

Supplemental Information for:
The role of maternal environment and dispersal ability in plants'
transgenerational plasticity

Simulation of dispersal distance with the WALD mechanistic model

The WALD model is an analytical mechanistic model derived from a simplified 3-D stochastic dispersion model that retains the essential physics contained within the more computationally intensive coupled Eulerian-Lagrangian closure (CELC) model (Nathan et al., 2002). The analytical model reduces to the Wald (or inverse Gaussian) distribution (eqn 5b in Katul et al., 2005) that describes the probability density of dispersal distances x

$$p(x) = \left(\frac{\lambda}{2\pi x^3}\right)^{1/2} \exp\left[-\frac{\lambda(x-\mu)^2}{2\mu^2 x}\right] \quad (1)$$

where μ and λ are dispersal kernel parameters, and $\mu = H_r * U / V_t$, $\lambda = (H_r / \sigma)^2$, H_r is seed release height, U is the horizontal wind speed, V_t is seed terminal velocity, and σ is a turbulent flow parameter reflecting wind speed variation (Katul et al., 2005, Skarpaas and Shea, 2007).

$$\sigma^2 = \frac{4\sigma_w^4}{C_0 \varepsilon U} \quad (2)$$

where σ_w is the vertical turbulence, C_0 is Kolmogorov constant (3.125), and ε is the dissipation rate. While estimating ε is challenging within the canopy (Katul et al. 2005), we are mainly concerned with turbulent flow above the canopy, so we assume $\varepsilon = u_*^3 / K(z-d)$ and the constant $A_w \equiv \sigma_w / u_* \approx 1.3$ following Skarpaas and Shea (2007), where K is von Kármán's constant (0.41), z is height above ground, d is zero-plane displacement distance. Based on these assumptions and equation (2), we obtain

$$\sigma = 2A_w^2 \sqrt{\frac{K(z-d)u_*}{C_0 U}} \quad (3)$$

In the WALD simulation, each seed released was dispersed by randomly drawing a distance from the probability distribution function generated by the WALD model with parameters U , H_r and V_t . U was drawn from a Weibull distribution fitted to wind measurements with an eddy covariance station at the Heidfeldhof research station (Wulfmeyer et al., 2018), University of

Hohenheim, Germany. H_t and V_t were simulated with linear mixed-effects models where H_t and V_t are response variables, hydrological conditions, species identity and their interaction are fixed effects, and pot identity nested in pool identity are random effects.

Dispersal environments

For the biological dispersal environment, the leaf area index (LAI) was estimated from the total aboveground biomass. For the physical dispersal environment, mean horizontal wind speed, friction velocity, zero-plane displacement distance and aerodynamic roughness length were measured with an eddy covariance station at the reference height of 2.63 m with high temporal resolution (0.1 Hz) throughout the dispersal season from June to September 2019 and 2020 (Wulfmeyer et al., 2018). A logarithmic wind profile was used to calculate the horizontal wind speed at any height of interest,

$$u = \frac{u_*}{k} \ln \frac{z-d}{z_0} \quad (4)$$

where u is the mean horizontal wind speed at the height z ; u_* is the friction velocity; k is von Kármán's constant (0.41); d is zero-plane displacement distance; and z_0 is aerodynamic roughness length (Monteith & Unsworth, 2013).

Table S1. Additional information about study species

Species	Family	Plant height (cm)	Ellenberg moisture indicator (F-value)	Diaspore appendages	Pollination	Habitat	Life forme
<i>Atriplex hortensis</i> L.	Amaranthaceae	50 - 120	5	seed dimorphism: brown seeds – covered by a pale-yellow membrane black seed – without appendages	outcrossing and selfing ⁶	Roadsides, field edges	Annual therophyte
<i>Bellis perennis</i> L.	Asteraceae	10 – 15	5	none	outcrossing and selfing ⁶	Well-drained and moderately moist meadows, pastures, lawns	Perennial hemicryptophyte
<i>Capsella bursa-pastoris</i> (L.) Medik.	Brassicaceae	5 – 80	5	none	outcrossing and selfing (predominately) ⁵	Roadsides, fields, wasteland	Annual or short-lived perennial monocarpic hemicryptophyte, therophyte
<i>Crepis sancta</i> (L.) Bornm.	Asteraceae	30 – 50	2	seed dimorphism: pappus: 4-5 mm long seed without pappus	outcrossing and selfing ³	Roadsides, vineyards, railroad areas, warm locations	Annual therophyte
<i>Hypochaeris glabra</i> L.	Asteraceae	5 – 50	3	seed dimorphism: pappus: central 9.5-15 mm long; peripheral 3-4 mm long	outcrossing and selfing (predominately) ¹	Roadsides	Annual/perennial therophyte
<i>Hypochaeris radicata</i> L.	Asteraceae	20 – 30	4	pappus: 9-10 mm long	outcrossing, self-incompatible ^{1,2}	Meadows	Perennial hemicryptophyte
<i>Jacobaea vulgaris</i> L.	Asteraceae	30 – 100	4	pappus: 4 mm long	outcrossing (predominately) and selfing ⁴	Pastures, woods and roadsides	Perennial hemicryptophyte, annual, biennial or short-lived perennial

¹Ortiz et al., 2006; ²Pico et al., 2004; ³Cheptou et al., 2001; ⁴Andersson, 1996; ⁵Douglas et al., 2015; ⁶Walter, 2020.

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Table S2. Number of replicas used in offspring generation.

Maternal – offspring hydrological treatments											
Species	Seed positions	Seed pappus size	DD	DM	DL	DM	MM	LM	ML	LL	DL
<i>Hypochaeris glabra</i>	Upper	Big	9	9	9	9	9	9	9	9	9
	Lower	Big	9	8	9	9	6	8	8	7	8
	Upper	Small	9	9	9	9	9	8	9	8	8
	Lower	Small	9	9	9	9	9	6	9	6	6
<i>Hypochaeris radicata</i>	Upper	-	10	8	10	10	9	3	9	3	3
	Lower	-	2	6	2	2	6	1	6	1	1
<i>Atriplex hortensis</i>	Upper	-	9	5	9	9	5	4	5	4	1
	Lower	-	10	4	10	9	4	1	4	1	4
<i>Crepis sancta</i>	Upper	-	8	9	7	8	9	4	9	4	4
	Lower	-	4	8	3	4	9	2	8	2	2
<i>Jacobea vulgaris</i>	Upper	-	7	10	8	5	10	10	10	6	6
<i>Bellis perennis</i>	Lower	-	7	8	8	7	8	4	8	4	4
<i>Capsella bursa-pastoris</i>	Upper	-	7	3	7	6	3	3	3	2	3
	Lower	-	6	4	6	6	3	1	4	2	1
Total	Upper	-	59	53	59	54	53	41	54	36	37
	Lower	-	47	48	46	46	46	23	47	23	23

Hydrological conditions (D – drought, M – mesic, L – waterlogging) applied in offspring and maternal plants. The first letter represents maternal hydrological conditions, and the second offspring hydrological conditions.

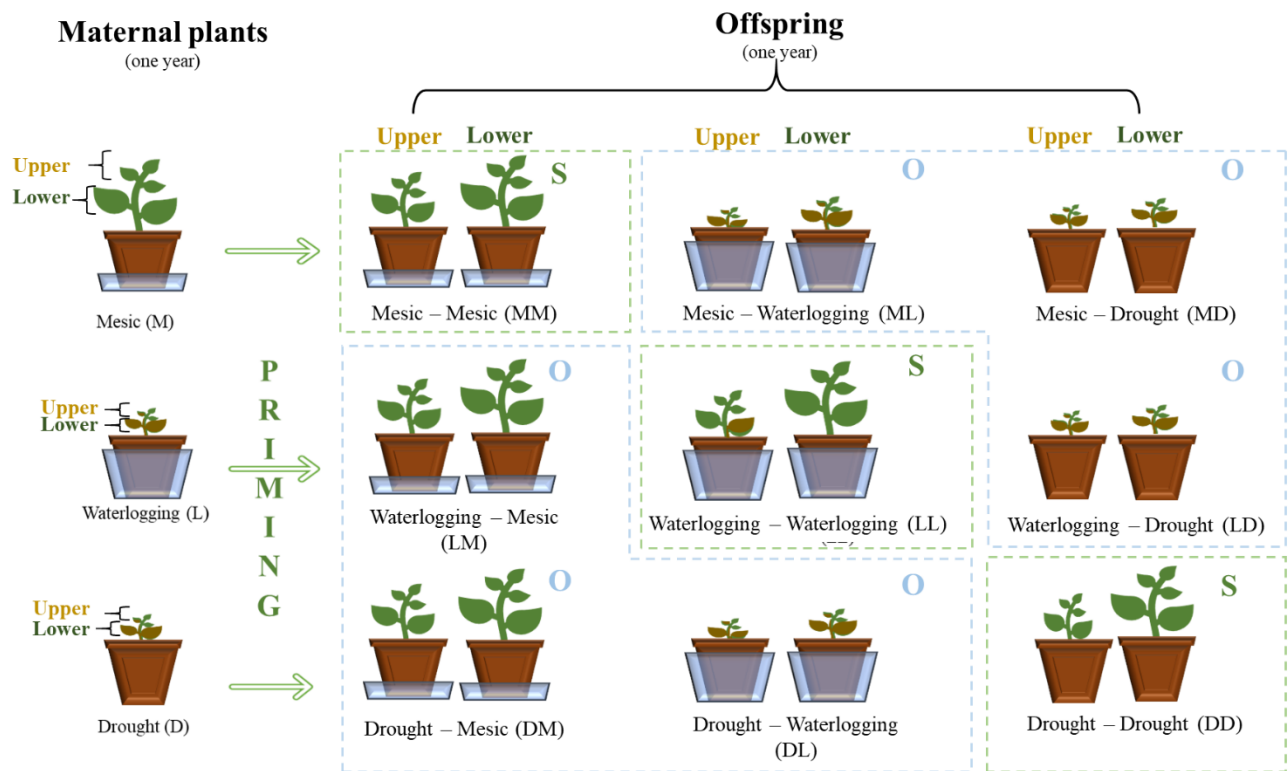


Figure S1. Design of the experiment used to investigate the strength of transgenerational stress memory. Mothers and offspring were subjected to waterlogging or drought stress for one year. Seeds were collected from lower and upper parts of mother plants and sowed separately in offspring generation. D - drought; M - mesic; L – waterlogging. The first letter signifies the maternal treatment and the second offspring conditions. S – the same (DD, LL and MM), O – other (DL, DM, LD, LM, MD and ML) hydrological conditions applied in offspring and maternal plants.

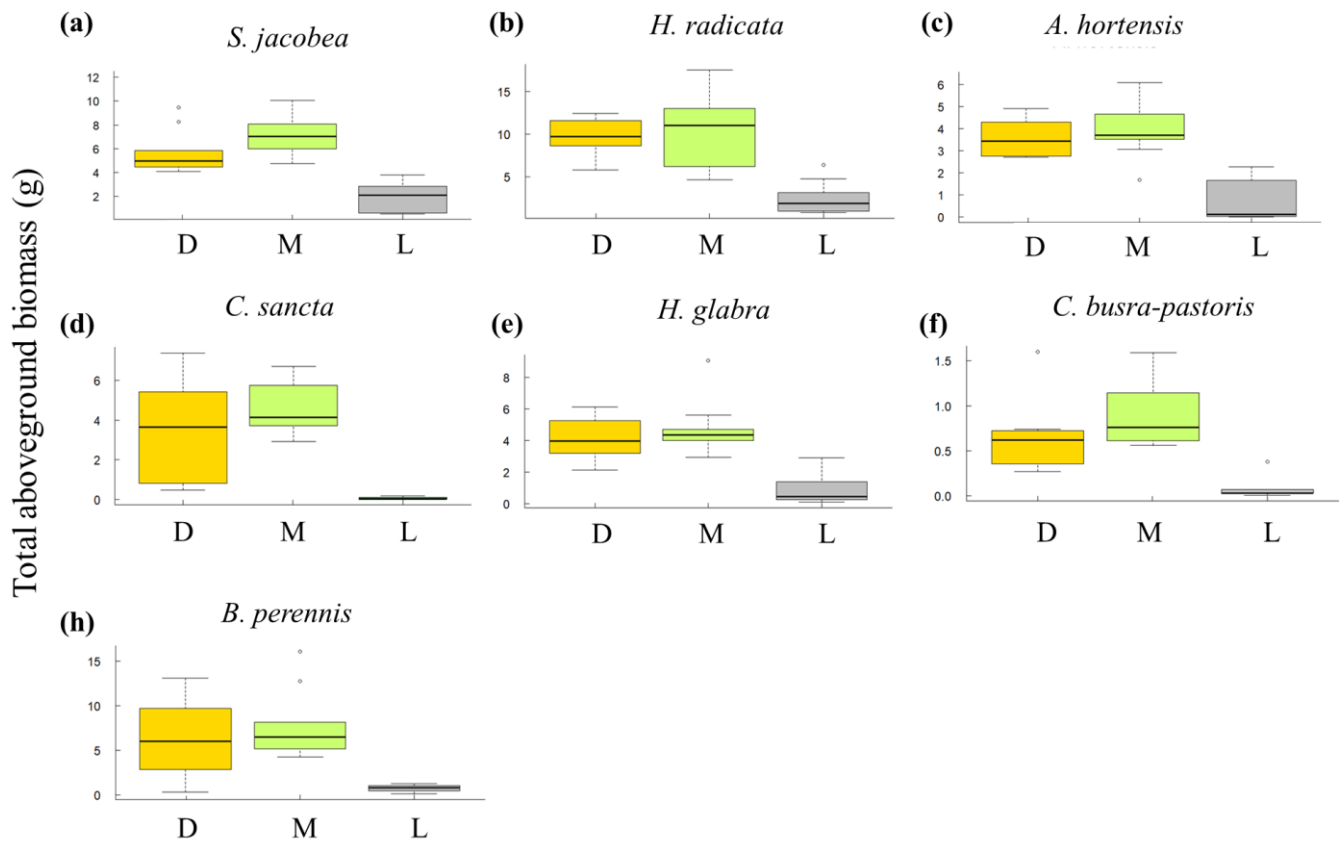


Figure S2. Effects of different hydrological conditions on the total aboveground biomass of maternal plants (a) *Jacobaea vulgaris*, (b) *H. radicata*, (c) *Atriplex hortensis*, (d) *Crepis sancta*, (e) *Hypochaeris glabra*, (f) *Capsela bursa-pastoris* and (g) *Bellis perennis*. Hydrological conditions (D – drought, M – mesic, L – waterlogging) applied in maternal plants.

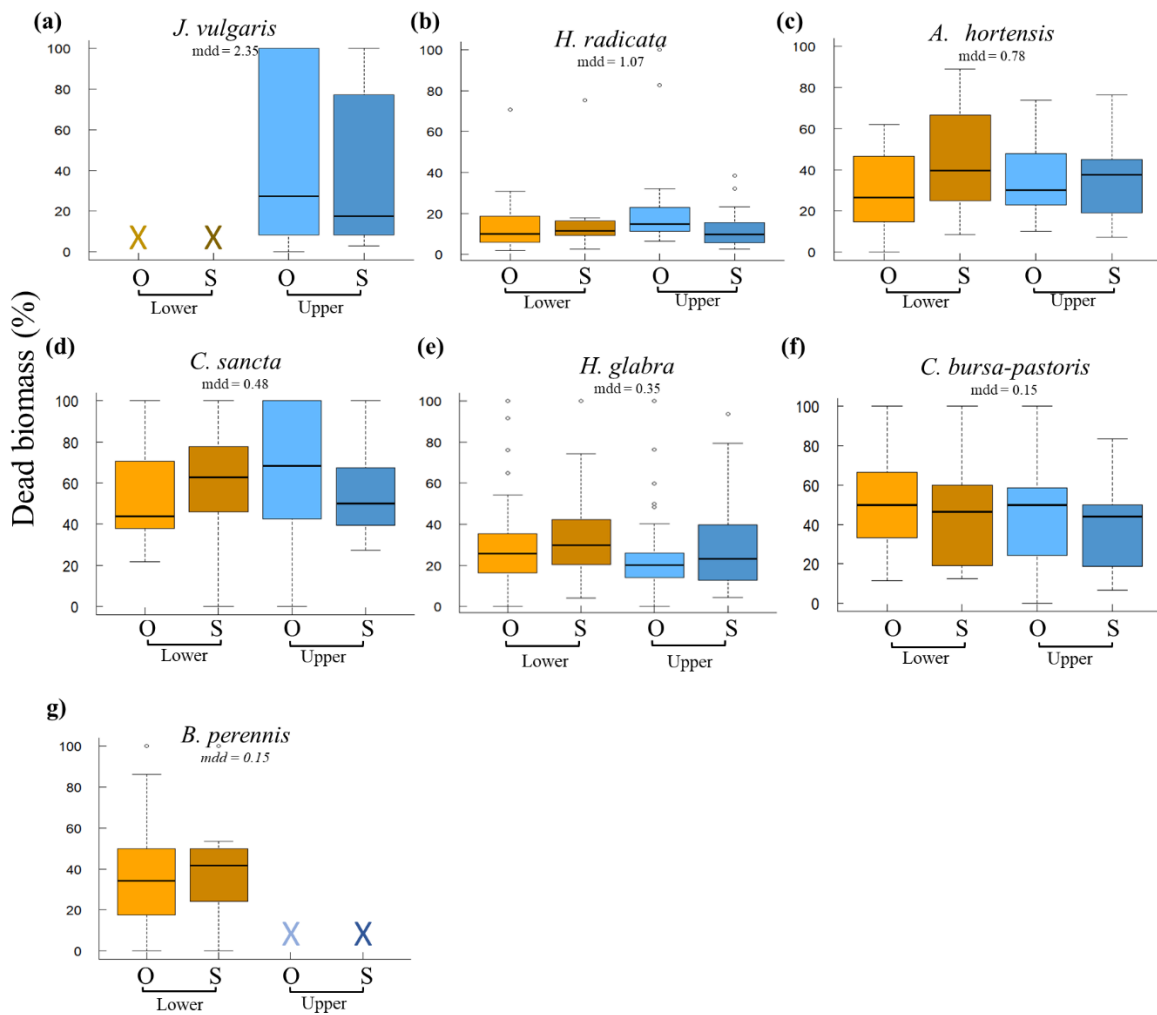


Figure S3. Effects of different hydrological conditions on the proportion of dead biomass of (a) *Jacobaea vulgaris*, (b) *H. radicata*, (c) *Atriplex hortensis*, (d) *Crepis sancta*, (e) *Hypochaeris glabra*, (f) *Capsela bursa-pastoris* and (g) *Bellis perennis*. S – the same (DD, LL and MM), O – other (DL, DM, LD, LM, MD and ML) hydrological conditions (D – drought, M – mesic, L – waterlogging) applied in offspring and maternal plants. mdd – mean dispersal distance (in m) on species level. Crosses indicate that data was not available in the respective treatments.

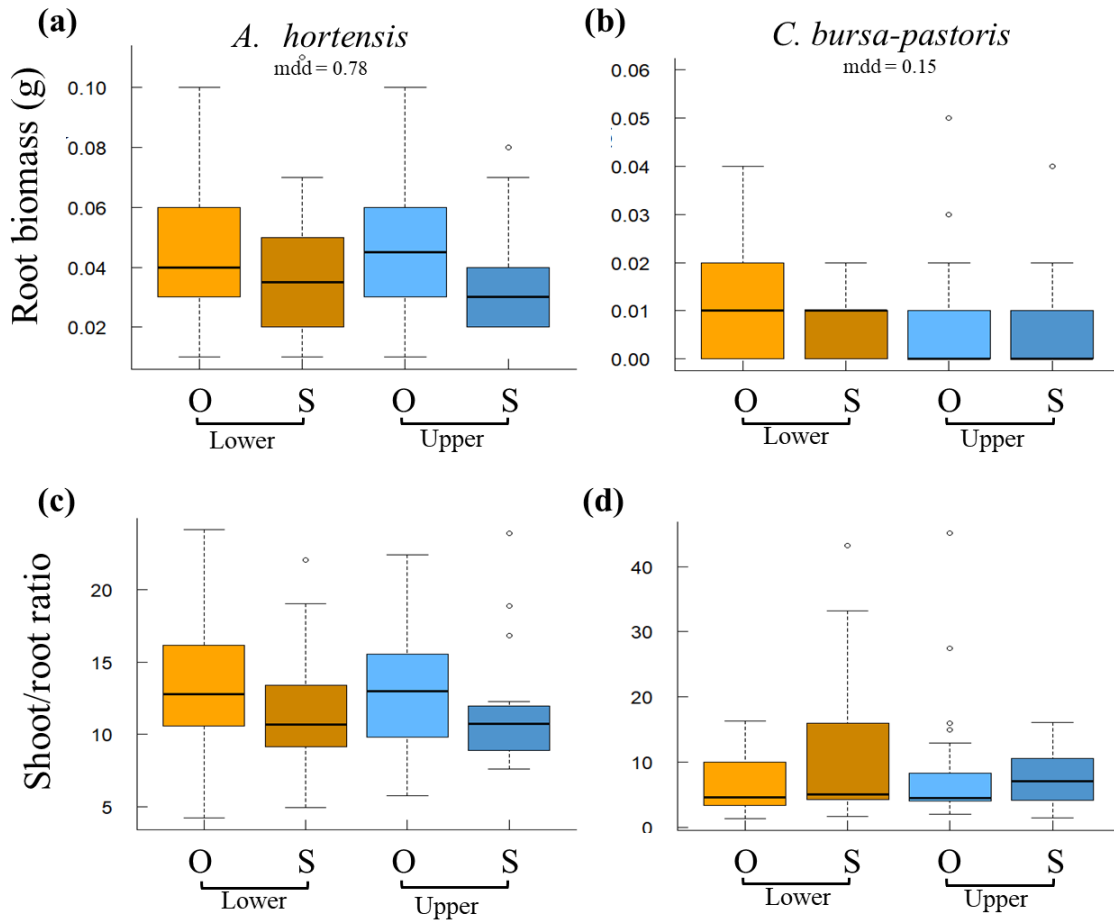


Figure S4. Effects of different hydrological conditions on root biomass and shoot/root ratio of (a, c, respectively) *Atriplex hortensis* and (b, d, respectively) *Capsela bursa-pastoris*. S - the same (DD, LL and MM), O - other (DL, DM, LD, LM, MD and ML) hydrological conditions (D – drought, M – mesic, L – waterlogging) applied in offspring and maternal plants. mdd – mean dispersal distance (in m) on species level.

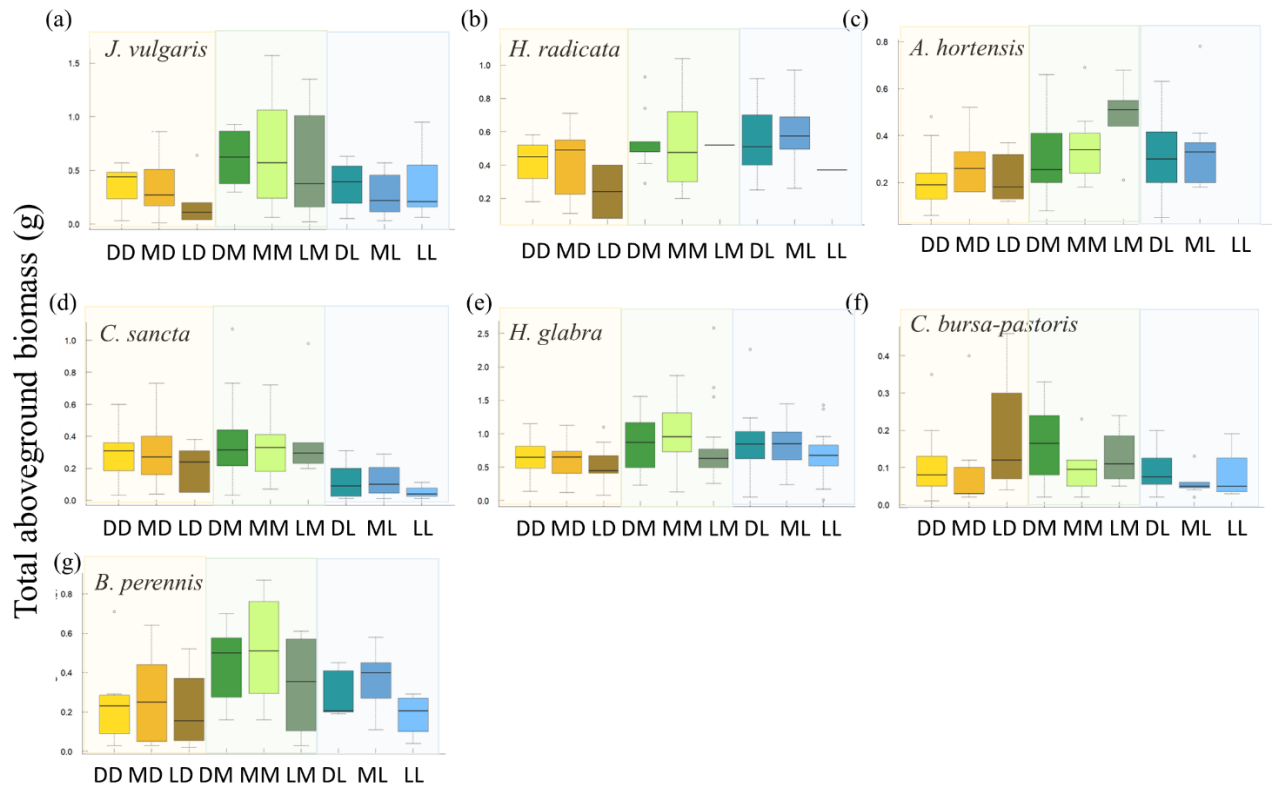


Figure S5. Effects of maternal and offspring hydrological conditions on the total aboveground biomass of (a) *Jacobaea vulgaris*, (b) *Hypochaeris radicata*, (c) *Atriplex hortensis*, (d) *Crepis sancta*, (e) *Hypochaeris glabra*, (f) *Capsela bursa-pastoris* and (g) *Bellis perennis*. Hydrological conditions (D – drought, M – mesic, L – waterlogging) applied in offspring and maternal plants. The first letter represents maternal hydrological conditions, and the second offspring hydrological conditions.

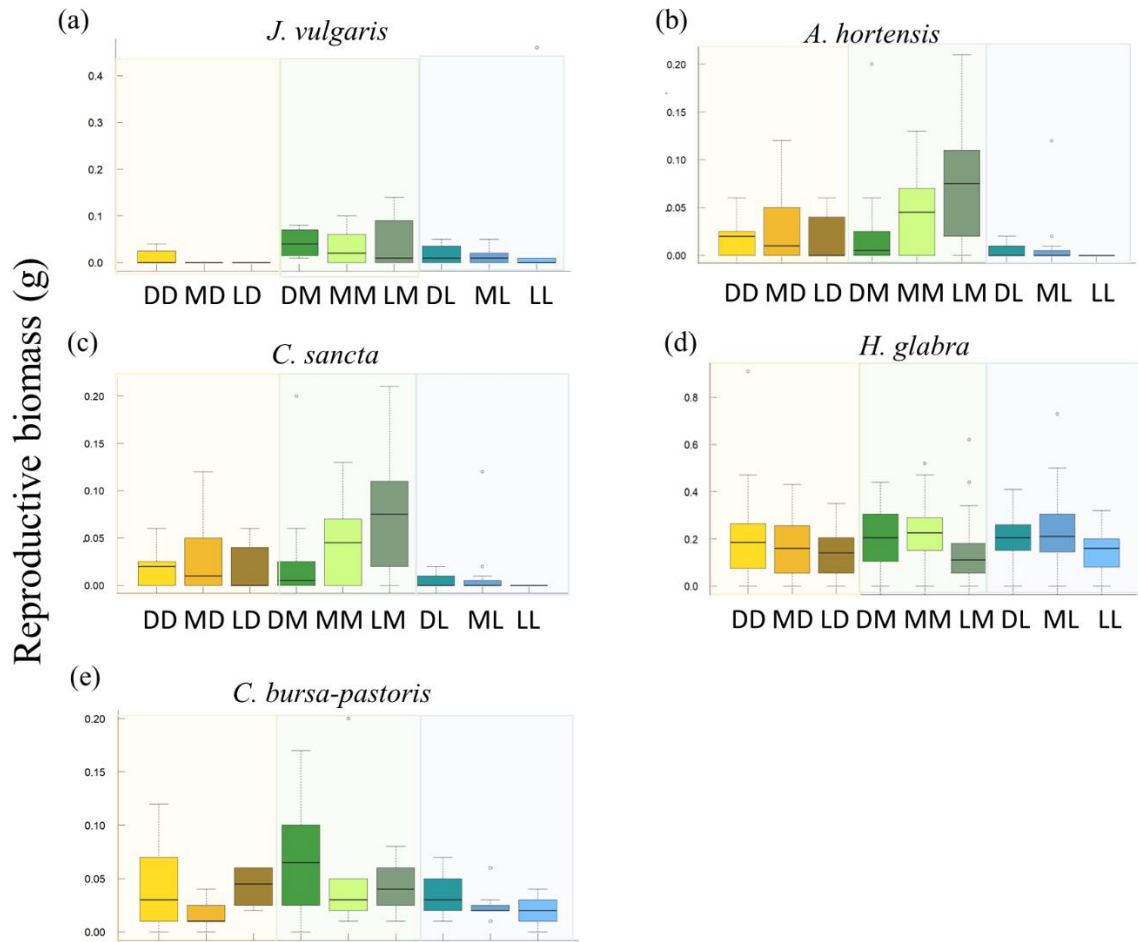


Figure S6. Effects of maternal and offspring hydrological conditions on the reproductive biomass of (a) *Jacobaea vulgaris*, (b) *Atriplex hortensis*, (c) *Crepis sancta*, (d) *Hypochaeris glabra*, and (e) *Capsela bursa-pastoris*. Hydrological conditions (D – drought, M – mesic, L – waterlogging) applied in offspring and maternal plants. The first letter represents maternal hydrological conditions, and the second offspring hydrological conditions.

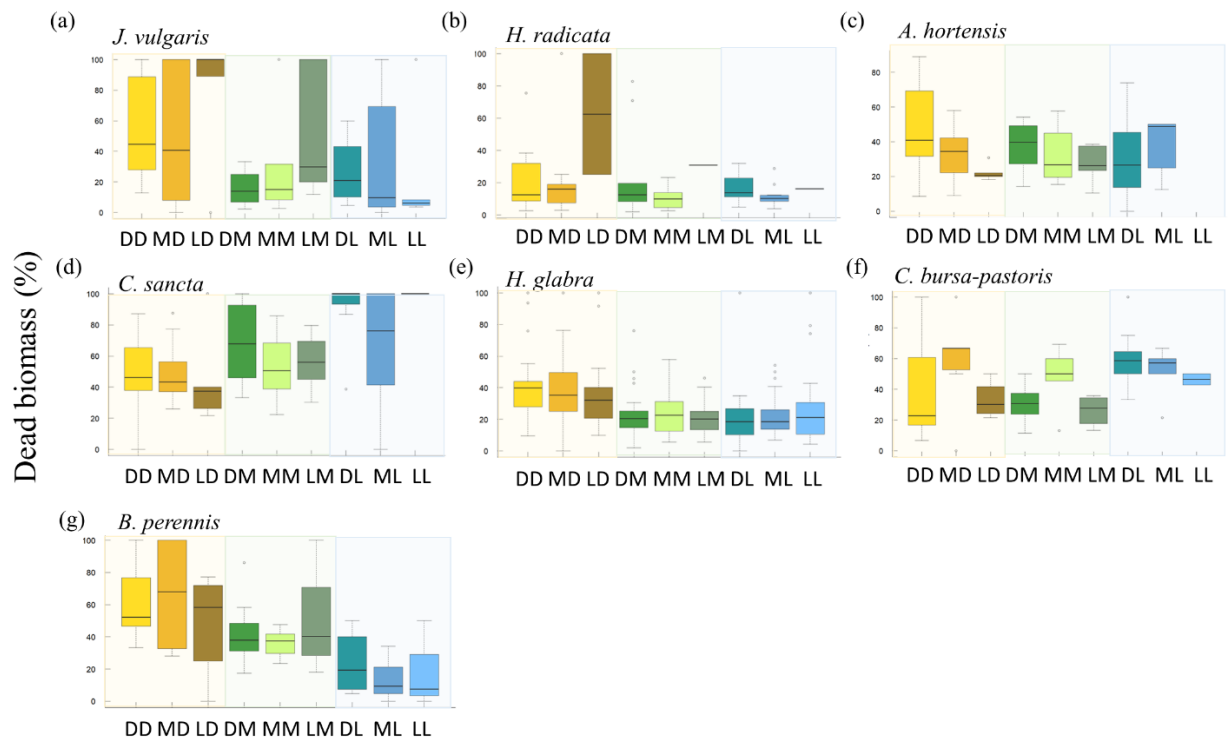


Figure S7. Effects of maternal and offspring hydrological conditions on the percentage of dead biomass of (a) *Jacobaea vulgaris*, (b) *Hypochaeris radicata*, (c) *Atriplex hortensis*, (d) *Crepis sancta*, (e) *Hypochaeris glabra*, (f) *Capsela bursa-pastoris* and (g) *Bellis perennis*. Hydrological conditions (D – drought, M – mesic, L – waterlogging) applied in offspring and maternal plants. The first letter represents maternal hydrological conditions, and the second offspring hydrological conditions.

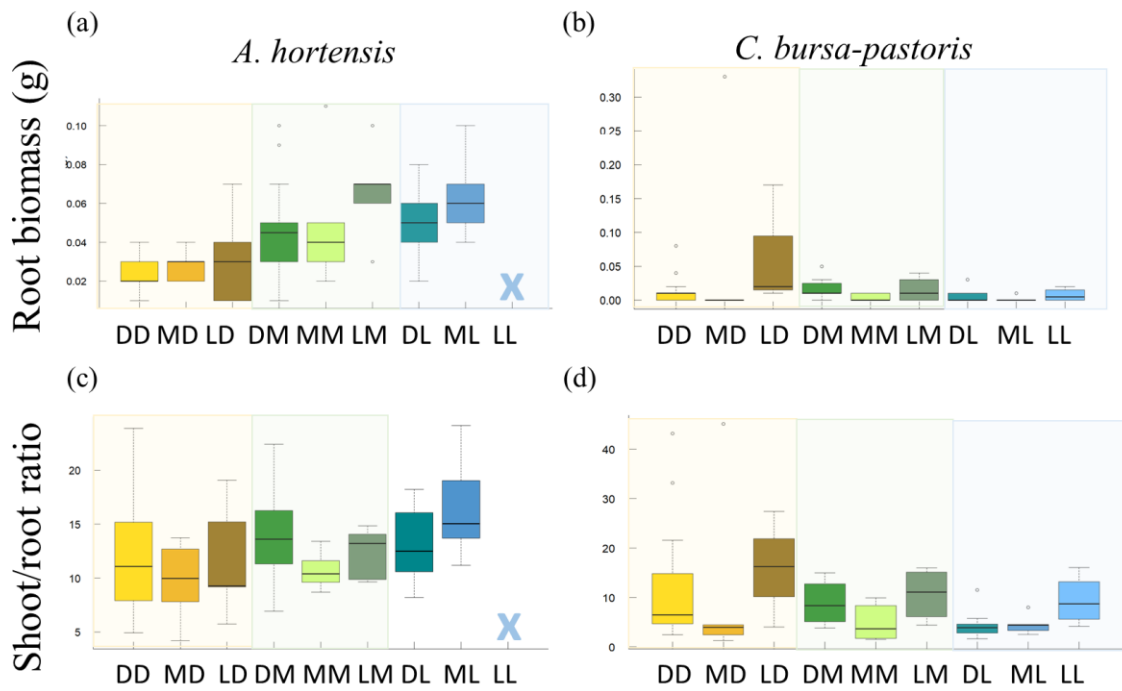


Figure S8. Effects of maternal and offspring hydrological conditions on root biomass and shoot/root ratio of (a, c, respectively) *Atriplex hortensis* and (b, d, respectively) *Capsela bursa-pastoris*. Hydrological conditions (D – drought, M – mesic, L – waterlogging) applied in offspring and maternal plants. The first letter represents maternal hydrological conditions, and the second offspring hydrological conditions. Crosses indicate that data was not available in the respective treatments.

Table S3. An overview of degree of freedom (df), *F*-value and *P*-values obtained from offspring and maternal interaction model measured in offspring plants (hypothesis 1).

Species		Total aboveground biomass	Reproductive biomass	Percentage of dead biomass	Root biomass
<i>All species together</i>	df	4	4	4	4
	<i>F</i> -value	0.450	0.919	0.131	1.887
	<i>P</i> -value	0.772	0.452	0.971	0.117
<i>Jacobea vulgaris</i>	df	4	4	4	
	<i>F</i> -value	0.244	0.278	0.572	NA
	<i>P</i> -value	0.911	0.891	0.684	
<i>Hypochaeris radicata</i>	df	4		4	
	<i>F</i> -value	0.172	NA	1.051	NA
	<i>P</i> -value	0.952		0.392	
<i>Atriplex hortensis</i>	df	4	4	4	4
	<i>F</i> -value	1.326	1.278	1.915	1.242
	<i>P</i> -value	0.275	0.287	0.134	0.302
<i>Crepis sancta</i>	df	4	4	4	
	<i>F</i> -value	0.172	1.278	1.158	NA
	<i>P</i> -value	0.952	0.287	0.187	
<i>Hypochaeris glabra</i>	df	4	4	4	
	<i>F</i> -value	1.270	1.581	0.390	NA
	<i>P</i> -value	0.283	0.179	0.817	
<i>Capsella bursa-pastoris</i>	df	4	4	4	4
	<i>F</i> -value	0.878	0.788	1.023	1.170
	<i>P</i> -value	0.484	0.538	0.408	0.337
<i>Bellis perennis</i>	df	4		4	
	<i>F</i> -value	0.162	NA	0.755	NA
	<i>P</i> -value	0.956		0.554	

NA – data not available for those species.

Table S4. An overview of degree of freedom, sample size and variance for tested hypothesis and models.

Hypothesis	Response variables	Model	Degree of freedom	Sample size	Variance	R ²
1.	Total aboveground biomass	Same/ different	1	742	0.516	-
	Reproductive biomass		1	671	0.699	-
	Percentage of dead biomass		1	739	0.532	-
	Root biomass		1	158	0.271	-
	Shoot/root ratio		1	158	0.445	-
	Total aboveground biomass	Maternal x offspring interaction	4	737	0.519	-
	Reproductive biomass		4	671	0.727	-
	Percentage of dead biomass		4	734	0.536	-
	Root biomass		4	154	0.277	-
	Shoot/root ratio		4	154	0.477	-
2.	Total aboveground biomass	Same/ different	1	7	-	0.280
	Reproductive biomass		1	6	-	0.580
	Total aboveground biomass	Testing drought	5	7	-	0.011
	Reproductive biomass		5	6	-	0.074
	Total aboveground biomass	Testing waterloggi ng	7	7	-	0.164
	Reproductive biomass		6	6	-	0.332
3.	Total aboveground biomass	Same/ different	1	12	0.005	-
	Reproductive biomass		1	10	0.016	-
	Total aboveground biomass	Testing drought	8	12	0.047	-
	Reproductive biomass		5	12	0.083	-
	Total aboveground biomass	Testing waterloggi ng	7	12	0.613	-
	Reproductive biomass		3	12	0.363	-

The models used to test the second hypothesis did not include random effects, so we report standard R² values, but not variance. And for models with random effect, we reported variance instead of R².