available at ScienceDirect

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Reduction of heavy metal uptake from polluted soils and associated health risks through biochar amendment: A critical synthesis

Jackson Nkoh Nkoh[a,b,*], Fidelis Odedishemi Ajibade[b,c], Edidiong Okokon Atakpa[b,d], M. Abdulaha-Al Baquy[e], Shamim Mia[f,**], Elijah Chibueze Odii[b,g], Renkou Xu[a]

Environmental Pollution 230 (2017) 329–338

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The role of tailored biochar in increasing plant growth, and reducing bioavailability, phytotoxicity, and uptake of heavy metals in contaminated soil☆

**Hundreds of publications showing biochar can reduce this bioaccessibility**

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The effect of biochar and crop straws on heavy metal bioavailability and plant accumulation in a Cd and Pb polluted soil

Ping Xu, Cai-Xia Sun, Xue-Zhu Ye, Wen-Dan Xiao, Qi Zhang, Qiang Wang*

*Institute of Quality and Standards for Agricultural Products, Zhejiang Academy of Agricultural Sciences, Hangzhou 310021, China*

6-791, South Korea

2017

Journal of Environmental Quality TECHNICAL REPORTS

TRACE ELEMENTS IN THE ENVIRONMENT

Biochars Reduce Mine Land Soil Bioavailable Metals

J. A. Ippolito,* C. M. Berry, D. G. Strawn, J. M. Novak, J. Levine, and A. Harley

## Gap

- Limited research:
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## Objectives

- Determine the efficacy of different biochar amendments to reduce bioaccessible Pb to plants and soil invertebrates
- Determine the efficacy of different biochar amendments to reduce bioaccessible Pb from soil/dust ingestion

# Approach

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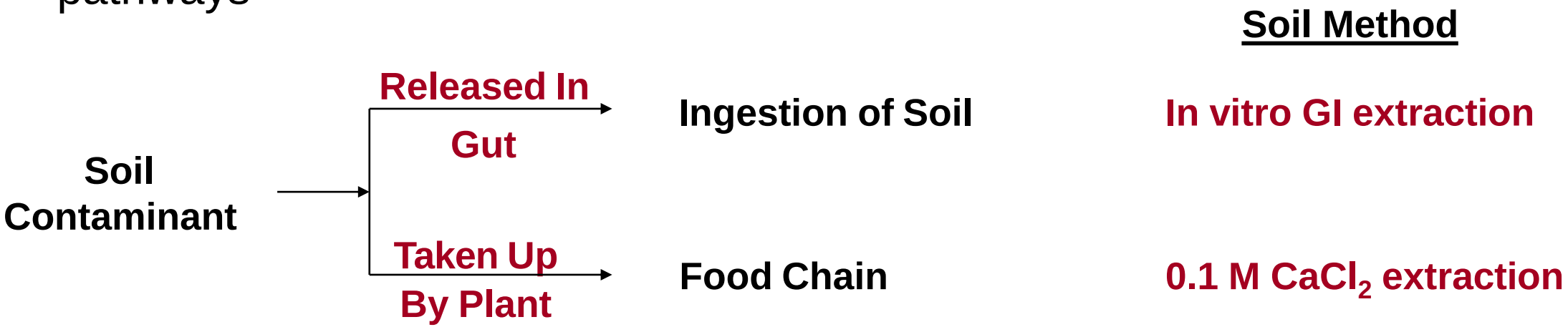

# Soil Property Information

| Property | Soils | | | | |
|---|---|---|---|---|---|
| | Smelter / Mine Land | | | Military | |
| | C1 | C5 | SS_Blend | Portsmouth | Travis |
| Soil pH, water | 2.6 | 5.7 | 6.75 | 6.20 | 7.04 |
| Total C (%) | 0.36 | 0.61 | 6.9 | 2.57 | 1.22 |
| Total Pb (mg $kg^{-1}$) | 10182 (519) | 4756 (179) | 3504 (162) | 2610 (98.0) | 2232 (107) |
| 0.1 $CaCl_2$ Pb (mg $kg^{-1}$) | 1.22 (0.29) | 0.23 (0.06) | 5.16 (0.23) | 91.6 (10.2) | 21.3 (3.28) |
| IVBA Pb (mg $kg^{-1}$) | 113 (53.3) | 158 (15.5) | 1591 (37.0) | 1730 (79.7) | 1947 (188) |
| IVBA Pb (%) | 1.12 (0.57) | 3.33 (0.44) | 45.5 (2.67) | 66.3 (0.63) | 88.8 (14.0) |

Values are averages ± SD (n=3)

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# Biochar Property Information

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| | **Biosolid 1** | **Biosolid 2** | **Poultry Litter** | **Switchgrass** |
| Pyrolysis Temperature (°C) | 900 | | 900 | 900 |
| pH | 8.06 (0.02) | 7.32 (0.06) | 11.3 (0.04) | 11.2 (0.03) |
| EC (dS $m^{-1}$) | 1.06 (0.01) | 1.11 (0.04) | 8.82 (0.20) | 0.87 (0.03) |
| Volatile Matter (%) | 0.00 (0.00) | 23.0 (0.35) | 14.9 (4.73) | 10.6 (5.80) |
| Ash Content (%) | 94.0 (0.43) | 62.2 (0.30) | 62.8 (1.50) | 16.2 (4.61) |
| Fixed Carbon (%) | 6.02 (0.43) | 14.8 (0.30) | 22.4 (3.30) | 73.2 (10.20) |
| Total C (%) | 15.9 (0.14) | 23.0 (0.59) | 39.8 (5.11) | 69.4 (4.67) |
| Total N (%) | 0.40 (0.00) | 3.10 (0.04) | 1.72 (0.05) | 0.69 (0.03) |
| C/N Ratio | 40.3 (0.30) | 7.39 (0.18) | 23.2 (2.44) | 100 (8.58) |
| $NO_3$–N (mg $kg^{-1}$) | 0.00 (0.00) | 104 (0.66) | 4.46 (0.29) | 0.00 (0.00) |
| $NH_4$–N (mg $kg^{-1}$) | 28.3 (0.32) | 44.0 (0.29) | 0.00 (0.00) | 0.00 (0.00) |
| Total Pb (mg $kg^{-1}$) | 23.5 (0.60) | 90.0 (2.19) | 0.63 (0.09) | 0.47 (0.28) |

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# Approach

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Spiked with Pb

0.1 M CaCl2 Extraction

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Measure Pb concentration using ICP-OES

Calculate Pb desorbed

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## b. Biochar + Contaminated Soil Blend

Pb Contaminated Soil + Biochar mix *3 & 5% w/w*

Put on shaker for 24 Hrs.

Air-dried and processed

0.1 M CaCl2 Extraction

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# Bioaccessible Pb for Plants/Invertebrates

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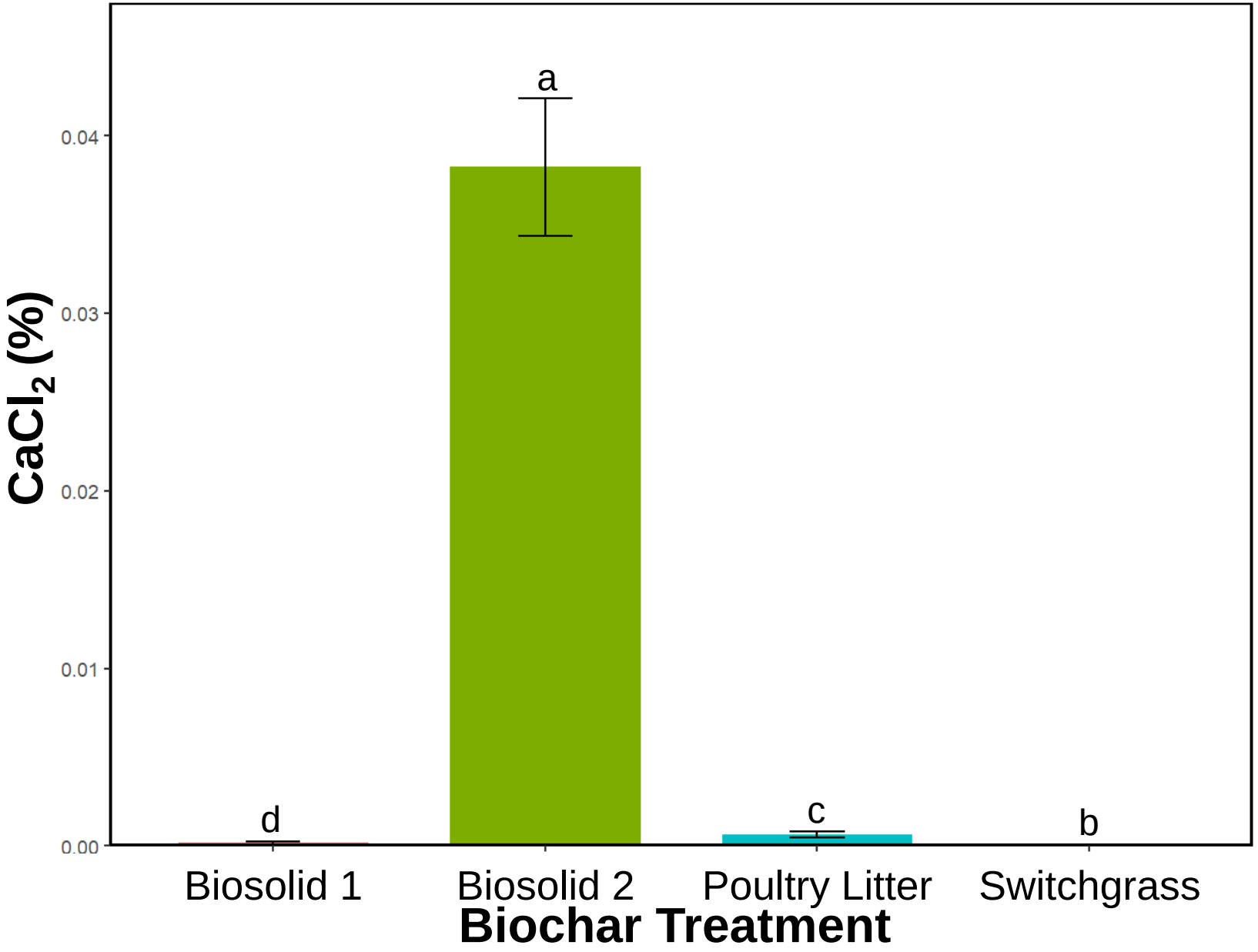

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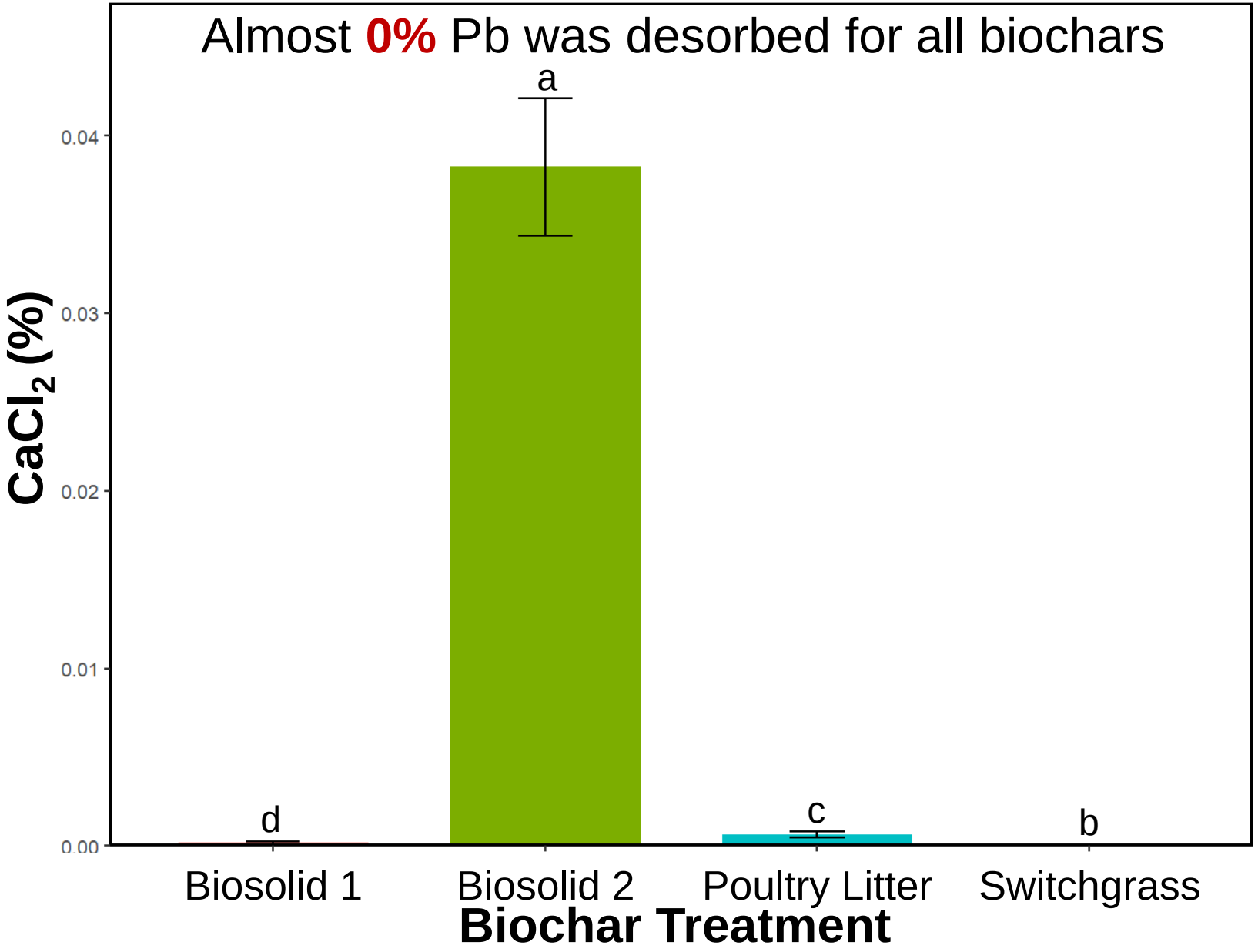

# Bioaccessible Pb for Soil Ingestion

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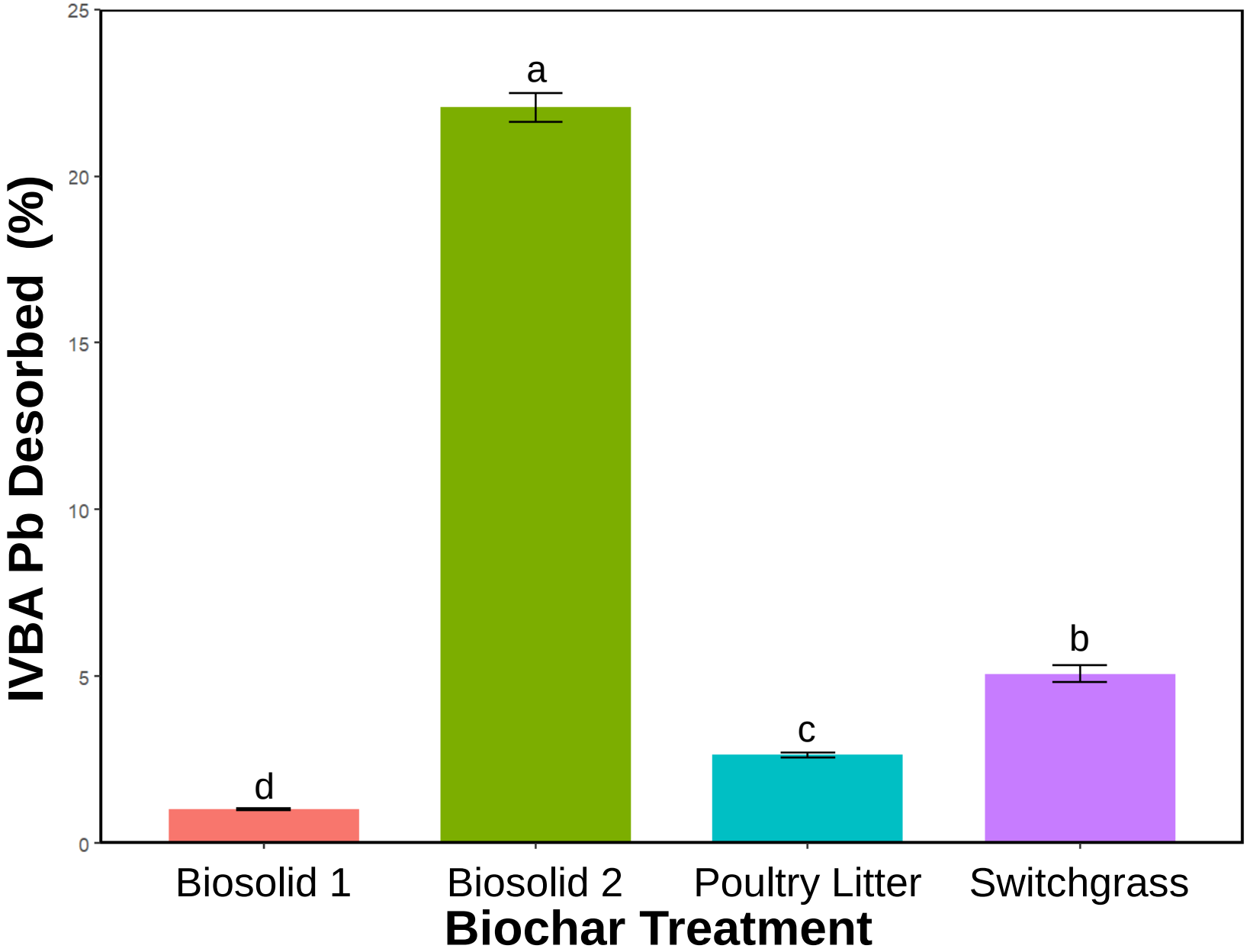

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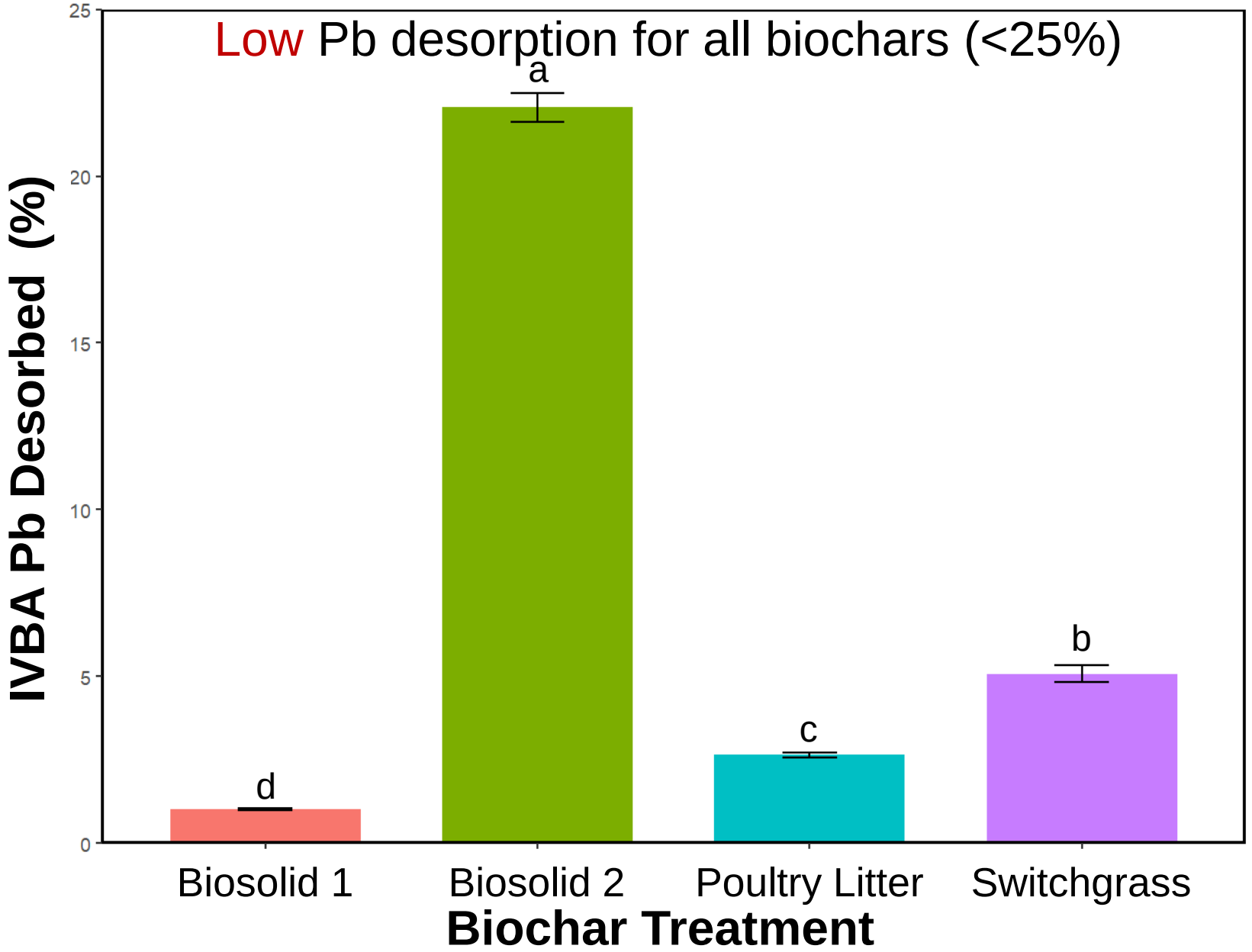

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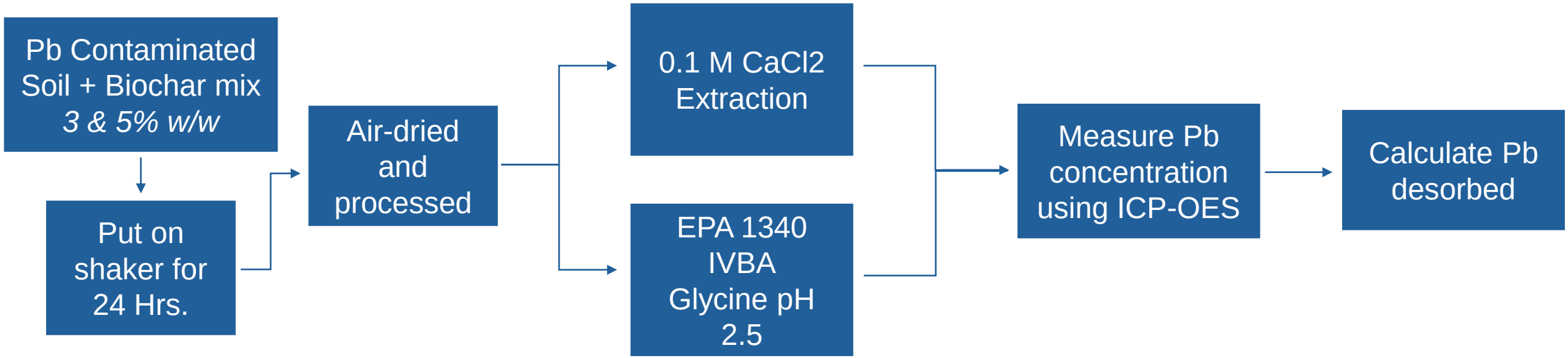
a. Spiked Biochars




b. Biochar + Contaminated Soil Blend



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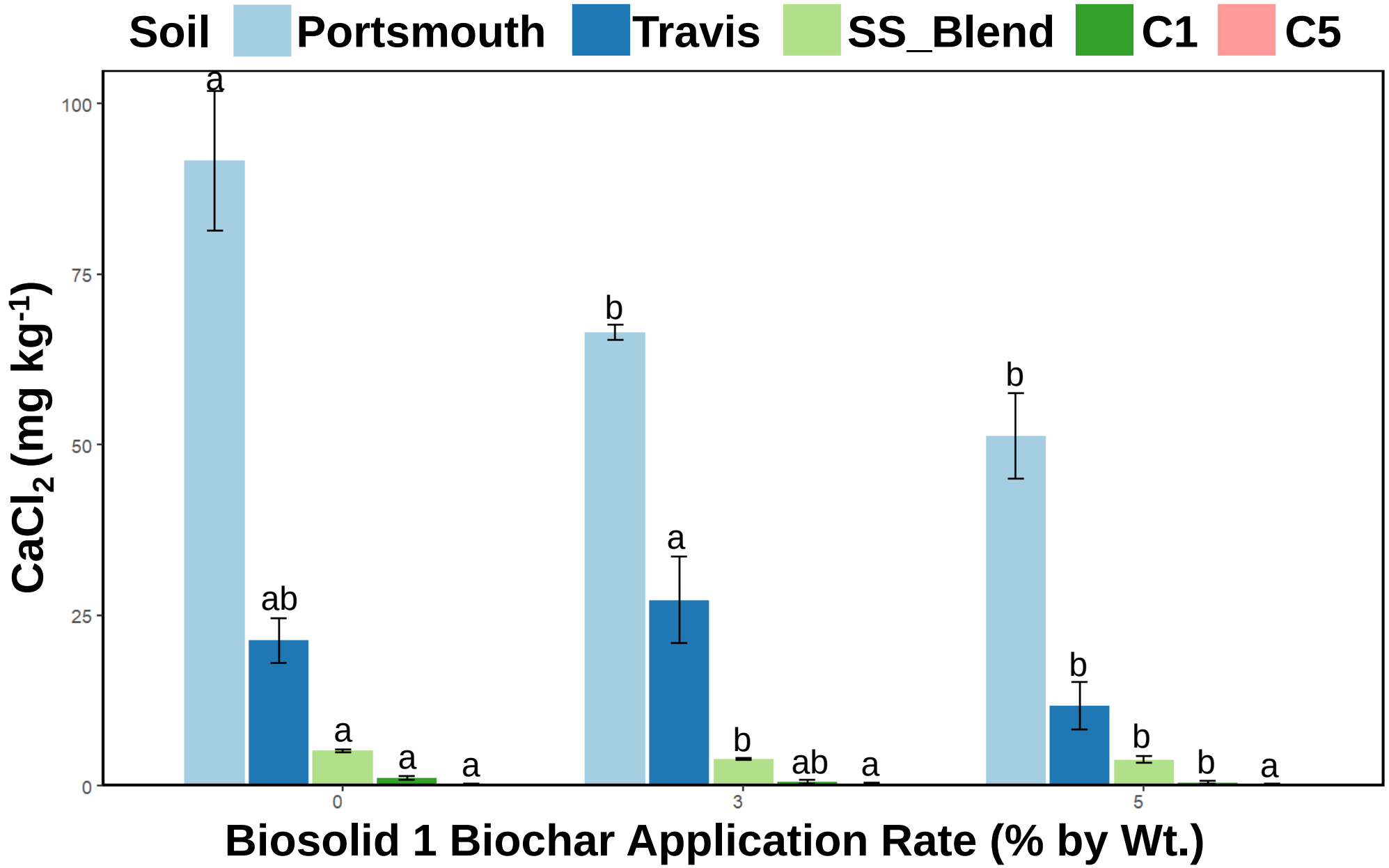

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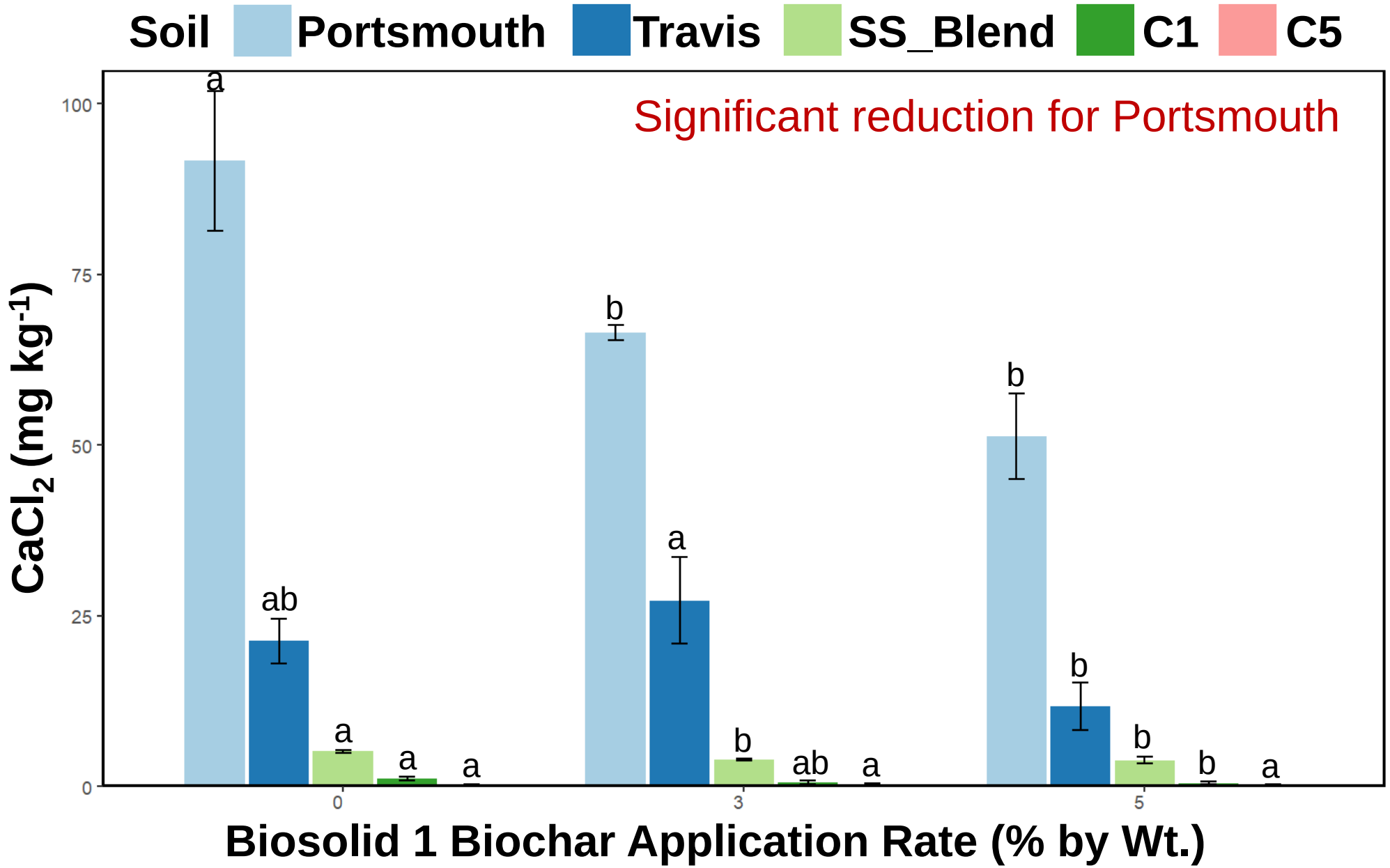

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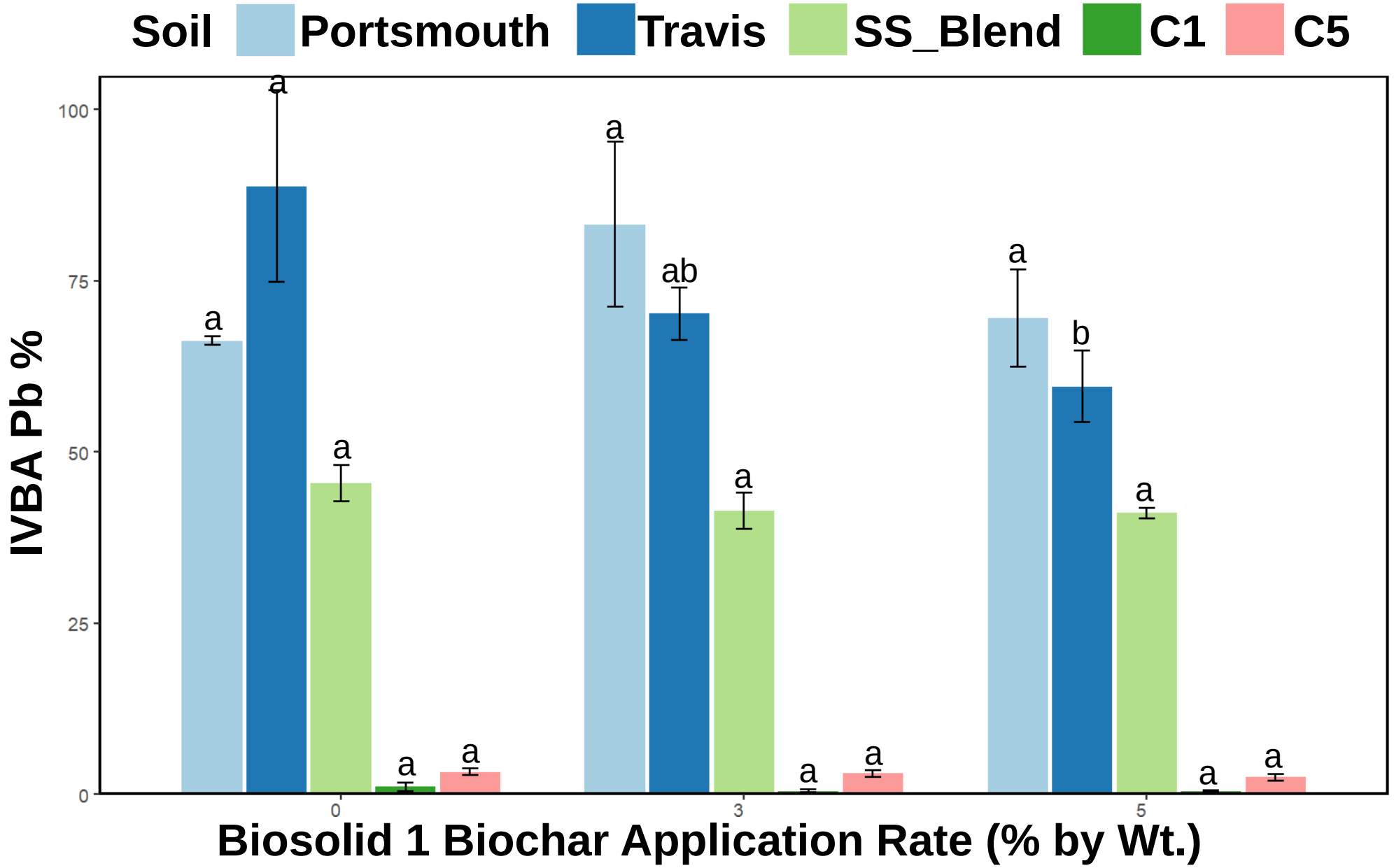

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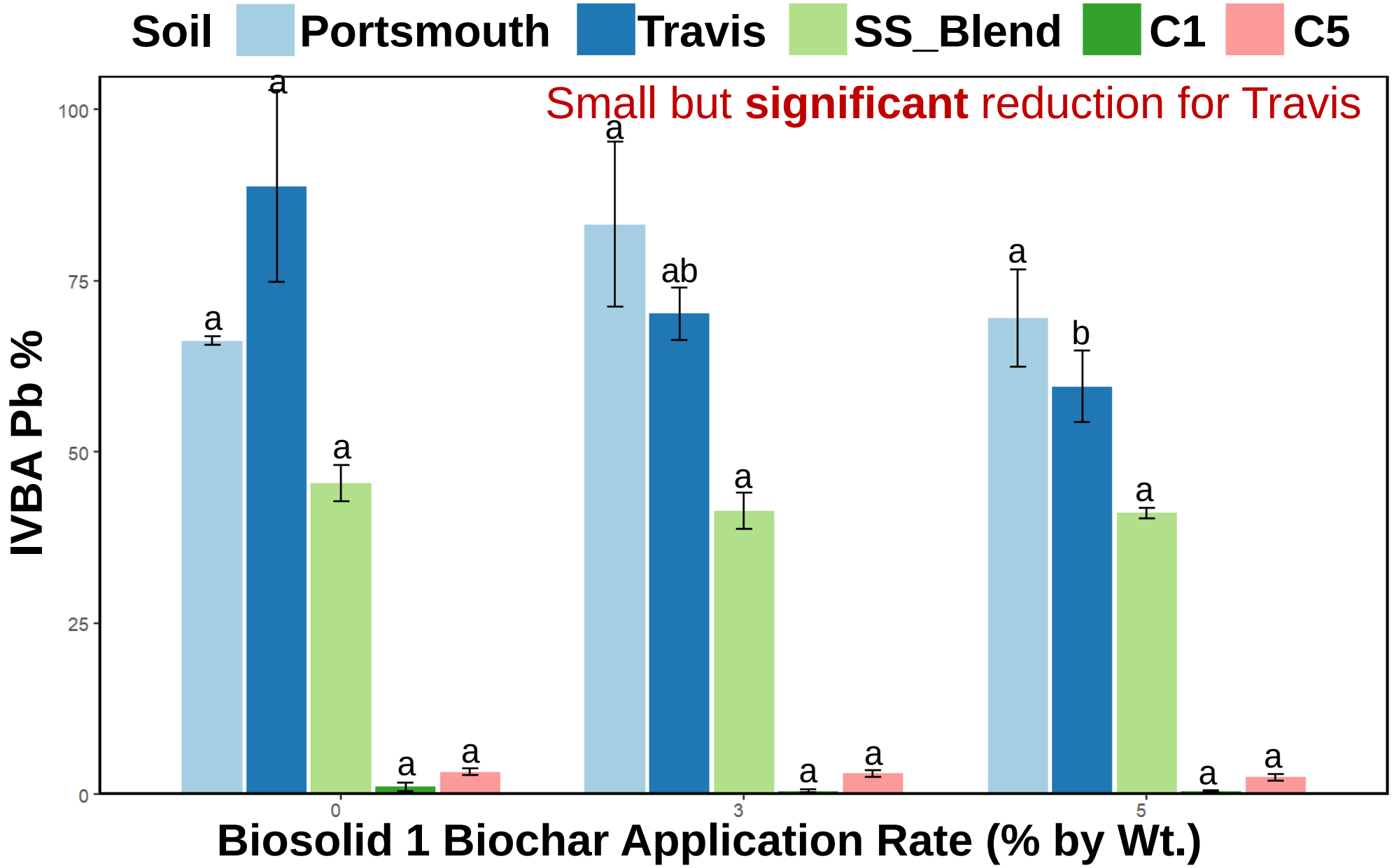

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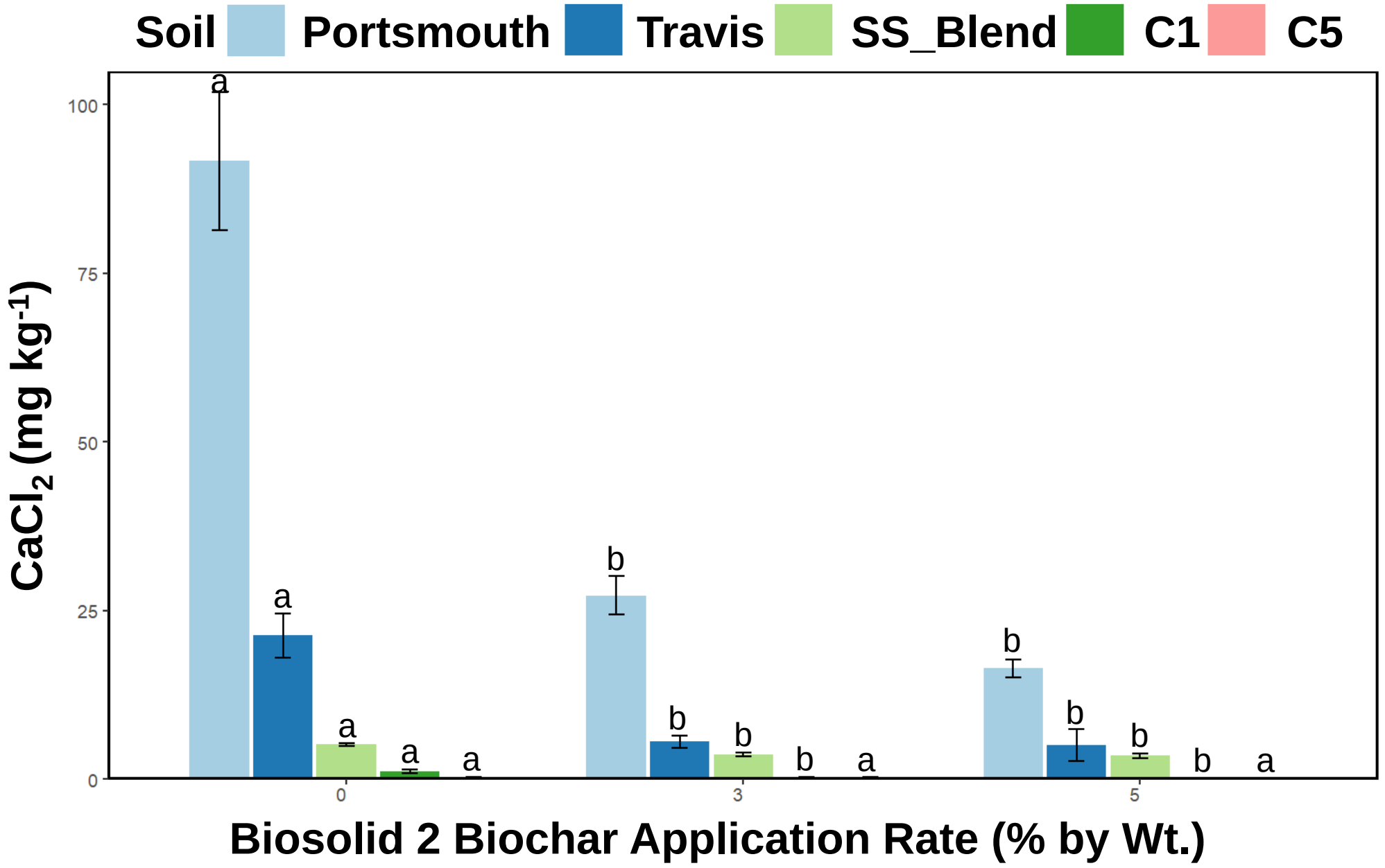

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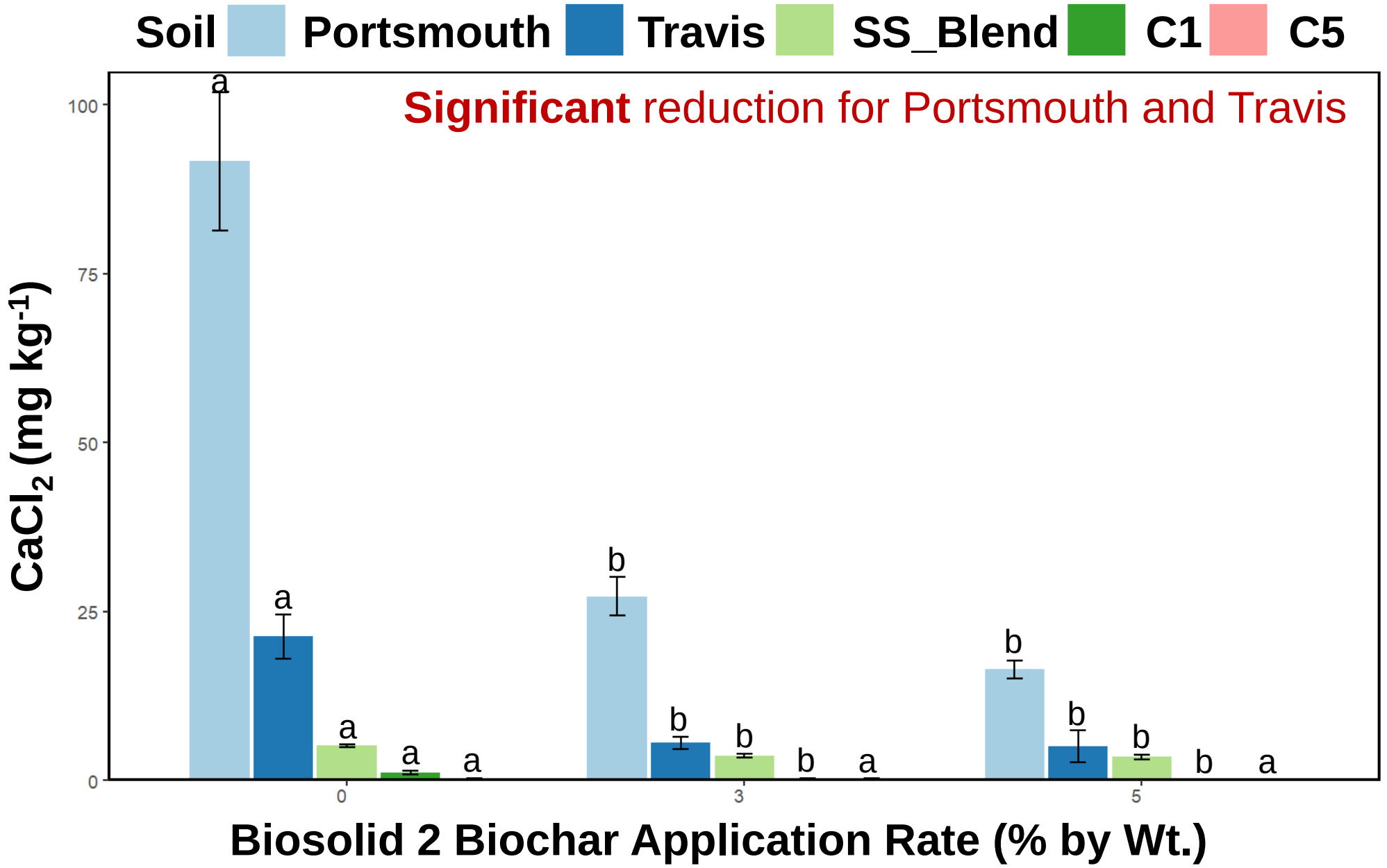

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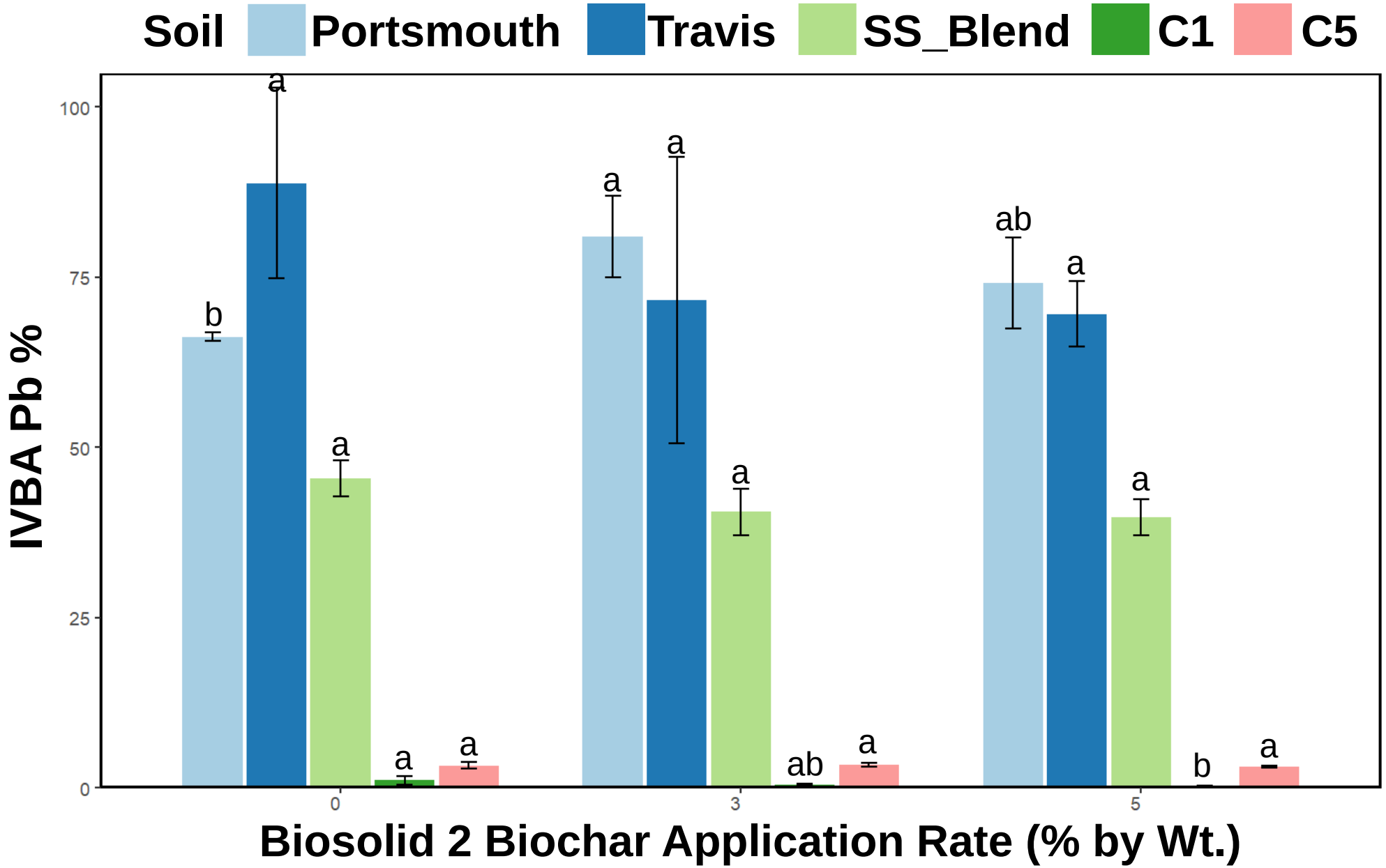

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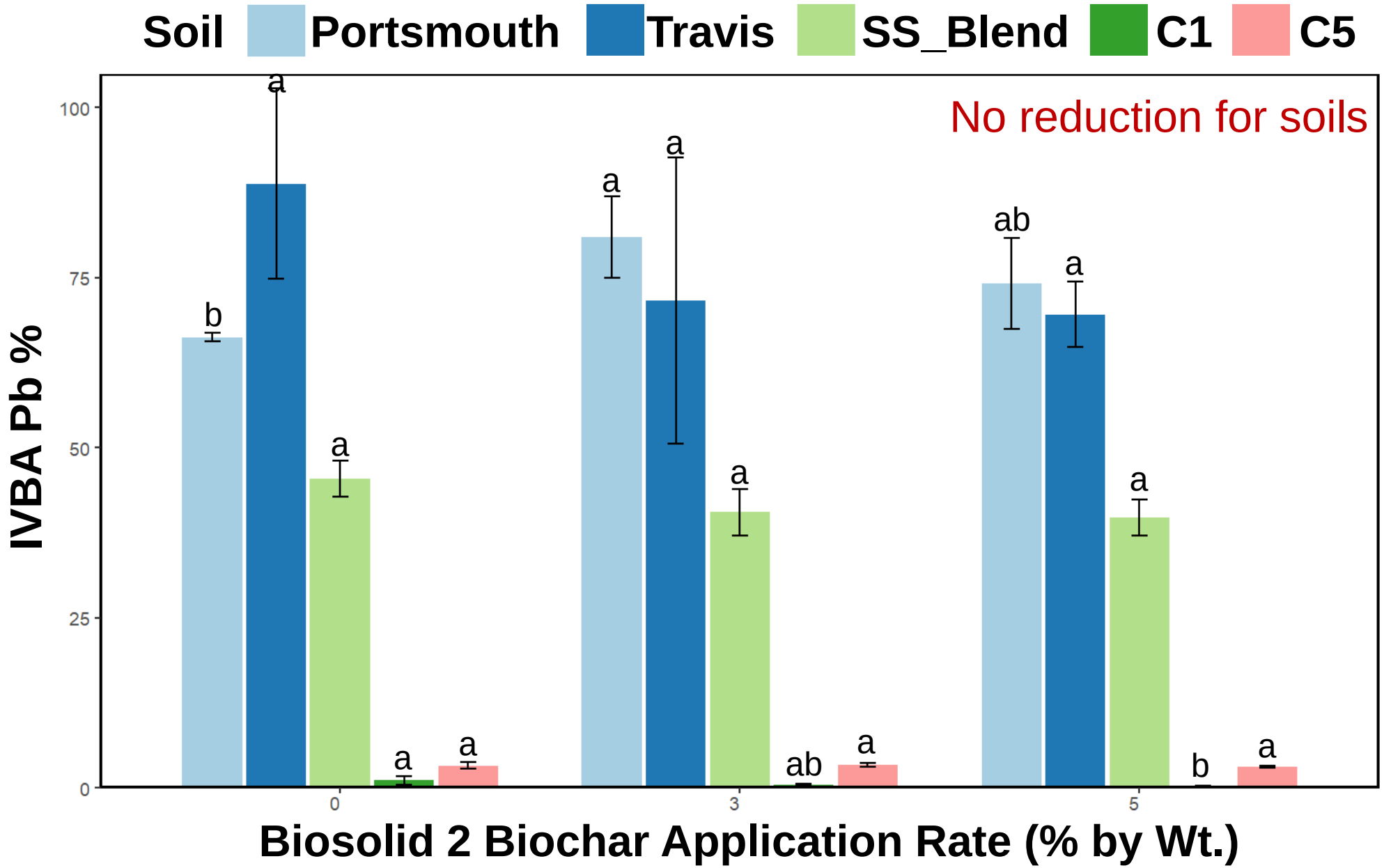

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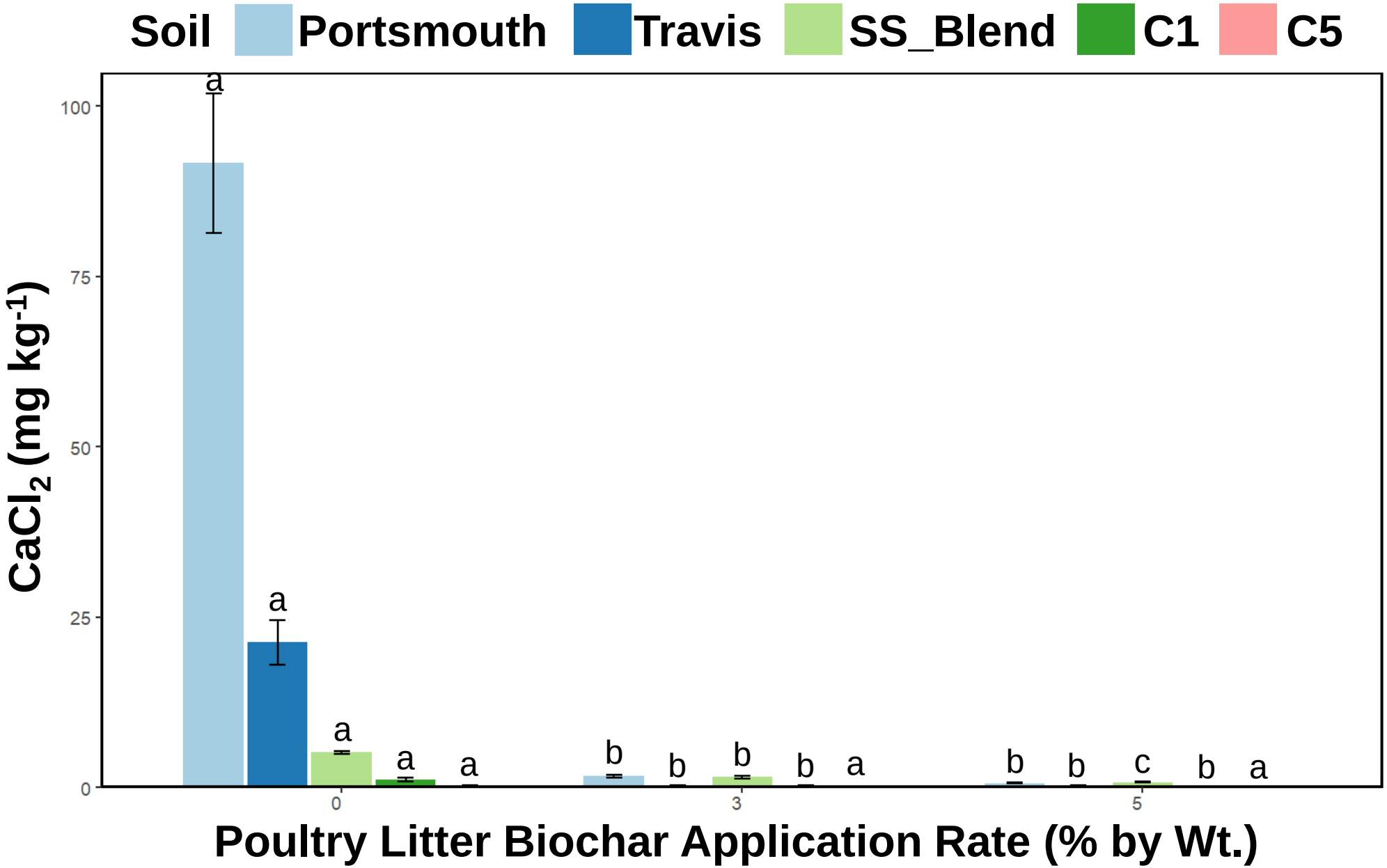

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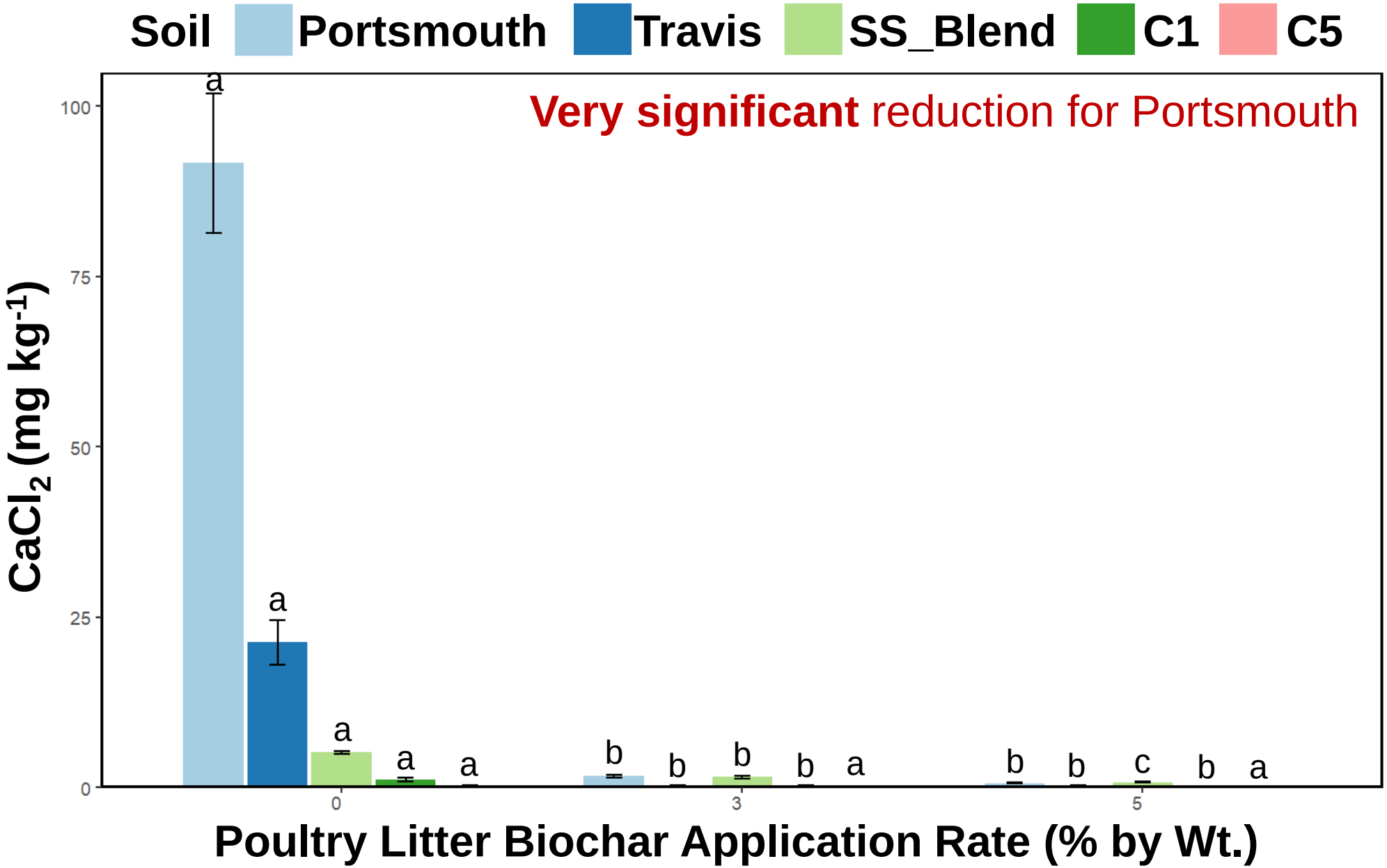

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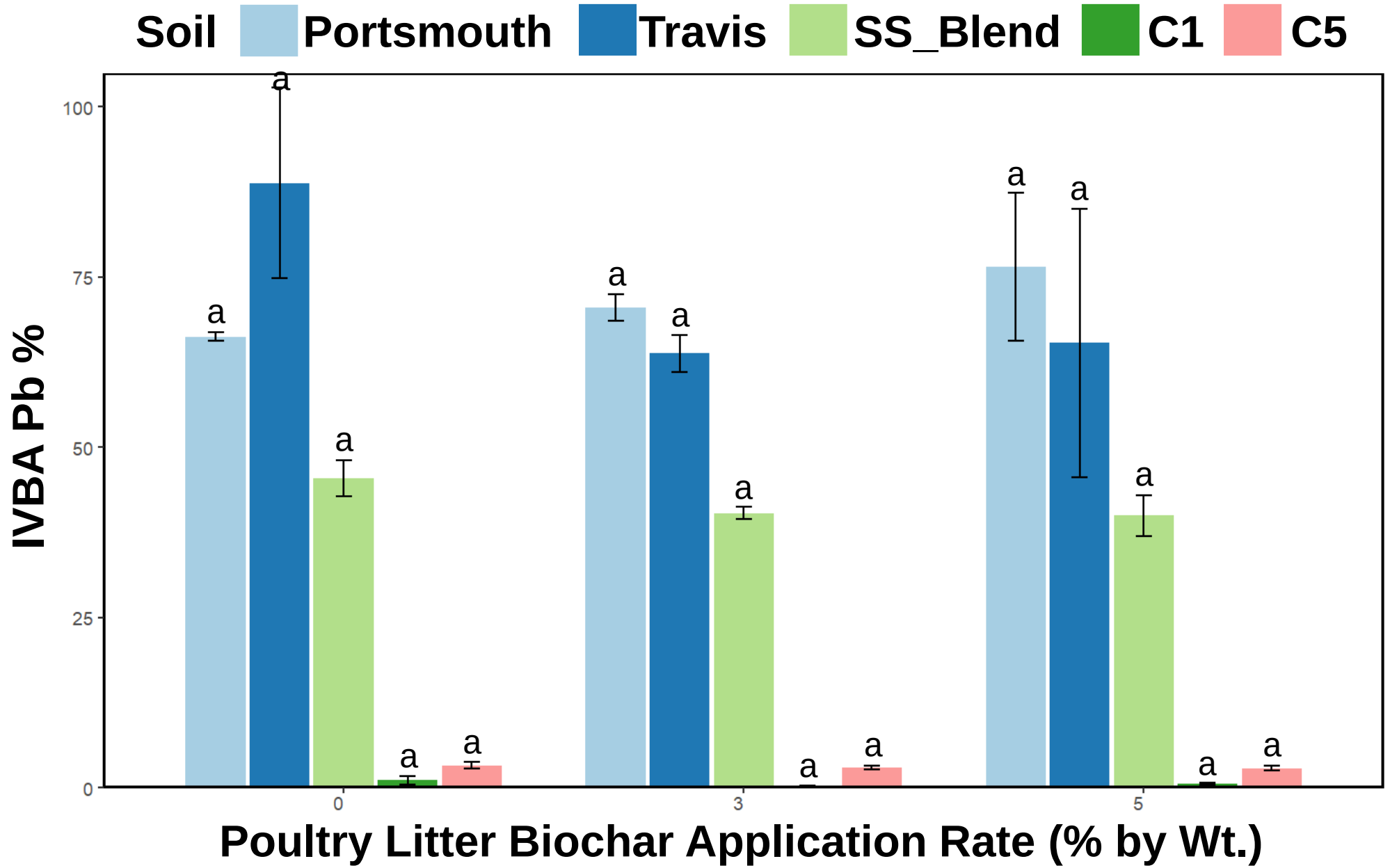

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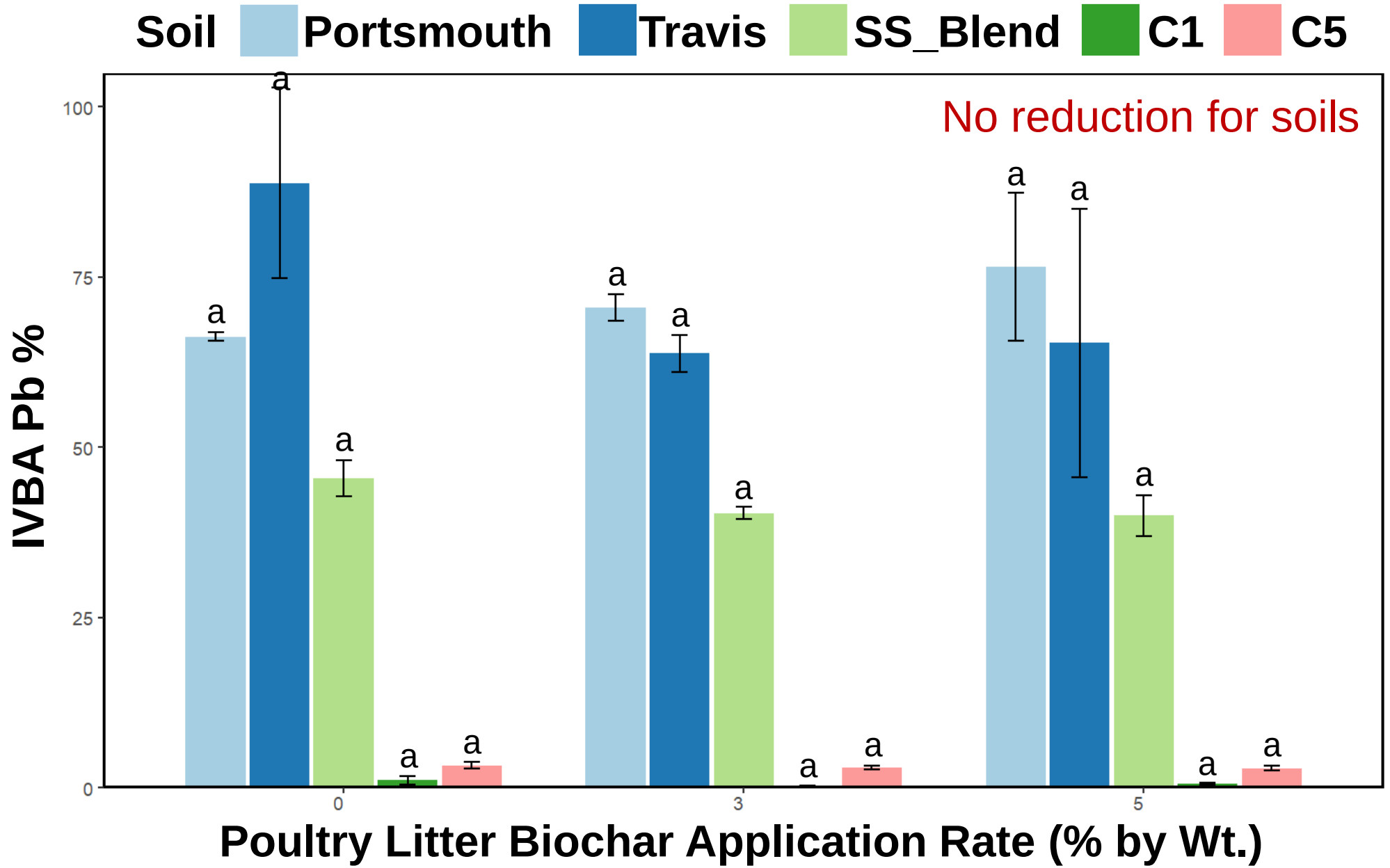

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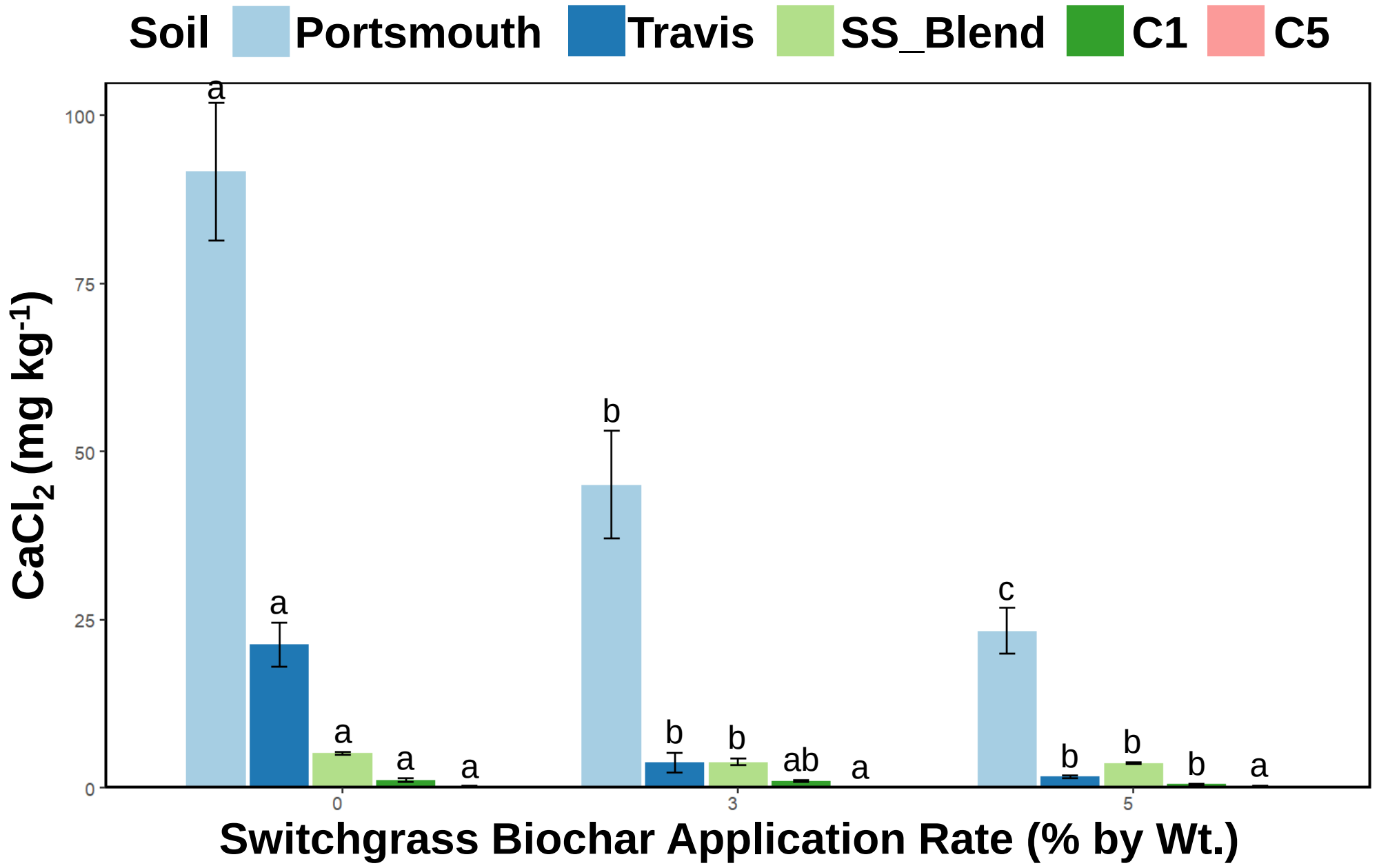

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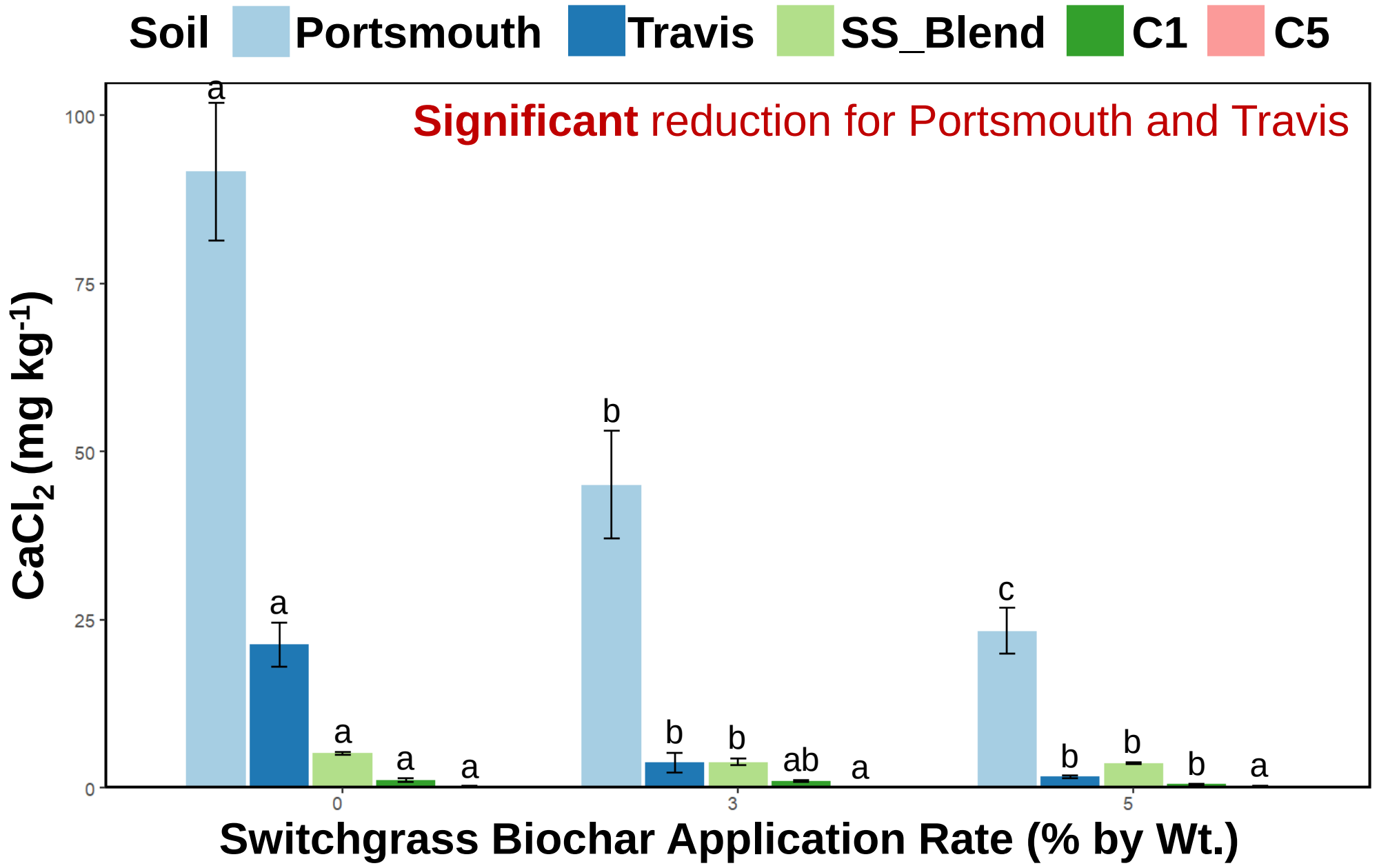

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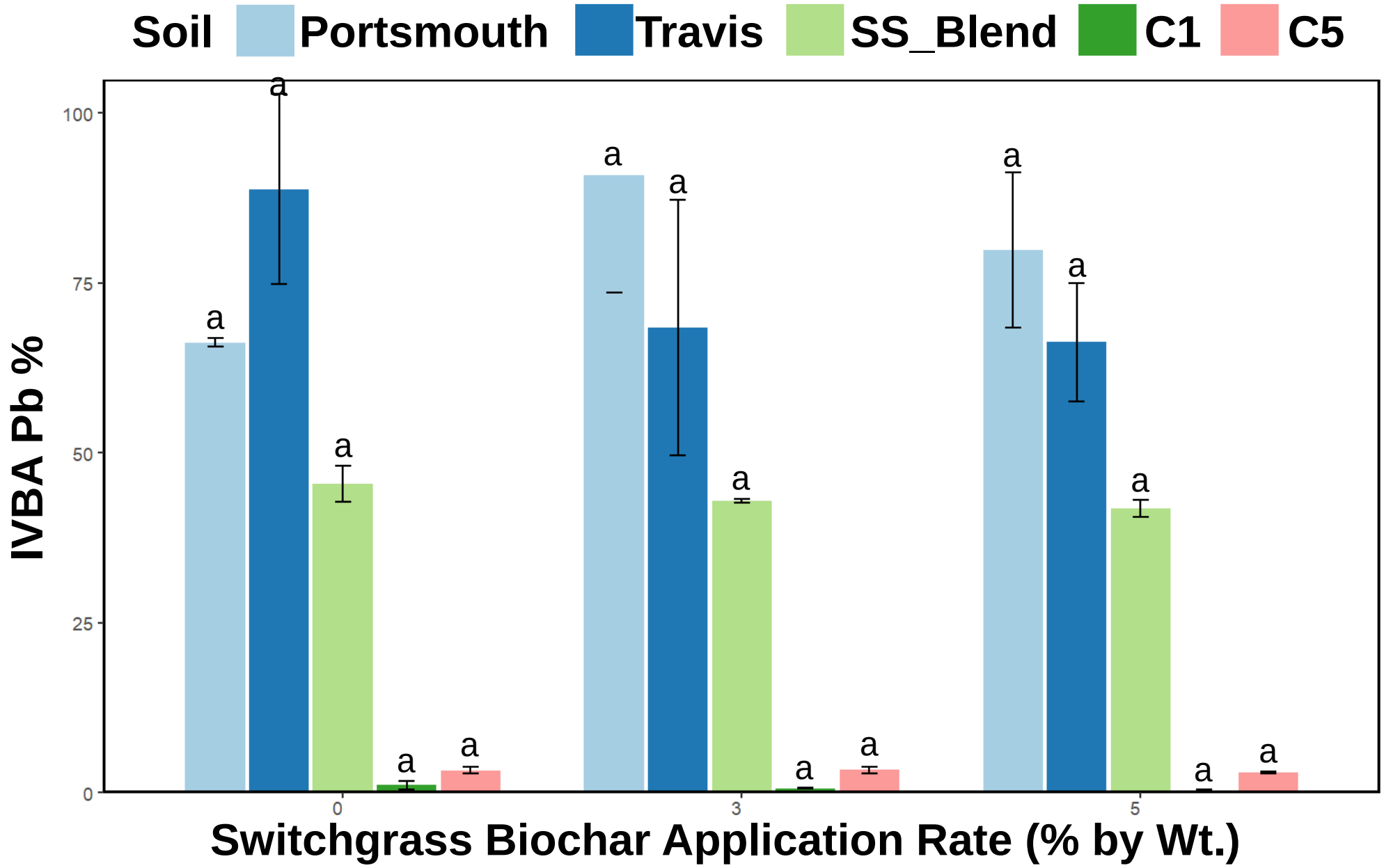

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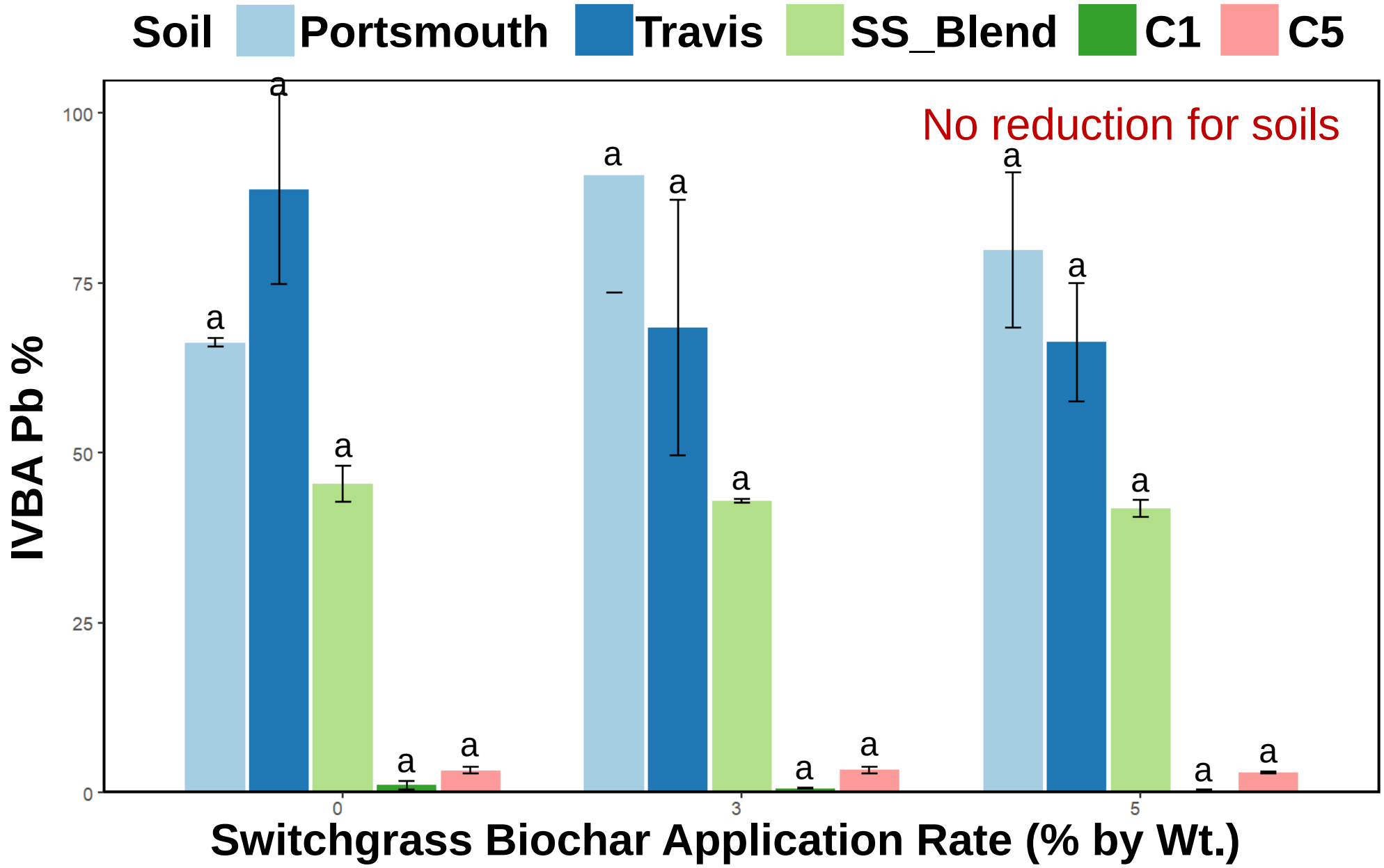

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- Overall, biochars ⬇ available Pb in soils

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## Soil Ingestion IVBA Pb

- Overall, biochars did not significantly affect the %IVBA Pb
  - One exception – Biosolid 1 with Travis soil
- Inconsistent with studies showing BC reducing soil %IVBA specifically in P-rich biochars.
  - Previous studies showed statistically significant but small reductions

# Conclusion

| Observation | Spiked Biochars | Soil & Biochar Blend |
|---|---|---|
| Biochars significantly reduced plant / invertebrate available Pb | | |
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- Biochar is **effective** at reducing bioaccessible Pb to plant and soil invertebrates at **environmental conditions**
- Biochar is **ineffective** at reducing bioaccessible Pb for human soil ingestion in the **highly acidic** environment of stomach conditions

# Acknowledgements


- **Nicholas Basta, PhD**
- **Simon Power, PhD**
- **The Soil Water and Environmental Laboratory (SWEL), OSU**



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