Characterization of biochars from fresh and reused miscanthus horticultural substrate for agricultural use

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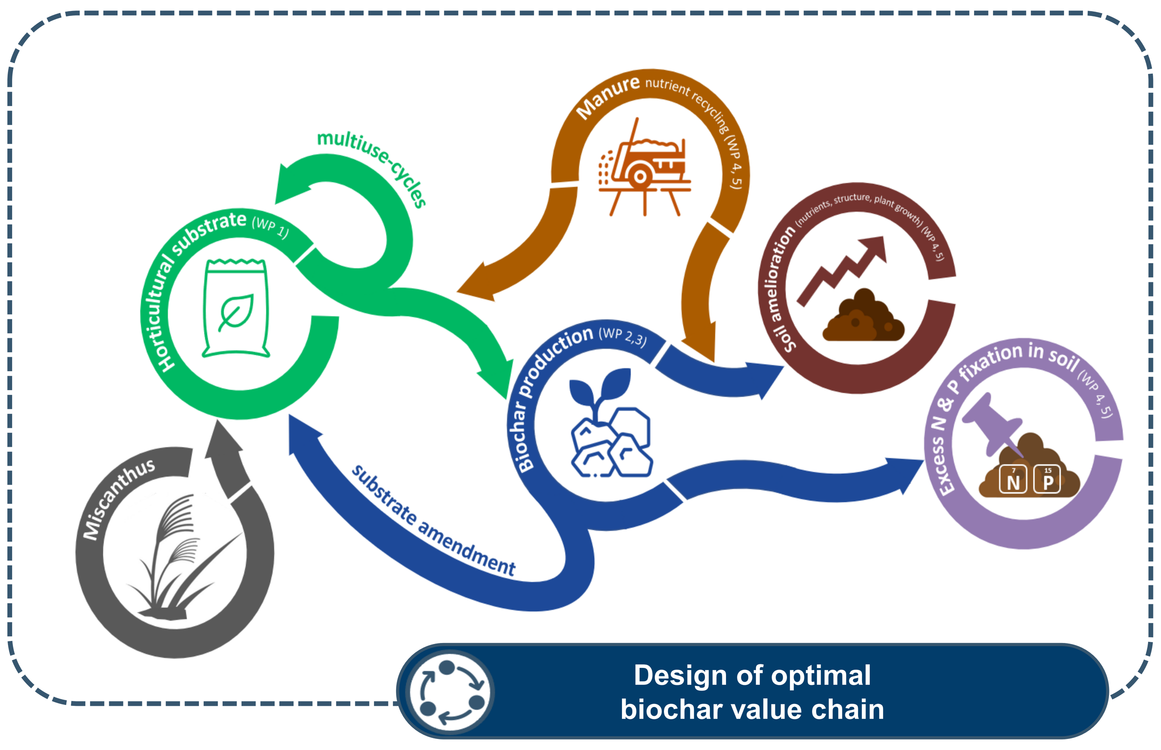
Concept and goal

NewBIAS (**New Biochars** for **Improvement** of **Agricultural Soils**) project **goal**: evaluate the technical, environmental and economic aspects of the cascade-use of *Miscanthus x giganteus* as alternative horticultural-substrate for peat and as biochar for carbon storage and nutrient recovery in soil.



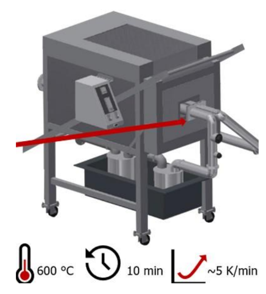
- In Germany, 8.5 million m³ of peat are used annually as horticultural substrate, emitting 1.0 million tons of CO_2 eq.
- *Miscanthus giganteus* grows well in diverse soils and climates and can successfully substitute peat.
- **Goal:** characterize **biochars** from fresh miscanthus and miscanthus used as horticultural substrate for their **optimal agricultural use**.

Feedstocks, biochar production and analyses

Figure 1. Illustration of fresh miscanthus (a), miscanthus substrate used 1x (b), biochar from fresh miscanthus (c) and biochar from miscanthus substrate used 1x (d).

Abbreviation feedstocks and biochars:
FM = fresh miscanthus substrate
UM = miscanthus used 1x as substrate
UM2x = miscanthus used 2x as substrate
Bfm = biochar from FM
Bum = biochar from UM
Bum2x = biochar from UM2x

- **Feedstocks:** fresh *Miscanthus giganteus* (FM); *M. giganteus* used as growth substrate for one (UM) or two (UM2x) tomato cycle(s) in greenhouse.
- **Biochars:** biochar from FM (Bfm), UM (Bum) and UM2x (Bum2x) were produced in a muffle furnace. Illustration in Fig. 1



Biochar Analyses:

- **Yield, chemical and elemental analysis:** yield (kg kg⁻¹ dry weight), pH ($CaCl_2$), ash (%), C (%), N (%), H (Table 1).
- **Inductively Coupled Plasma Optical Emission spectroscopy (ICP-OES):** digestion of samples (50 mg) with 2 ml HCl+0.7 ml HNO_3 in microwave (Table 2).
- **Particle-size:** the mass of biochar retained in each sieve was expressed as percentage of the total initial mass (75 g) (Fig. 2).
- **Chemical structure (^{13}C-nuclear magnetic resonance, ^{13}C-NMR):** the spectra of FM, UM, UM2x, Bfm, Bum, and Bm2x, were divided in six chemical regions (Fig. 3). The relative intensity of each region was obtained and used to calculate the aromaticity index = aryl C/(alkyl C + *O*-alkyl C) and the hydrophobicity index = (aryl C + alkyl C)/(carboxyl C + *O*-alkyl C) (Table 3).

Chemical, physical and structural characterization of biochars

Table 1. Yield, pH, and ash, C, N, and H content, of biochar from fresh miscanthus (Bfm), miscanthus used one time (Bum) and two times (Bum2x) as substrate for tomato growth. Values are means of analysis in triplicate.

Biochar	Yield (kg kg⁻¹, dry)	pH	Ash (%)	C (%)	N (%)	H (%)
Bfm	27.7	9.0	10.1	82.3	0.26	1.72
Bum	29.6	9.1	28.2	64.7	1.37	1.38
Bum2x	11.9	9.0	21.4	70.8	1.10	1.70

Table 2. ICP-OES analysis of biochar from fresh miscanthus (Bfm), miscanthus used one time (Bum) and two times (Bum2x) as substrate for tomato growth. Values are means of analysis in triplicate.

Element (g kg⁻¹)	Bfm	Bum	Bum2x
P	3.0	24.4	14.4
K	15.1	13.1	21.2
Ca	2.4	59.2	51.1
Mg	1.0	5.4	7.8
Na	0.2	1.1	2.2
S	0.1	7.7	10.7

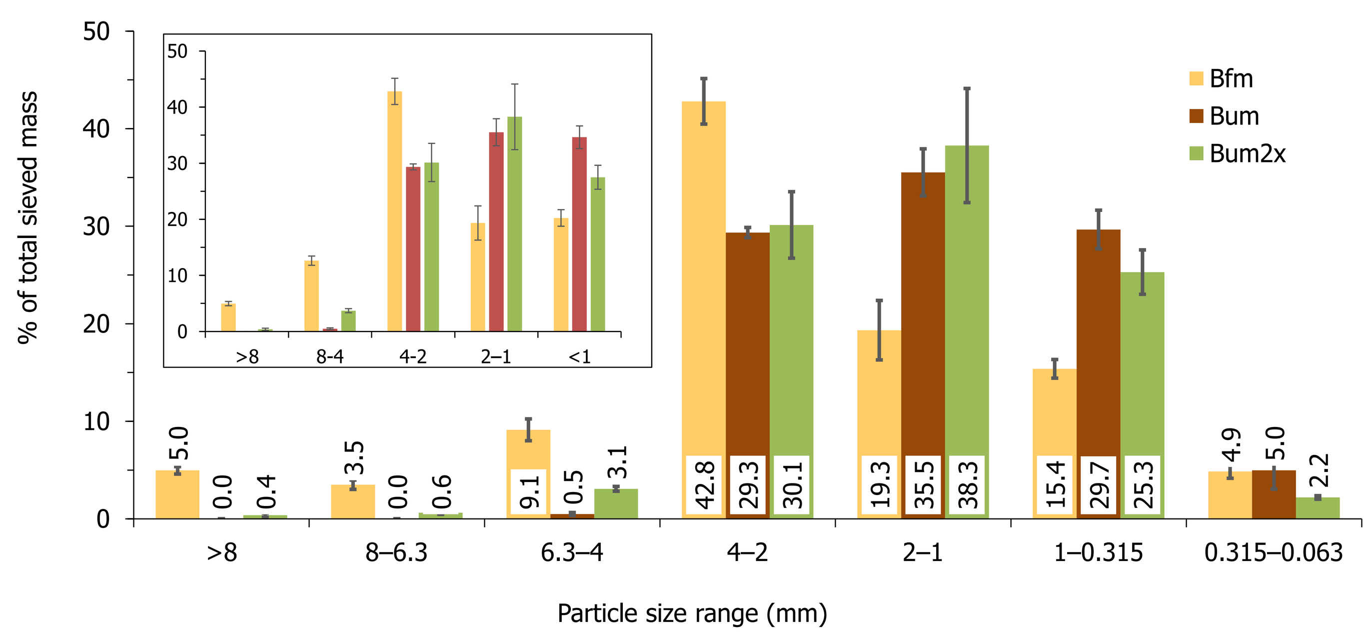


Figure 2. Particle size distribution of biochar from fresh miscanthus (Bfm), miscanthus used one time (Bum) and two times (Bum2x) as substrate for tomato growth. Values are means and error bars show standard deviation of analysis in triplicate.

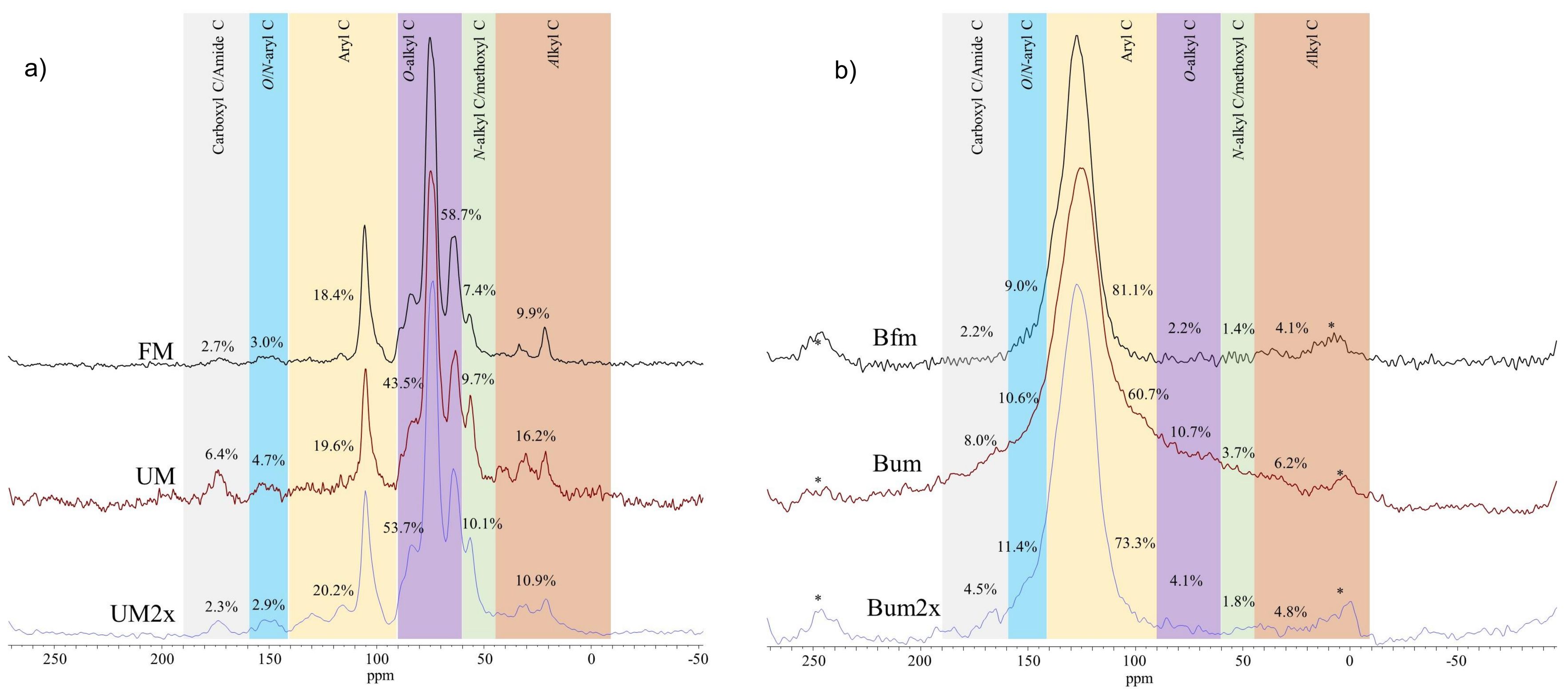


Figure 3. Solid-state ^{13}C-nuclear magnetic resonance spectrum of fresh miscanthus (FM), miscanthus used one time (UM) and two times (UM2x) as growth substrate for tomato (a), and their respective biochars, Bfm, Bum, and Bum2x (b). *spinning-side bands.

Table 3. ^{13}C-NMR aromaticity (Ar) and hydrophobicity (Hy) index of fresh miscanthus (FM), miscanthus used one time (UM) and two times (UM2x) as growth substrate for tomato, and their respective biochars, Bfm, Bum, and Bum2x.

Index	FM	UM	UM2x	Bfm	Bum	Bum2x
Ar	0.27	0.33	0.31	12.9	3.9	8.2
Hy	0.46	0.72	0.56	19.4	3.5	9.0

Remarks and Outlook

- ✓ The **enrichment of Bum and Bum2x with nutrients in comparison to Bfm** (Table 2) likely reflects the presence of root residues and residual fertilizer in UM and UM2x substrate.
- ✓ **Bum and Bum2x fragmentation relative to Bfm** (Fig. 2) reflects the partial decomposition of UM and UM2x during tomato growth.
- ✓ The carboxyl-C (%) in Bum and Bum2x was 3.6- and 2.0-fold greater than in Bfm (Fig. 3). The **Ar and Hy indexes were higher in Bfm** (Table 3) due to the partial decomposition of UM and UM2x relative to FM.
- ✓ Particularly, **Bum is proximate to Bum2x** in terms **of particle-size and nutrient status,** while being **more functionalized and exhibiting similar yield** (Table 1) in relation to Bfm**.**
- ✓ Together with Bfm, **Bum emerges as a valuable product more viable to up-scaling** compared to Bum2x.

Ministry of Culture and Science
of the German State
of North Rhine-Westphalia

Facts and Figures
Established: 2010
Staff: > 1400
Funding: u.a. MKW, BMBF, DFG, EU
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Support
The BioSC is supported by ministry of Culture and Science of the state of North Rhine-Westphalia on a long-term basis within the framework of the NRW-Strategieprojekt BioSC.