Reversing the C Balance of Soil-Free Substrates By Substituting Biochar for Peat

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Question

Can softwood biochar (BC) be used to replace peat moss (PM) in soil-free substrates?

Rationale

- Soil-free substrates are the basis for greenhouse and nursey industries, including production of ornamental flower plants
- Substrates typically have an inorganic + organic component
- There is increasing pressure for alternative to PM
  - Increasing expense and competing uses for PM
  - Harvest impacts on wetland ecosystems
  - Conversion of C sink to source
  - Perception as unsustainable
- BC is a strong candidate substitute for PM
- Most studies involve low substitution (generally <20%), or examine BC additions (1-5%) to PM-based substrates
- Liming effect of BC may produce elevated (alkaline) pH substrates at high substitution rates

Methods

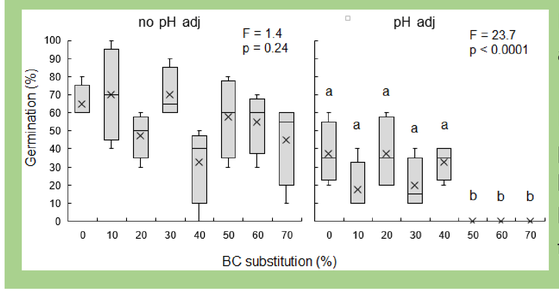
- Marigold (*Tagetes erecta* cv. Crackerjack) germination, growth, and early flowering (9 weeks) tested across a gradient of BC substitution
  - Greenhouse trial, 2x8 factorial RCB (n=4)
  - Fertigation with 1% Hoagland solution
  - BC substituted for PM in standard 70:30 (v/v) PM:perlite substrate at 10 %v increments
- pH adjusted to 5.8 in a duplicate set of substrates using the pyrolysis by-product pyroligneous acid (PLA), or $Ca(OH)_2$

BC (% vol)	Substrate composition (BC-Peat-Perlite)	Substrate pH	
		no pH adj	pH adj
0	0-70-30	4.4	5.8
10	10-60-30	5.6	5.8
20	20-50-30	6.6	5.8
30	30-40-30	7.7	5.8
40	40-30-30	8.2	5.8
50	50-20-30	9.3	5.8
60	60-10-30	9.7	5.8
70	70-0-30	10.4	5.8

- BC produced by 800 °C pyrolysis of mixed softwood (n=8 species) from Sierra Nevada
- Properties: pH 10.9, EC 515 µS cm^{-1}, 62% C, C:N 98.0, ash 16.6%, BET surface area 408.4 m^2 g^{-1}, WHC 238 g g^{-1}

Results

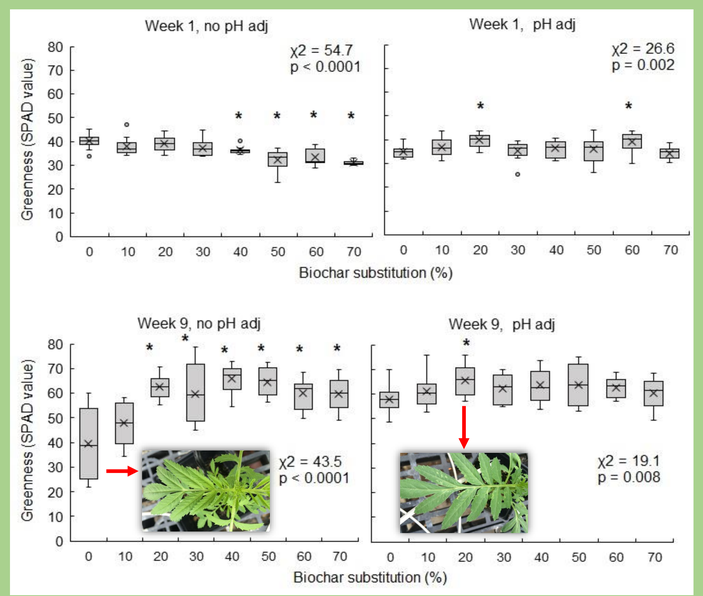
1. Plant Germination



Lower germ. in pH adj substrates

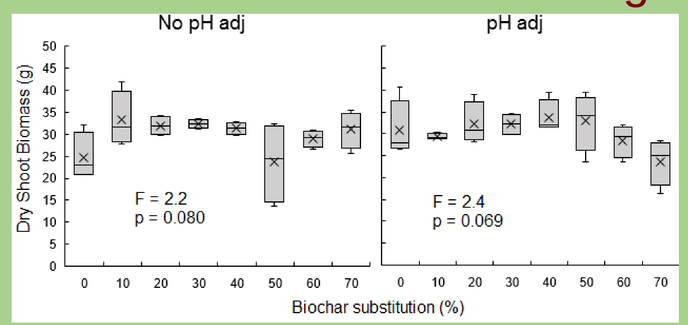
No germ. in high BC, pH adj substrates likely due to use of high amounts of PLA to suppress pH

2. Plant Growth



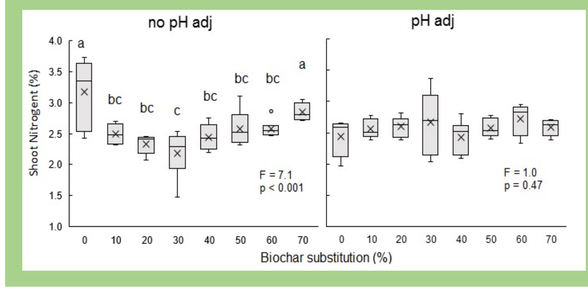
- Greenness (SPAD values) serves as proxy for chlorophyll content
- Lower initial (wk 1) chlorophyll in high BC substrates, but higher for BC substrates adjusted to pH 5.8
- Final (wk 9) greater chlorophyll in BC substrates without pH adj
- Plant heights show similar response as chlorophyll

3. Plant Biomass & Flowering



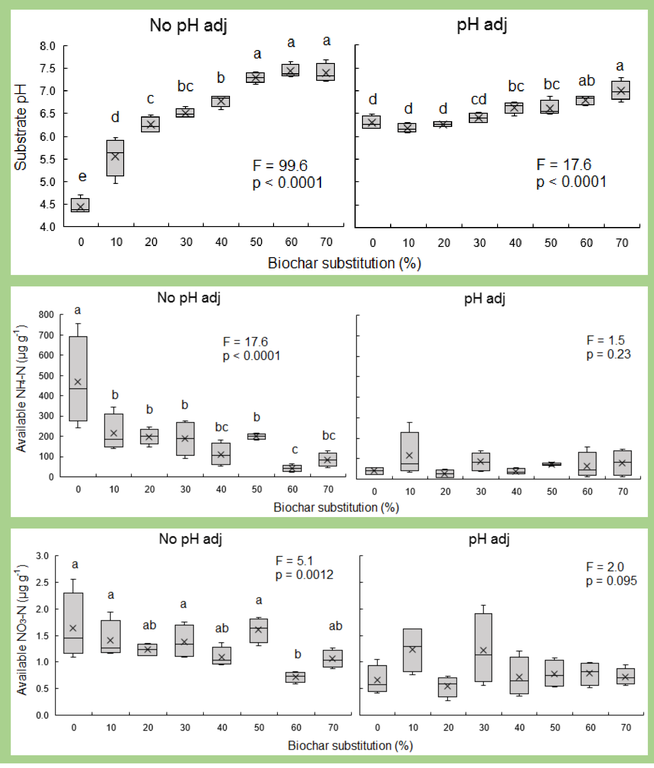
Shoot, flower, non-flower biomass, harvest index, and number of flowers did not significantly ($p < 0.05$) differ across gradient of BC substitution

4. Plant N uptake

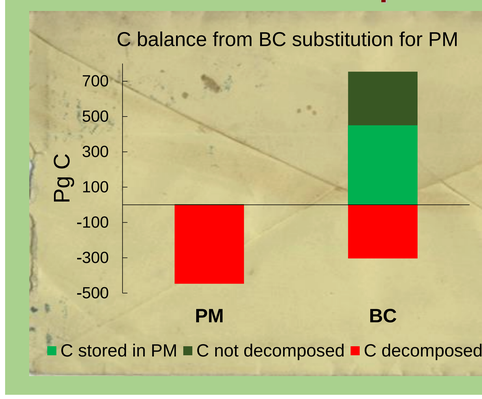


Shoot N was reduced under 10-60% BC vs 0% BC control when substrate pH was not lowered to 5.8

5. Changes in BC substrates



6. Theoretical Impact on C balance



Assumptions:

Half-life ($t_{1/2}$):
- PM = 13.5 yr
- BC = 100 yr*

C content:
- PM 50%
- BC 68%
- 450 Pg C in global peatlands
- BC made from wastestream

*conservative estimate

Discussion

- Full BC substitution of PM (70% substrate volume) does not compromise marigold growth or early-stage flowering
- Use of PLA to adjust pH to substrate optimum (5.8) may inhibit germination and retard plant growth
- Though high BC substrates have alkaline pH that initially retards plant growth and chlorophyll content, under fertigation pH decreases and does not impact 9 wk growth
- BC substitution x pH impacts N availability and plant uptake

Conclusions & Implications

- BC can be fully substituted for PM without negative effects on plant performance in greenhouse production
- BC substitution can impact N availability and plant uptake, which may vary by fertilization, BC, and plant type
- The 'liming effect' of BC at high substitution rates can impact initial but not final (9 week) plant growth, indicating pH adjustment may not be necessary depending on BC liming equivalence and plant type
- Greater recalcitrance ($t_{1/2}$) of BC relative to PM means that BC-based substrates could improve C balance by lowered CO_2 release, in addition to preserving the key C sink represented by global peatlands (450 Pg C)
- High nutrient loading under greenhouse fertigation makes post-harvest substrates a potential fertilizer
- Additional work should examine diverse plant and BC types

Acknowledgements: We thank Mike Woelk of Corigin, LLC for providing the Biochar.