

Supplementary Material tables S1–S5 and figures S1–S3

Table S1. Mean \pm standard errors for the key soil community and edaphic variables measured during the 16-week experiments with different plant litter (PL) amount and temperature (T) treatments.

PL (g)	T (°C)	Community abundance (ind.)	Community biomass (mg)	Overall CWMBM (mg)	Collembola CWMBM (mg)	Mite CWMBM (mg)	Nematode CWMBM (mg)
0	4	585 \pm 23	4.49 \pm 0.65	0.0065 \pm 0.0007	0.194 \pm 0.010	0.022 \pm 0.001	5.4 \times 10 ⁻⁵ \pm 1.4 \times 10 ⁻⁶
0	12	690 \pm 76	18.37 \pm 1.27	0.0121 \pm 0.0010	0.194 \pm 0.005	0.018 \pm 0.001	6.0 \times 10 ⁻⁵ \pm 1.5 \times 10 ⁻⁶
0	20	597 \pm 57	10.08 \pm 1.35	0.0082 \pm 0.0004	0.140 \pm 0.008	0.019 \pm 0.003	9.8 \times 10 ⁻⁵ \pm 2.9 \times 10 ⁻⁶
0	30	10 \pm 2	0.88 \pm 0.24	0.0041 \pm 0.0004	0.156 \pm 0.006	0.020 \pm 0.002	5.5 \times 10 ⁻⁵ \pm 3.2 \times 10 ⁻⁷
2.5	4	893 \pm 48	13.95 \pm 1.73	0.0104 \pm 0.0012	0.253 \pm 0.010	0.019 \pm 0.004	5.0 \times 10 ⁻⁵ \pm 7.8 \times 10 ⁻⁷
2.5	12	1102 \pm 20	45.14 \pm 4.53	0.0187 \pm 0.0029	0.262 \pm 0.016	0.023 \pm 0.000	5.4 \times 10 ⁻⁵ \pm 1.7 \times 10 ⁻⁶
2.5	20	1277 \pm 99	53.95 \pm 2.33	0.0215 \pm 0.0003	0.271 \pm 0.010	0.021 \pm 0.003	5.8 \times 10 ⁻⁵ \pm 3.1 \times 10 ⁻⁶
2.5	30	54 \pm 21	0.95 \pm 0.04	0.0043 \pm 0.0003	0.165 \pm 0.011	0.022 \pm 0.002	5.1 \times 10 ⁻⁵ \pm 1.8 \times 10 ⁻⁶
5	4	1213 \pm 29	26.39 \pm 0.92	0.0132 \pm 0.0001	0.288 \pm 0.007	0.021 \pm 0.002	5.3 \times 10 ⁻⁵ \pm 2.5 \times 10 ⁻⁶
5	12	1720 \pm 45	71.93 \pm 2.70	0.0180 \pm 0.0007	0.237 \pm 0.004	0.022 \pm 0.000	4.8 \times 10 ⁻⁵ \pm 4.0 \times 10 ⁻⁷
5	20	1690 \pm 66	153.65 \pm 6.47	0.0383 \pm 0.0011	0.288 \pm 0.004	0.018 \pm 0.001	5.6 \times 10 ⁻⁵ \pm 1.8 \times 10 ⁻⁶
5	30	106 \pm 20	1.55 \pm 0.45	0.0039 \pm 0.0001	0.155 \pm 0.010	0.027 \pm 0.001	5.3 \times 10 ⁻⁵ \pm 2.2 \times 10 ⁻⁶
PL (g)	T (°C)	F:B ratio	SOC (%)	Available P (mg kg ⁻¹)	Total Soil N (mg kg ⁻¹)	Soil C:N ratio	Soil C:P ratio
0	4	0.20 \pm 0.05	4.39 \pm 0.05	11.07 \pm 0.18	12.51 \pm 2.36	38.44 \pm 8.81	39.71 \pm 0.34
0	12	0.35 \pm 0.07	4.88 \pm 0.02	8.40 \pm 0.17	26.37 \pm 6.35	20.54 \pm 4.28	58.17 \pm 1.42
0	20	0.39 \pm 0.08	4.28 \pm 0.02	9.62 \pm 0.19	32.34 \pm 1.38	13.28 \pm 0.59	44.54 \pm 1.04
0	30	0.52 \pm 0.02	4.14 \pm 0.27	10.92 \pm 0.00	50.88 \pm 3.15	8.13 \pm 0.21	37.91 \pm 2.46
2.5	4	0.31 \pm 0.03	4.43 \pm 0.04	11.86 \pm 0.21	9.23 \pm 1.15	49.46 \pm 5.67	37.41 \pm 1.02
2.5	12	0.45 \pm 0.02	4.49 \pm 0.11	8.18 \pm 0.14	32.77 \pm 4.47	14.12 \pm 1.55	54.93 \pm 1.89
2.5	20	0.23 \pm 0.02	4.72 \pm 0.42	10.11 \pm 0.60	35.59 \pm 6.20	14.14 \pm 2.60	47.60 \pm 7.42
2.5	30	0.47 \pm 0.03	3.36 \pm 0.25	11.80 \pm 1.60	44.05 \pm 11.18	9.17 \pm 3.13	28.99 \pm 1.90
5	4	0.27 \pm 0.01	4.36 \pm 0.11	12.90 \pm 1.66	14.58 \pm 0.64	30.00 \pm 1.34	34.85 \pm 4.27
5	12	0.43 \pm 0.05	4.88 \pm 0.30	9.64 \pm 0.67	21.23 \pm 2.40	23.81 \pm 3.78	50.72 \pm 0.44
5	20	0.24 \pm 0.02	4.36 \pm 0.04	11.58 \pm 0.31	34.68 \pm 3.17	12.80 \pm 1.25	37.70 \pm 0.79
5	30	0.40 \pm 0.06	3.68 \pm 0.12	11.40 \pm 0.67	67.88 \pm 9.10	5.64 \pm 0.81	32.63 \pm 2.75
PL (g)	T (°C)	Litter mass loss (g)	Relative litter loss				
0	4	0					
0	12	0					
0	20	0					
0	30	0					
2.5	4	0.30 \pm 0.02	0.12 \pm 0.01				
2.5	12	0.37 \pm 0.02	0.15 \pm 0.01				
2.5	20	0.51 \pm 0.06	0.20 \pm 0.02				
2.5	30	0.26 \pm 0.04	0.10 \pm 0.02				
5	4	0.50 \pm 0.05	0.10 \pm 0.01				
5	12	0.66 \pm 0.08	0.13 \pm 0.02				
5	20	0.93 \pm 0.04	0.19 \pm 0.01				
5	30	0.37 \pm 0.03	0.07 \pm 0.01				

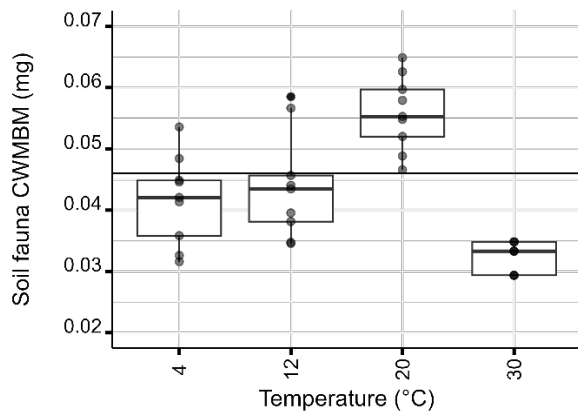


Figure S1. Soil mesofauna community weighted mean body mass (CWMBM) across treatments at day 0 of the plant litter experiment, following a 30-day temperature incubation period. The solid black horizontal line indicates the mean soil fauna CWMBM on day -30, prior to temperature incubation.

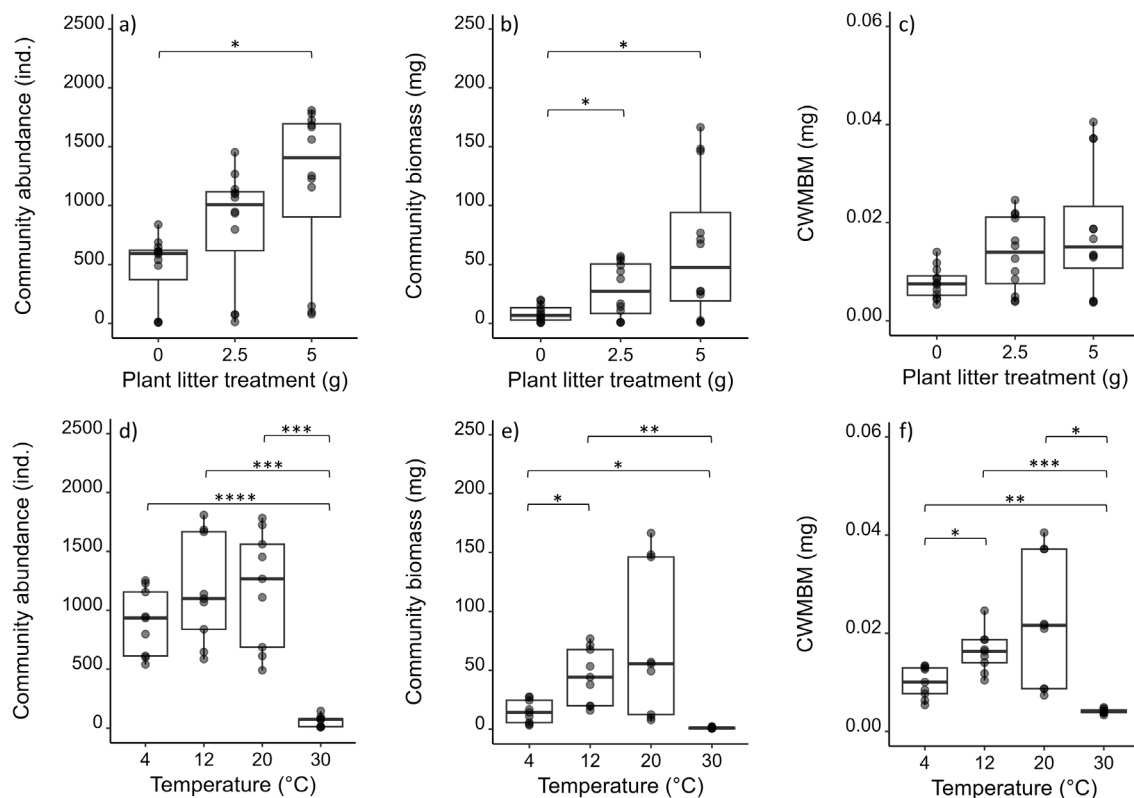


Figure S2. Soil mesofauna community metrics sampled in response to different plant litter and temperature treatments over a 16-week period, showing pairwise Tukey test comparisons: *: $p < 0.05$; **: $p < 0.01$, ***: $p < 0.001$, ****: $p < 0.0001$. Plots show a & d) total community abundance; b & e) total community biomass; and c & f) community weighted mean body mass (CWMBM) for a-c) three plant litter treatments and d-f) four temperature treatments, with 3 replicates for each treatment ($N = 36$). One-way ANOVA's for the overall effect of each treatment were: a & b) **, c) *, d-f) ***.

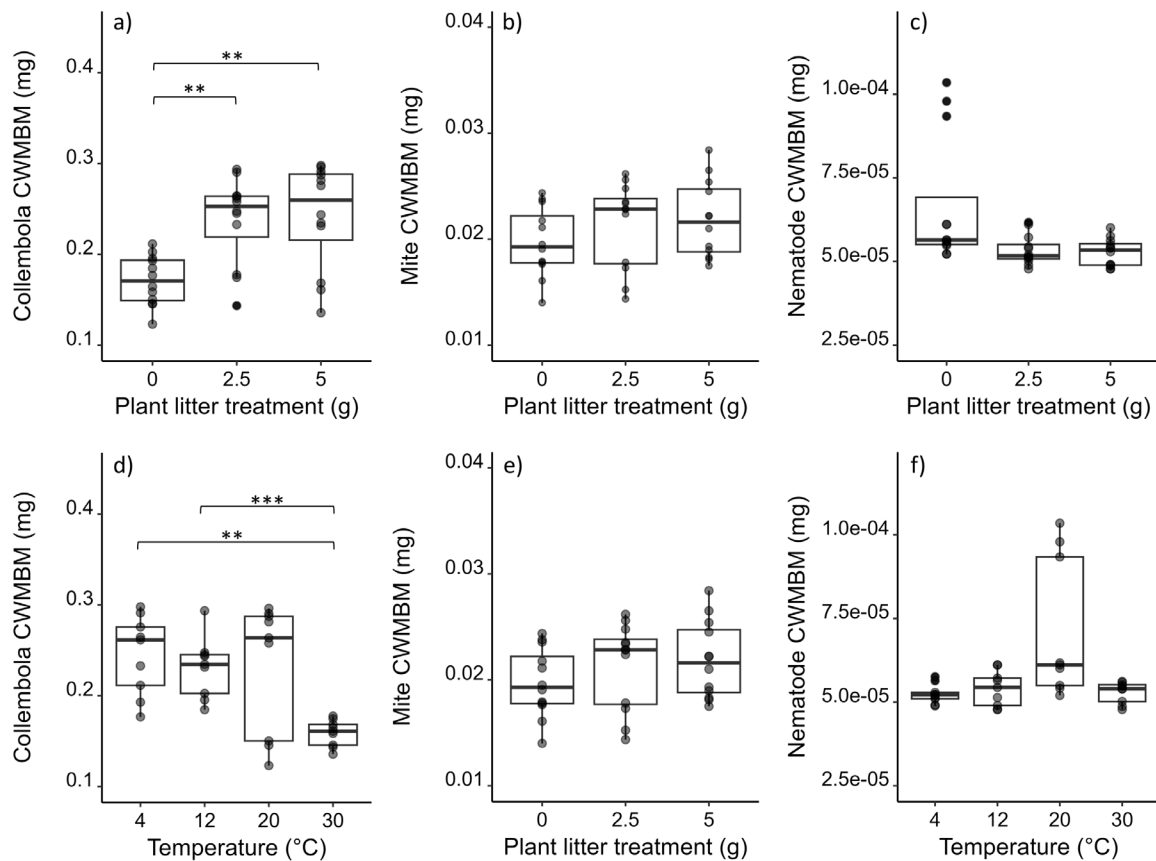


Figure S3. Treatment responses of collembola (a & d), mite (b & e) and nematode (c & f) community weighted mean body mass (CWMBM, mg) for plant litter availability (a-c) and temperature (d-f) showing pairwise Tukey test comparisons: *: $p < 0.05$; **: $p < 0.01$, ***: $p < 0.001$, ****: $p < 0.0001$. One-way ANOVA's for the overall effect of each treatment were: a & b)***, c – f) **.

Table S2. Summary of path coefficients from the final structural equation model (SEM) evaluating the effects of temperature, plant litter, and soil fauna community body size structure on litter decomposition. The table presents unstandardized and standardized path coefficients (β), standard errors (SE), and p -values for each directional path in the model. The residual correlation between Collembola and Nematode community-weighted mean body mass (CWMBM) is also reported. The model showed excellent fit ($C = 12.43$, $df = 14$, $p = 0.572$; $AIC = -1212.3$; $R^2 = 0.64$ for Collembola CWMBM; $R^2 = 0.39$ for Nematode CWMBM; $R^2 = 0.84$ for overall soil fauna CWMBM; and $R^2 = 0.93$ for Litter Loss).

Response	Predictor	Estimate	SE	Std. β	P
Collembola CWMBM	Temperature ²	-0.0001	0.00002	-0.586	<0.0001
Collembola CWMBM	Plant litter	0.0142	0.0029	0.530	<0.0001
Nematode CWMBM	Temperature	0.0000	0.0000	1.935	0.0036
Nematode CWMBM	Temperature ²	0.0000	0.0000	-1.852	0.0051
Nematode CWMBM	Plant litter	0.0000	0.0000	-0.442	0.0032
CWMBM	Collembola CWMBM	0.1347	0.0156	0.768	<0.0001
CWMBM	Temperature	0.0022	0.0003	2.230	<0.0001
CWMBM	Temperature ²	-0.0001	0.0000	-2.040	<0.0001
Litter loss	CWMBM	14.297	1.57	0.473	<0.0001
Litter loss	Plant litter	0.0928	0.0074	0.653	<0.0001
Residual correlation	Collembola CWMBM ~ Nematode CWMBM	—	—	-0.374	0.0135

Table S3. Results of causal mediation analysis testing the indirect effect of T² on mean CWMBM via Collembola CWMBM. The average causal mediation effect (ACME) quantifies the indirect effect of quadratic temperature (T²) on CWMBM through Collembola CWMBM, while the average direct effect (ADE) captures the remaining direct influence. The proportion mediated indicates the relative contribution of the indirect pathway to the total effect. Estimates are based on nonparametric bootstrapping (1,000 simulations).

Effect Type	Estimate	95% CI (Lower)	95% CI (Upper)	<i>p</i>
ACME (indirect)	-1.28×10 ⁻⁵	-1.89×10 ⁻⁵	-7.14×10 ⁻⁶	< 0.0001
ADE (direct)	-5.79×10 ⁻⁵	-7.03×10 ⁻⁵	-4.53×10 ⁻⁵	< 0.0001
Total Effect	-7.06×10 ⁻⁵	-8.67×10 ⁻⁵	-5.49×10 ⁻⁵	< 0.0001
Proportion Mediated	0.181	0.116	0.249	< 0.0001

Table S4. Leave-one-out sensitivity analysis of the final SEM shown in Table S2, assessing the effects of litter, temperature, and community body size traits on litter decomposition. Each SEM variant excludes a single pathway or predictor to evaluate its contribution to model fit (*Fisher's C*, *P*, *df*), model parsimony (AIC), and explanatory power (*R*²) for litter loss and CWMBM. The full model showed excellent fit (*C* = 12.43, *df* = 14, *p* = 0.572; AIC = -1212.26). Asterisks (*) highlight models with significantly worse fit (*p* < 0.05) or large reductions in *R*² (> 0.10), suggesting high sensitivity to the excluded pathway.

SEM	Fischer's <i>C</i>	<i>P</i>	<i>df</i>	AIC	<i>R</i> ² (Litter loss)	<i>R</i> ² (CWMBM)
Full model	12.425	0.572	14	-1212.26	0.93	0.84
- Nematodes	10.277	0.417	10	-496.46	0.93	0.84
- Collembola	28.694	0.001*	10	-1036.62	0.93	0.46*
- T effects	10.875	0.209	8	-1153.78	0.93	0.57*
- CWMBM ~ LL	44.519	0*	16	-1169.00	0.75*	0.84
- Litter effects	24.698	0.016*	12	-1125.05	0.59*	0.84

Table S5. Summary of the best fitting linear mixed-effect models between relative litter loss (proportion of litter loss compared to original plant litter) and overall soil mesofauna community weighted mean body mass (CWMBM, mg).

Relative litter loss ~ CWMBM + CWMBM², random = ~ 1 | Litter amount (g)
AIC = -97.31; R^{2m} = 0.528; R^{2c} = 0.719; N = 24

Random effects	Std. Dev.			
Litter amount, g (Intercept)	0.022			
Residual	0.027			
Fixed effects	Value	Std. Error	t-value	<i>p</i> -value
(Intercept)	0.065	0.023	2.884	0.009
CWMBM (mg)	5.308	1.893	2.803	0.011
CWMBM ²	-46.18	44.99	-1.026	0.317