**Supplementary Material**

**File S1**Measurements of length, width, area, perimeter, and ratios of L/W, W/L, and A/P for all taxa and temperatures (data assets).

**File S2**. The median aspect ratios (*W/L*) of charred particles from the individual measurements burned at 250°C, 300°C, 350°C, and 400 °C respectively. The abbreviations used in the figure are S & L – stem and leaf, I-inflorescence; where this is not noted it implies mixed plant parts. The individual taxa grouped into grass and forb in the inset are indicated by the same colour as in individual measurements. Box plots represent the distribution of data as follows: the horizontal line in each box denotes the median, the upper quartile is the median value of the upper half of the data points, the lower quartile is the median value of the lower half of the data points, and whiskers represent the respective minimum and the maximum values. Individual and mean *W/L* values for each temperature are presented in Table 2. For color coding see Fig. 1.



**File S3**. The median Area to Perimeter ratio (*A/P*) of charred particles from the individual measurements burned at 250°C, 300°C, 350°C, and 400 °C. The individual taxa grouped into grass and forb in the inset are indicated by the same colour as in individual measurements. Box plots represent the distribution of data as follows: the horizontal line in each box denotes the median, the upper quartile is the median value of the upper half of the data points, the lower quartile is the median value of the lower half of the data points, and whiskers represent the respective minimum and the maximum values. Individual and mean *A/P* values for each temperature are presented in Table 2. Abbreviations and colour coding as in File S2.

****

**Table S1.** Mann-Whitney test for L/W equal medians between fuel types. Significance of p-values (<0.0001\*\*\*, 0.001\*\*, 0.01\* ). S=stem, L=leaf; I=inflorescence.

***L/W* Grass all Forbs Grass (I)**

**250°C**

Grass (all) - 0.0001 -

Grass (S, L) - - 0.0001

**300 °C**

Grass (all) - 0.0001 -

Grass (S, L) - 0.0001

**350°C**

Grass (all) - 0.0001 -

Grass (S, L) - - 0.013

**400°C**

Grass (all) - 0.0001 -

Grass (S, L) - - 0.001

**Table S2.** Summary of the mean aspect (*L/W, W/L*) and area to perimeter (*A/P*) ratios and mass retained (%) of charcoal produced in the muffle oven for individual plant species and fuel types from Mangalia near the Black Sea, Romania and Konoplyanka, Trans-Urals, Russia at 250°C, 300°C, 350°C, 400°C. Mean all T represents the mean values of each variable at all temperatures and for all taxa, and separated by plant parts (S=stem, L=leaf; I=inflorescence), see also Table 1. SD=standard deviation.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Fuel types** | **Species** | **Aspect ratio (L/W and W/L)** | | | | **Area/Perimeter** | | | | **Mass retained** | | | |
| **Temperature** |  | **250** | **300** | **350** | **400** | **250** | **300** | **350** | **400** | **250** | **300** | **350** | **400** |
| **Graminoid** | *Agropyron repens* (S) | 4.9±3.5  0.3 ±0.16 | 4.8±4.6  0.31 ±0.15 | 3.5±2.1  0.37 ±0.18 | N/A | 53±30 | 60±36 | 55±35 | N/A | 52 | 31 | 13 | 7 |
|  | *Agropyron repens* (F) | 4.3±1.4  0.3 ±0.05 | 2.8±1.8  0.5 ±0.19 | 2.7±1.2  0.44 ±0.18 | 2.1±0.7  0.52±0.15 | 59±38 | 60±36 | 54±33 | 55±33 | 53 | 37 | 25 | 8 |
|  | *Agropyron sp* | 4.5±2.5  0.28 ±0.13 | 4.0±2.3  0.32 ±0.16 | 4.2±2.5  0.32 ±0.17 | N/A | 47±24 | 48±29 | 37±24 | N/A | 44 | 29 | 20 | 3 |
|  | *Agropyron cristatum* (S) | 4.6 ±3.7  0.28 ±0.26 | 3.4 ±1.8  0.35 ±0.15 | 3.4 ±2.0  0.40 ±0.2 | 4.1 ±3.1  0.35 ±0.2 | 65±33 | 66±38 | 60±37 | 42±28 | 50 | 35 | 25 | 5 |
|  | *Agropyron cristatum* (F) | 3.1 ±1.9  0.4 ±0.18 | 3.8±2.2  0.4 ±0.19 | 3.5±1.6  0.38 ±0.21 | 2.7±1.9  0.47±0.2 | 55±26 | 51±30 | 49±33 | 47±30 | 54 | 37 | 20 | 3 |
|  | *Bromus sterilis* | 4.7 ±3  0.28 ±0.14 | 4.7 ±2.9  0.29 ±0.17 | 4.5 ±2.6  0.29 ±0.15 | N/A | 51±30 | 53±29 | 42±27 | N/A | 48 | 31 | 13 | 3 |
|  | *Festuca sp.* | 4.0 ±2.2  0.31 ±0.15 | 3.7 ±2.1  0.34 ±0.17 | 3.4 ±1.8  0.37 ±0.18 | 4.7 ±2.9  0.3±0.17 | 52±33 | 57±29 | 49±30 | 38±25 | 49 | 32 | 20 | 6 |
|  | *Poa sp* | 4.9 ±3.1  0.28 ±0.16 | 5.1 ±3.6  0.28 ±0.16 | 4.3 ±2.4  0.30 ±0.16 | 4.3 ±3.1  0.33 ±0.18 | 49±27 | 50±29 | 46±55 | 27±15 | 55 | 33 | 17 | 4 |
|  | *Stipa capilata* | 5.3 ±3.8  0.26 ±0.15 | 3.2 ±2.1  0.41 ±0.19 | 3.8 ±2.2  0.36 ±0.18 | 3.4 ±1.8  0.36±0.14 | 65±40 | 66±41 | 43±33 | 24±12 | 49 | 36 | 17 | 4 |
|  | ***Mean*** | ***5.2 ±2.9***  ***0.36 ±0.29*** | ***3.9±2.2***  ***0.39 ±0.18*** | ***3.3 ±2.8***  ***0.38 ±0.18*** | ***3.7 ±2.7***  ***0.4 ±0.13*** | ***54 ±64*** | ***53 ±34*** | ***49±30*** | *44±24* | ***50*** | ***34*** | ***19*** | ***4.5*** |
|  | **Mean all T** | **4.0 ±2.5 (all taxa)** | **4.2±2.8 (S, L)** | **2.9±1.9 (I)** |  | **50±30 (all taxa)** | **47±29 (S,L)** | **52±24(I)** |  |  |  |  |  |
| **Forbs**  **(whole)** | *Anthemis tinctoria (stem)* | 3.1±1.7  0.4±0.2 | 3.2±1.8  0.4±0.17 | 2.5±1.5  0.5±0.18 | 3.2±2.6  0.44±0.21 | 64±50 | 51±37 | 53±33 | 35±20 | 57 | 38 | 25 | 7 |
|  | *Anthemis tinctoria (flower)* | 3.7±2.9  0.35±0.24 | 2.6±1.3  0.46±0.18 | 2.8±1.5  0.44±0.19 | N/A | 57±25 | 56±35 | 57±34 | 572±535 | 57 | 44 | 32 | 11 |
|  | *Artemisia campestris* | 3.8±3.1  0.38±0.2 | 3.0±1.7  0.43±0.2 | 3.5±2.2  0.39±0.2 | 3.8±2.7  0.35±0.18 | 53±36 | 58±36 | 56±30 | N/A | 60 | 42 | 32 | 13 |
|  | *Achillea* sp. | 3.2 ±1.9  0.4 ±0.19 | 3.0 ±1.5  0.4 ±0.17 | 3.0 ±1.9  0.4 ±0.18 | 3.4 ±2.0  0.4 ±0.18 | 53±29 | 50±58 | 46±27 | 36±21 | 53 | 45 | 35 | 16 |
|  | *Xeranthemum annuum* | 4.0 ±2.3  0.24 ±0.2 | 3.1 ±1.9  0.41 ±0.18 | 2.9 ±1.7  0.42 ±0.18 | 4.0 ±3.1  0.36 ±0.2 | 55±37 | 57±32 | 58±38 | 38±26 | 63 | 44 | 33 | 17 |
|  | *Eryngium campestre* | 2.5 ±1.0  0.4 ±0.16 | 2.7 ±1.9  0.47±0.2 | 2.9 ±2.3  0.46±0.2 | here | 68±51 | 68±42 | 52±33 |  | 56 | 36 | 24 | 8 |
|  | *Chenopodium* | 3.6 ±2.6  0.4 ±0.2 | 4.6 ±3.5  0.3 ±0.17 | 3.2 ±2.1  0.41 ±0.2 | 3.2 ±1.7  0.38 ±0.17 | 56±30 | 52±38 | 59±35 | 52±31 | 65 | 45 | 35 | 22 |
|  | *Euphorbia glareosa* | 2.7 ±1.7  0.46 ±0.2 | 2.7 ±1.6  0.47 ±0.2 | 2.1 ±1.1  0.55 ±0.18 | 2.5 ±1.5  0.48 ±0.2 | 47±24 | 61±35 | 63±43 | 44±27 | 52 | 43 | 32 | 9 |
|  | *Leonurus* | 2.5 ±1.17  0.46 ±0.16 | 2.7 ±1.8  0.48 ±0.19 | 2.2 ±0.9  0.51 ±0.16 | 2.4 ±1.2  0.49 ±0.18 | 63±45 | 79±52 | 64±42 | 41±25 | 58 | 42 | 32 | 8 |
|  | *Thymus hirsutus* | 3.7±2.5  0.38 ±0.2 | 2.9±1.5  0.42 ±0.17 | 2.9±1.7  0.42 ±0.18 | 2.9±2.0  0.44 ±0.2 | 55±27 | 47±30 | 56±33 |  | 57 | 41 | 25 | 9 |
|  | *Genista tinctoria* | 3.5±3.0  0.4 ±0.18 | 2.6±3.0  0.4 ±0.18 | 4.0 ±3.3  0.36 ±0.2 | 2.4 ±1.5  0.51 ±0.19 | 53±38 | 79±52 | 45±31 | 40±29 | 54 | 38 | 29 | 8 |
|  | *Astragalus sp.* | 3.9 ±2.1  0.32 ±0.16 | 2.5 ±1.2  0.48 ±0.18 | 3.0 ±1.8  0.42 ±0.18 | 2.6 ±1.7  0.48 ±0.2 | 51±24 | 59±42 | 61±43 | 46±31 | 47 | 41 | 24 | 7 |
|  | *Galium* | 2.6 ±1.4  0.46±0.18 | 3.4 ±2.1  0.38±0.2 | 3.3 ±1.9  0.38±0.18 | 3.9 ±4.0  0.41±0.2 | 63±41 | 56±33 | 45±25 | 47±33 | 55 | 40 | 25 | 5 |
|  | *Cannabis ruderalis* | 2.1 ±0.95  0.55 ±0.17 | 2.1 ±0.8  0.53 ±0.17 | 4.0 ±3.1  0.37 ±0.2 | 3.5 ±2.9  0.4 ±0.2 | 57±47 | 72±53 | 47±27 | 34±19 | 58 | 48 | 33 | 15 |
|  | ***Mean*** | ***3.2 ±2.2***  ***0.40 ±0.2*** | ***3.0 ±1.9***  ***0.43 ±1.9*** | ***3.0 ±2.1***  ***0.38 ±1.8*** | ***3.3 ±2.5***  ***0.40 ±1.3*** | ***57 ±38*** | ***59±38*** | ***49±30*** | ***40 ±25*** | ***57*** | ***42*** | ***30*** | ***11*** |
|  | **Mean all T** |  | **3.1±2.2**  **0.42±0.19** |  |  |  |  | **53±34** |  |  |  |  |  |
| **Wood (shrub twig)** | *Ephedra distachia* | 4.1±2.6  0.38±1.8 | 3.4±1.8  0.37±1.6 | 4.0±2.5  0.33±1.7 | 3.3±2.0  0.41±0.21 | 57±31 | 69±44 | 42±25 | 46±35 | 52 | 39 | 18 | 7 |