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Biomass yield and economic, energy and carbon balances of *Ulmus pumila* L., *Robinia pseudoacacia* L. and *Populus* × *euroamericana* (Dode) Guinier short rotation coppices on degraded lands under Mediterranean climate

Patricia Alesso [1], Raúl Tapias [1], Joaquín Alaejos [1] and Manuel Fernández [1,*]

[1] Department of Agroforestry Sciences, School of Engineering, University of Huelva, 21071 Huelva, Spain; palesso@hotmail.com (P.A.); rtapias@dcaf.uhu.es (R.T.); jalagut@dcaf.uhu.es (J.A.)
[2] Affiliation 2; e-mail@e-mail.com
* Correspondence: manuel.fernandez@dcaf.uhu.es (M.F.); Tel.: 34 959217712; Fax: 34 959217560

SUPPLEMENTARY MATERIAL

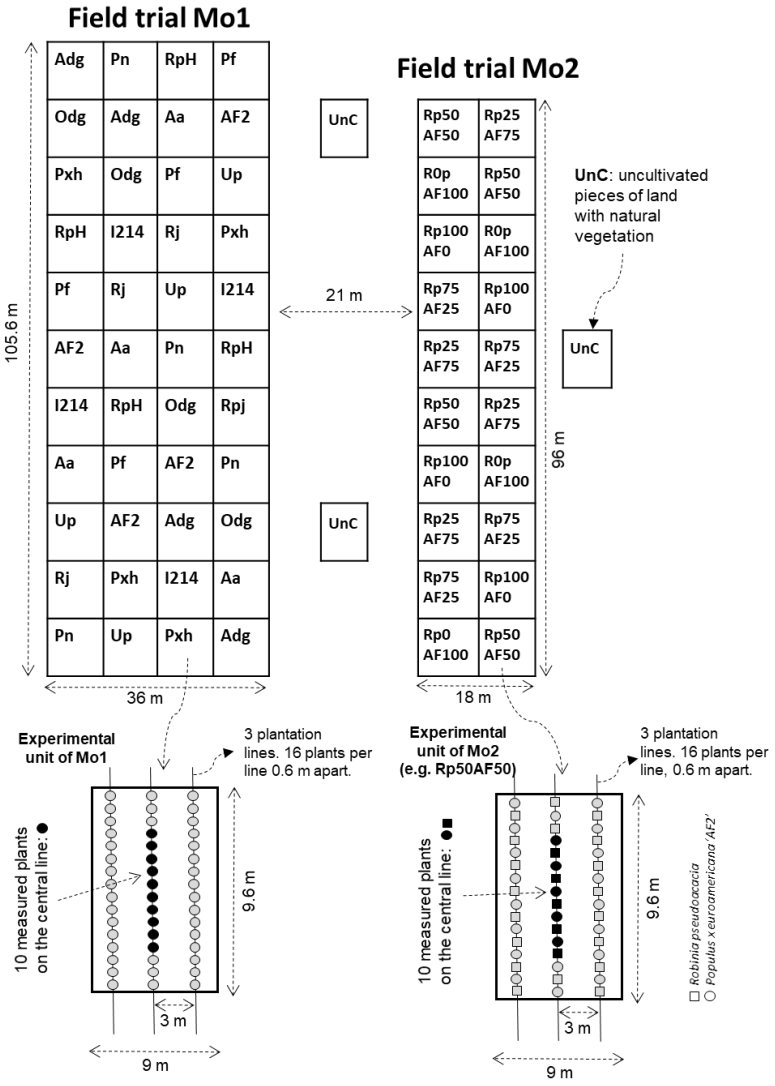

Figure S1. Schematic representation of the experimental design of the Mo1 (left) and Mo2 (right) field trials. Mo1 field trial: four hybrid clones of *Populus* × *euroamericana* (Dode) Guinier (clones 'Adige' [Adg], 'AF2' [AF2], 'Oudenberg' [Odg], I214 [I214]); one hybrid clone of *Populus* × *interamericana* van Broekhuizen (clone 'Raspalje' [Rj]); Pf, one clone of *Paulownia fortunei* (Seem.) Hemsl. (clone 'UHU'); RpH (*Robinia pseudoacacia*, improved cultivar 'Nyírségi'); commercial nursery plants of *Populus nigra* L. [Pn], *Ailanthus altissima* (Mill) Swingle. [Aa], *Platanus* × *hispanica* Mill. ex Münchh. [Pxh], and *Ulmus pumila* L. [Up]. Mo2 Treatments (combinations of the five different species compositions): 100% AF2 (Rp0-AF100); 25% Rp-G + 75% AF2 (Rp25-AF75); 50% Rp-G + 50% AF2 (Rp50-AF50); 75% Rp-G + 25% AF2 (Rp75-AF25); 100% Rp-G (Rp100-AF0). Rp-G (*Robinia pseudoacacia*, commercial nursery plants from Germany).

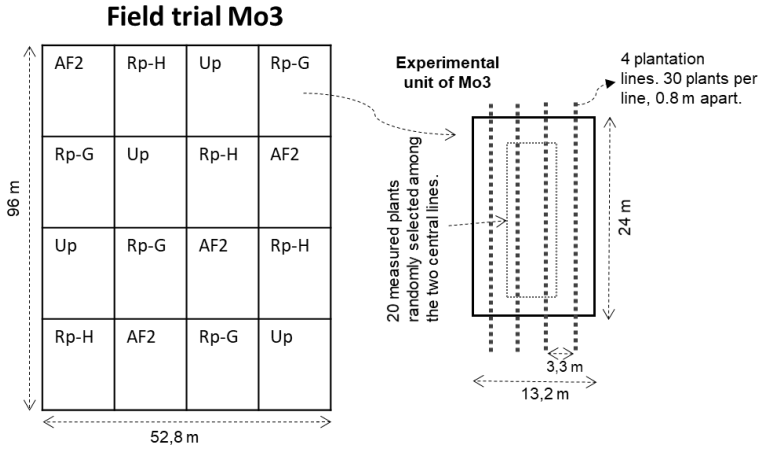

Figure S2. Schematic representation of the experimental design of the Mo3 field trial. AF2 (*Populus* × *euroamericana* 'AF2'), Rp-H and Rp-G (*Robinia pseudoacacia* cultivar 'Nyírségi' and German provenance, respectively); Up (*Ulmus pumila*).

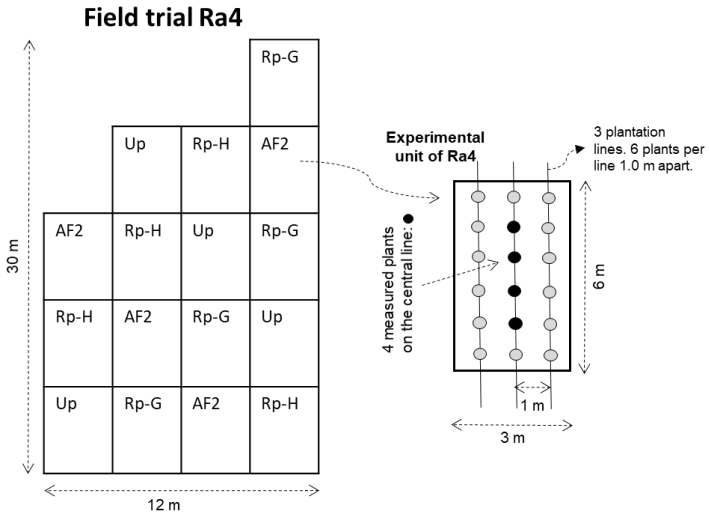

Figure S3. Schematic representation of the experimental design of the Ra4 field trial. AF2 (*Populus* × *euroamericana* 'AF2'), Rp-H and Rp-G (*Robinia pseudoacacia* cultivar 'Nyírségi' and German provenance, respectively); Up (*Ulmus pumila*).

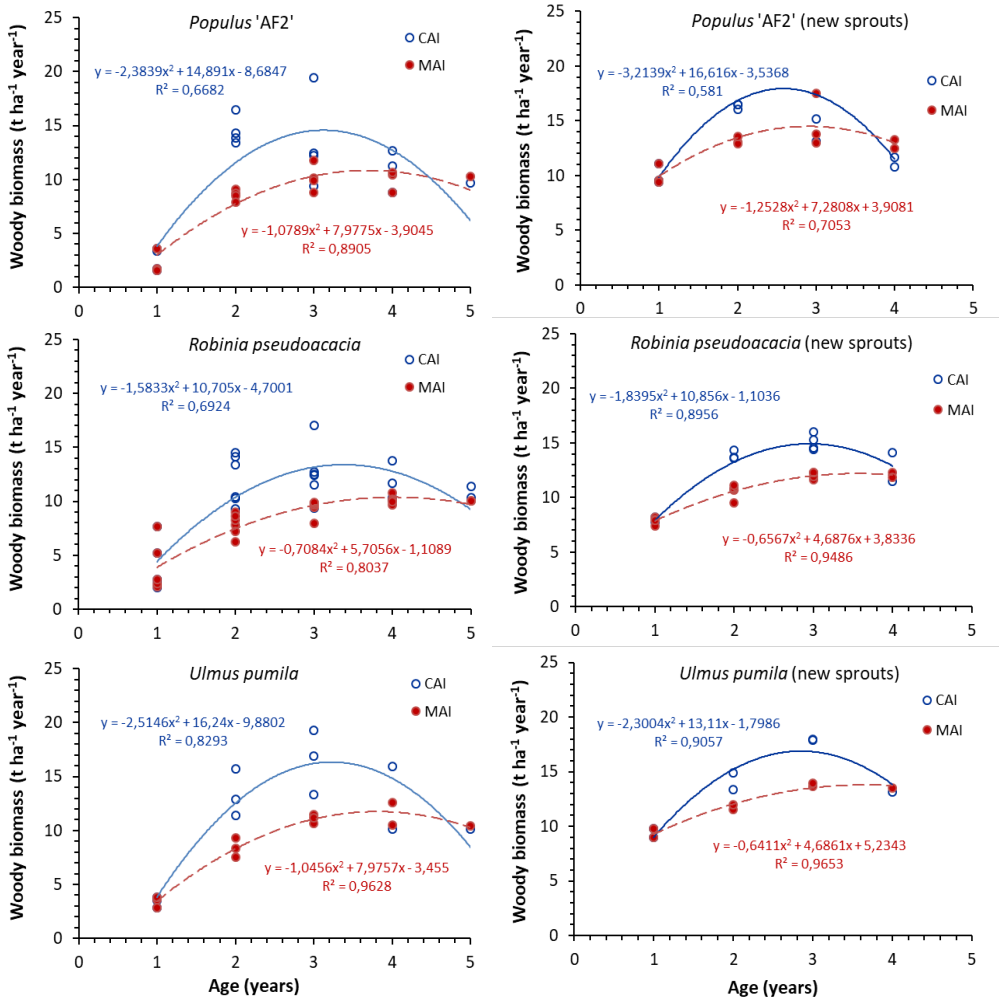

Figure S4. Current annual increment (CAI) and mean annual increment (MAI) of the woody biomass dry weight of the above-ground part of the plant (AGWB) throughout the period studied for the 1st (left) and 2nd (right) rotations and the three taxa. Data from all field trials are shown as a whole. Taxa: *Populus* AF2 (*Populus* × *euroamericana* 'AF2'), *Robinia pseudoacacia* (including cultivar 'Nyírségi' and German provenance); *Ulmus pumila*.

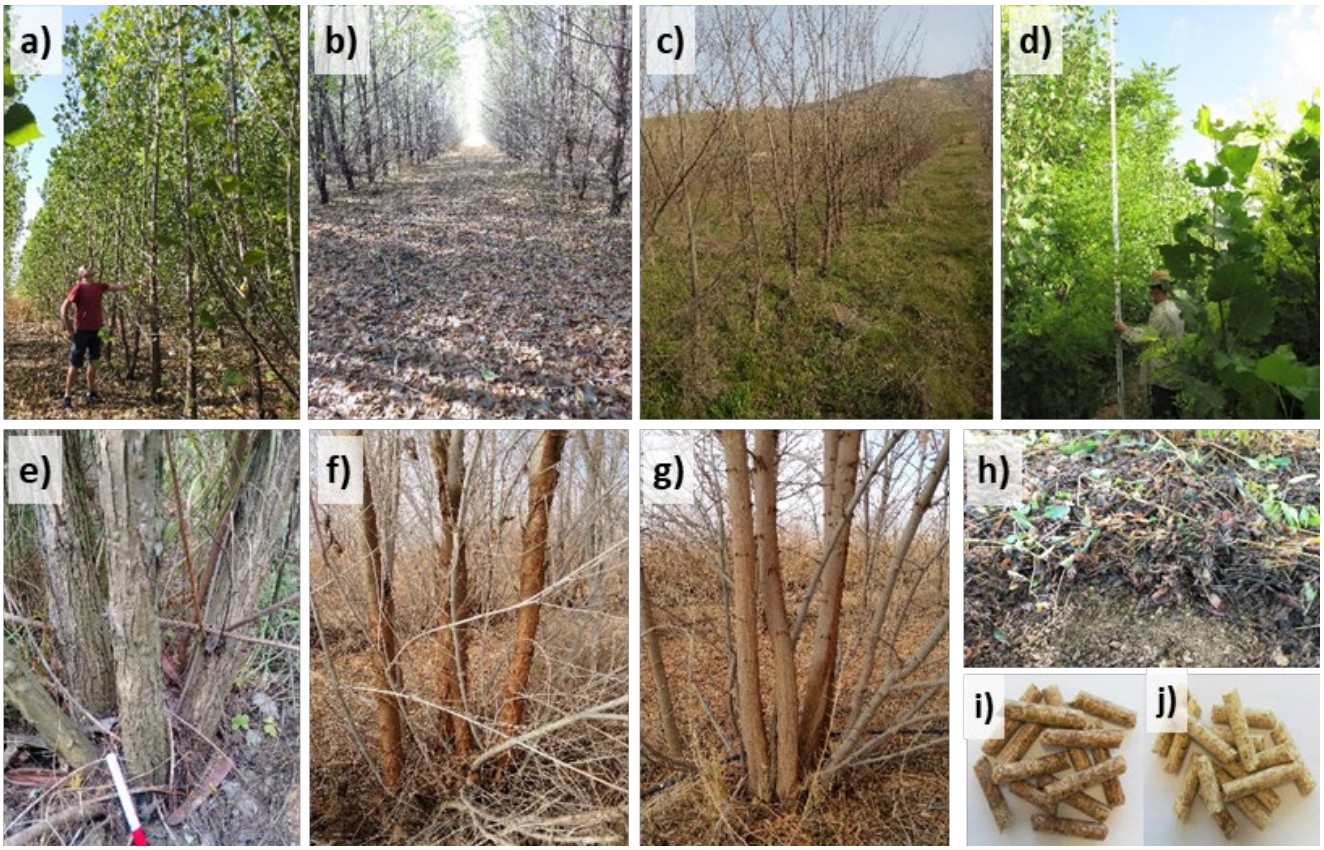

Figure S5. a) 3.5-years-old *Populus* × *euroamericana* 'AF2'; 1st rotation. **b)** 3.5-years-old *Ulmus pumila*; 1st rotation; it can be seen the litter layer on the soil surface; **c)** 2.0-years-old *Robinia pseudoacacia*; 1st rotation; it can be seen the grass grown during the cold season, which can be grazed by sheep. **d)** 2.0-years-old mixed plantation of *Populus* × *euroamericana* 'AF2' and *Robinia pseudoacacia*; 1st rotation. **e, f, g)** 3.0-years-old sprouts of *Populus* × *euroamericana* 'AF2', *Ulmus pumila* and *Robinia pseudoacacia*, respectively; 2nd rotation. **h)** Litterfall of *Robinia pseudoacacia.* **i, j)** Wood pellets from *Ulmus pumila* and *Robinia pseudoacacia*, respectively.

Table S1. Physical-chemical characteristics of the upper soil layer at the beginning of the experiments [mean (SE)]. *Mo* (Los Morales), *Ra* (La Rábida).

Variable	Field trials Mo1 and Mo2	Field trial Mo3	Field trial Ra4	
Sampling date	March 2011	March 2015	March 2015	
Soil layer thickness (cm)	0 – 30	0 – 30	0 – 15	15 – 30
Soil texture	Clay loam	Clay loam	Sandy loam	Sandy loam
Clay/silt/sand (%)	28.9 / 27.6 / 43.4	28.3 / 31.4 / 40.5	11.3 / 14.9 / 73.8	10.8 / 15.0 / 74.2
Fine soil (< 2 mm particle-size)	80.8	80.8	76.5	76.7
Bulk density (kg dm^{-3})	1.32	1.32	1.55	1.55
pH	8.30 (0.02)	8.25 (0.05)	8.62 (0.07)	8.68 (0.06)
Electric Conductivity (μS cm^{-1})	325 (6)	331 (3)	136 (1)	135 (3)
Exchangeable Sodium Percentage (%)	3.9 (0.2)	5.4 (0.1)	9.1 (0.3)	12.7 (0.1)
Organic Matter (%)	2.93 (0.09)	2.67 (0.03)	1.22 (0.02)	0.53 (0.05)
C/N ratio	10.64 (0.46)	9.16 (0.04)	11.27 (0.04)	13.74 (0.76)
Cation Exchange Capacity (meq/100 g)	16.2 (1.0)	16.24 (0.07)	6.27 (0.25)	5.14 (0.10)
Carbonates (%)	16.2 (1.7)	11.2 (0.04)	11.28 (0.08)	10.48 (0.15)
Active limestone (%)	7.57 (0.31)	3.31 (0.03)	1.27 (0.05)	1.71 (0.08)
N (%)	0.16 (0.01)	0.15 (0.01)	0.06 (0.01)	0.04 (0.01)
Organic Carbon (%)	1.51 (0.04)	1.46 (0.03)	0.71 (0.02)	0.31 (0.03)
Total P (mg kg^{-1}) (1)	88.8 (2.5)	78.4 (5.0)	59.6 (2.0)	42.9 (1.5)
Available Ca (meq/100 g)	41.6 (0.9)	47.5 (0.4)	28.4 (0.4)	28.9 (0.5)
Available Mg (meq/100 g)	4.67 (0.28)	5.15 (0.04)	2.97 (0.05)	2.81 (0.06)
Available K (meq/100 g)	1.37 (0.09)	1.40 (0.07)	0.27 (0.01)	0.21 (0.01)
B (mg kg^{-1})	2.20 (0.32)	1.75 (0.10)	1.83 (0.05)	1.19 (0.04)
Fe (mg kg^{-1})	21.5 (1.0)	16.2 (0.2)	70.8 (0.7)	60.5 (0.8)
Mn (mg kg^{-1})	59.6 (8.5)	71.2 (0.5)	29.2 (0.6)	26.8 (0.3)
Zn (mg kg^{-1})	4.4 (0.4)	3.88 (0.2)	20.771 (0.9)	7.7 (0.6)
Cu (mg kg^{-1})	2.1 (0.1)	2.1 (0.1)	93.5 (3.2)	43.6 (2.6)

(1) The available P (Olsen Method) averaged: 5.21 (0.41) mg kg-1 [mean (SE)] in the Mo1 and Mo2 trials; 4.02 (0.36) in the Mo3; and 3.59 (0.19) and 2.35 (0.20) for 0-15 and 15-30 cm layers, respectively, in the Ra4 trial.

Table S2. Relationships between stem diameter measured at 10 cm above ground (*D*, mm) and plant height (*H*, cm). $H = a\,D^2 + b\,D + c$. *D* ranged from 6 to 170 mm. r = Pearson coefficient. Significance level, $p < 0.001$ for all cases. n = sample size.

Taxon	*a*	*b*	c	r	n
Populus × *euroamericana* 'Adige'	-0.005	8.521	-25.453	0.959	222
Populus × *euroamericana* 'AF2'	-0.024	9.413	14.615	0.930	102
Populus × *euroamericana* 'Oudenberg'	-0.026	9.435	8.835	0.935	190
Populus × *euroamericana* 'I214'	0.010	7.210	6.544	0.949	180
Populus × *interamericana* 'Raspalje'	-0.027	9.540	-17.48	0.949	140
Populus nigra L.	-0.004	6.754	40.558	0.972	62
Paulownia fortunei 'UHU'	-0.021	10.531	-175.61	0.937	216
Robinia pseudoacacia	-0.036	9.237	3.716	0.926	126
Ulmus pumila	0.014	7.065	42.865	0.955	76
Ailanthus altissima	-0.009	7.762	-42.304	0.964	84
Platanus × *hispanica*	0.025	5.289	46.883	0.923	86

Table S3. Standard technical methods and instruments used to assess the physical-chemical properties of plant material, soil and litterfall. Modified from [12].

Property	Technical method	Observations
N	Kjedahl method (auto-analyser Bran+Luebbe®, Mod. AIII).	Plant, litterfall and soil.
S, C	Elemental analyzer (Thermo Scientific™ FLASH 2000).	Plant and litterfall.
K, Ca, P, Mg	ICP-OES (Thermo Jarrell Ash Corporation). Olsen method for soil available P.	Plant, litterfall and soil. Extraction with HNO_3; extraction with ammonium acetate for soil available K.
pH, Electrical conductivity (EC)	Multiparameter bench (PC 80, XS® Instruments)	Soil. Volume fraction 1:2.5 for pH and 1:5 for EC.
Organic C and oxidizable organic matter (OM)	Walkley and Black method.	Soil.
Active limestone	Bernard calcimeter	Soil.
Cl	Photometer (HI 83200, Hanna® Instruments).	Plant. Total extraction with HNO_3.
Ash	Muffle oven	Plant. 550 °C (ISO 18122:2015).
Heating values (constant volume)	According to the EU standard EN 14918:2011 for solid biofuels. Automatic isoperibol calorimeter (Parr 6300®).	Plant. Cold milling. Crushed and sieved through a 1 mm size mesh. Data referred to a dry basis after oven-drying at 105 °C (ISO 18134-3:2015).

Table S4. Morphological characteristics [average (SE)] of the main stems emerging from the stumps at the end of the 1st ($R_{04}S_4$ plants) and the 2nd ($R_{18}S_4$ plants) rotation for the Mo1 assay. D_{max}, maximum stem diameter among those emerging from a stump; NSt, number of stems; BA, basal area. The four variables showed significant differences between taxa and between rotations, $p < 0.001$.

Taxon	Rotation	NSt	Average D_{max} (mm)	Average D (mm)	BA (m^2 ha^{-1})
Populus × *euroamericana* 'Adige'	1st	1.60 (0.12)	77.1 (1.1)	73.0 (1.8)	35.6 (1.8)
	2nd	2.77 (0.14)	69.5 (1.6)	59.2 (1.2)	42.9 (1.8)
Populus × *euroamericana* 'AF2'	1st	1.88 (0.16)	88.3 (2.0)	76.0 (3.4)	44.3 (2.0)
	2nd	4.96 (0.19)	72.5 (1.6)	55.2 (0.7)	68.5 (2.2)
Populus × *euroamericana* 'Oudenberg'	1st	1.67 (0.13)	69.0 (1.0)	59.3 (2.0)	25.1 (1.0)
	2nd	2.71 (0.15)	56.8 (1.0)	20.5 (0.8)	30.3 (1.3)
Populus × *euroamericana* 'I214'	1st	1.05 (0.04)	80.3 (1.8)	80.2 (1.8)	29.1 (1.1)
	2nd	3.27 (0.17)	62.6 (0.9)	52.9 (0.5)	40.7 (1.8)
Populus × *interamericana* 'Raspalje'	1st	1.25 (0.09)	68.8 (1.3)	65.1 (1.7)	22.5 (1.0)
	2nd	2.83 (0.14)	56.8 (0.9)	48.8 (0.8)	29.5 (1.1)
Populus nigra L.	1st	1.33 (0.10)	76.2 (2.7)	70.8 (2.7)	29.1 (2.0)
	2nd	3.29 (0.15)	58.8 (1.1)	50.1 (0.8)	36.7 (1.8)
Paulownia fortunei 'UHU'	1st	1.03 (0.02)	93.5 (1.9)	93.4 (1.9)	38.5 (1.5)
	2nd	2.79 (0.13)	86.4 (1.6)	68.2 (1.7)	58.0 (1.6)
Robinia pseudoacacia	1st	1.04 (0.01)	87.9 (2.6)	87.8 (2.6)	34.3 (2.0)
	2nd	3.50 (0.15)	66.8 (1.4)	56.0 (1.1)	48.1 (1.6)
Ulmus pumila	1st	1.25 (0.11)	88.9 (2.4)	85.7 (2.7)	38.9 (2.4)
	2nd	3.21 (0.13)	69.5 (1.4)	60.5 (0.9)	51.6 (1.7)
Ailanthus altissima	1st	1.13 (0.07)	72.8 (1.7)	70.0 (1.9)	24.0 (1.2)
	2nd	3.13 (0.17)	64.0 (1.1)	51.7 (1.0)	37.0 (1.4)
Platanus × *hispanica*	1st	1.17 (0.02)	55.3 (1.2)	53.8 (1.4)	14.3 (0.7)
	2nd	3.504(0.18)	48.0 (1.2)	40.9 (0.8)	22.5 (1.2)