Table S1. Eigenvalues and percentage of variance explained by principal components

Component	Standard Deviation	Variance (%)	Cumulative (%)
PC1	1.836	30.6	30.6
PC2	1.723	27.0	57.6
PC3	1.274	14.8	72.4
PC4	0.983	8.8	81.2
PC5	0.804	5.9	87.1
PC6	0.663	4.0	91.1
PC7	0.563	2.9	94.0
PC8	0.456	1.9	95.9
PC9	0.191	0.3	99.8
PC10	0.124	0.1	99.9
PC11	0.036	0.01	100.0

Table S2. Loadings of spectral and physiological indices on the first three principal components (PC1–PC3)

Variable	PC1	PC2	PC3
SPAD	0.140	0.001	-0.094
NDVI	0.395	0.188	0.398
RDVI	0.396	-0.359	0.216
EVI	0.338	-0.448	-0.012
MCARI	0.315	-0.462	0.095
CRI	0.163	0.420	0.361
ARI	-0.302	-0.099	0.394
SIPI	-0.308	-0.118	-0.519
PRI	0.257	0.290	0.351
PWI	-0.309	-0.276	0.162
SRWI	0.282	0.249	-0.270

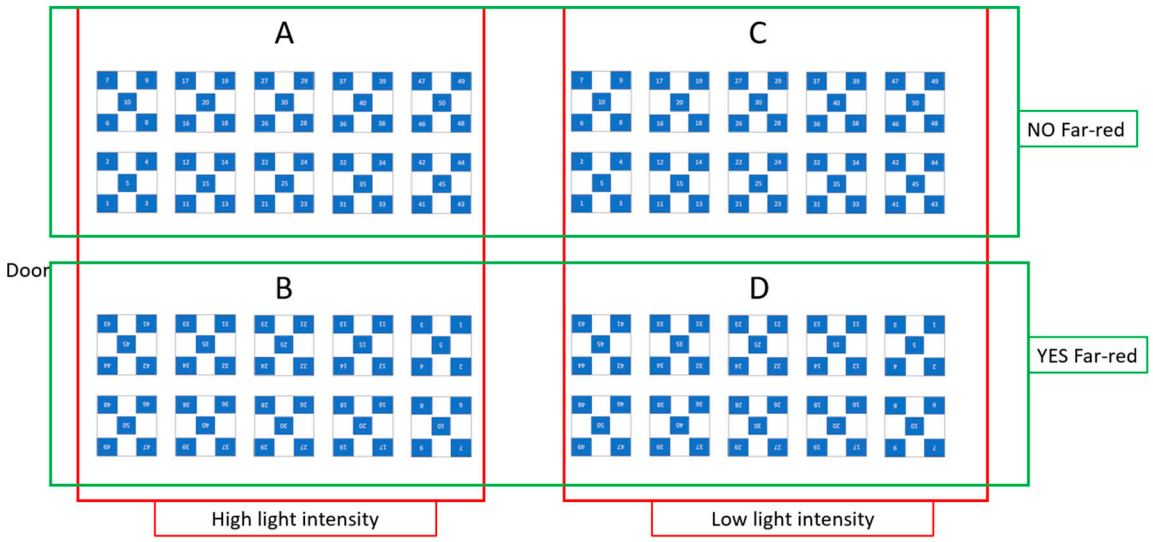


Figure S1. Layout of photon irradiance measurement positions and experimental design within the growth chamber, showing treatment combinations of light intensity (high and low) and far-red radiation (presence/absence).

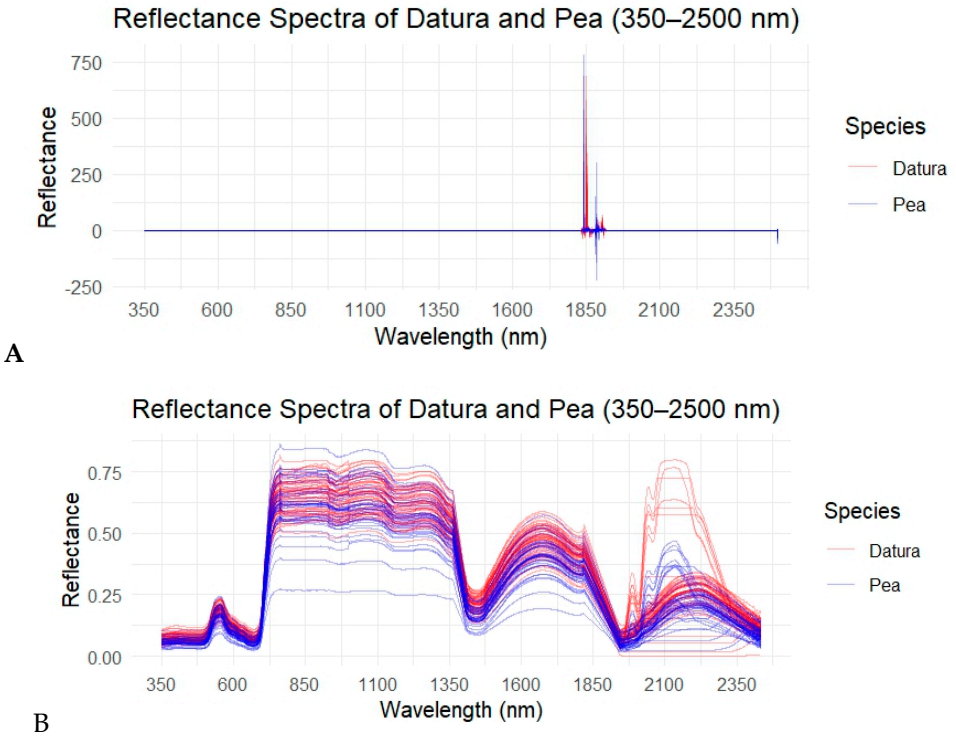


Figure S2. Hyperspectral reflectance spectra of *P. sativum* and *D. stramonium*: (A) raw spectra (350–2500 nm) before spectral preprocessing; (B) noise-filtered spectra after removal of wavelength regions affected by atmospheric water absorption and sensor noise.

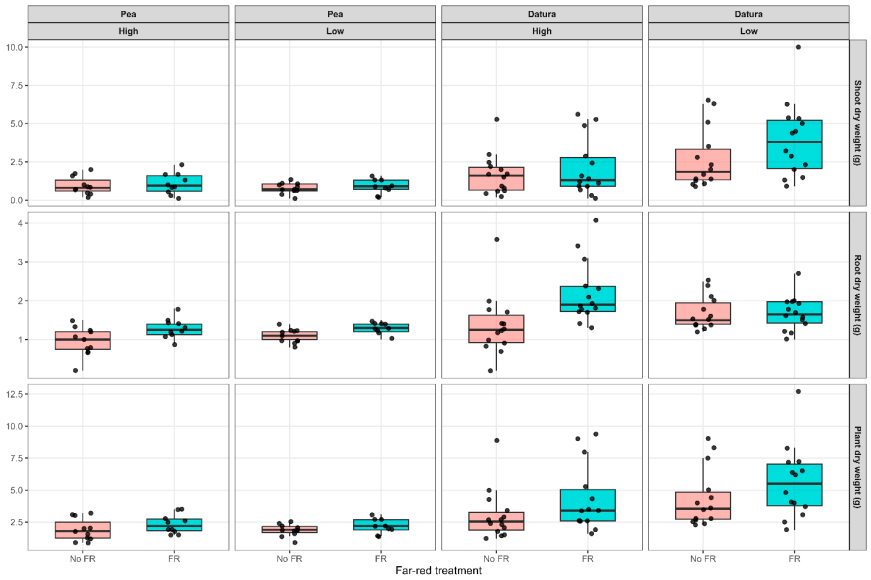


Figure S3. Effects of light intensity (photosynthetic photon flux density, PPFD; high and low) and far-red light supplementation (FR; present and absent) on shoot, root, and whole-plant dry biomass of *P. sativum* and *D. stramonium*. Boxplots show the distribution of shoot dry weight, root dry weight, and whole-plant dry weight for each treatment combination. The center line represents the median, the box indicates the interquartile range (IQR), whiskers extend to 1.5 × IQR, and individual points represent measurements from individual plants. Sample sizes were n = 14 per treatment for *D. stramonium* and n = 11, 10, 11, and 9 for *P. sativum* under NH, YH, NL, and YL, respectively.

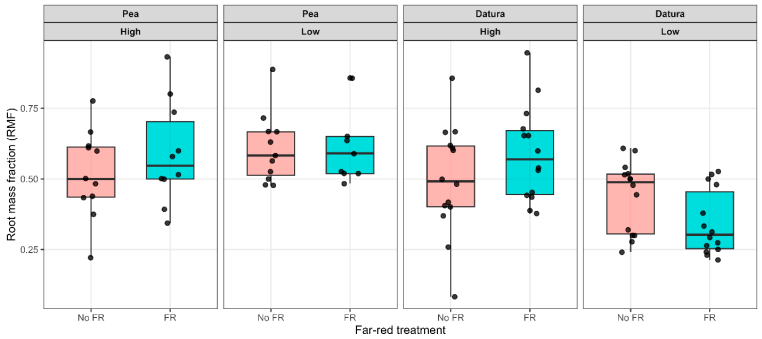


Figure S4. Effects of light intensity (photosynthetic photon flux density, PPFD; high and low) and far-red light supplementation (FR; present and absent) on root mass fraction (RMF) in *P. sativum* and *D. stramonium*. Boxplots show the distribution of RMF values for each treatment combination. The center line represents the median, the box indicates the interquartile range (IQR), whiskers extend to 1.5 × IQR, and individual points represent measurements from individual plants.

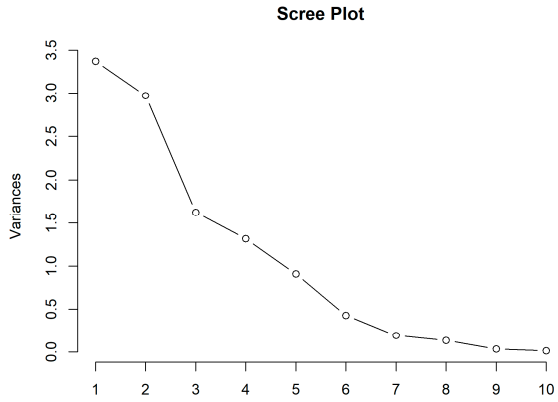


Figure S5. Scree plot showing variance explained by principal components

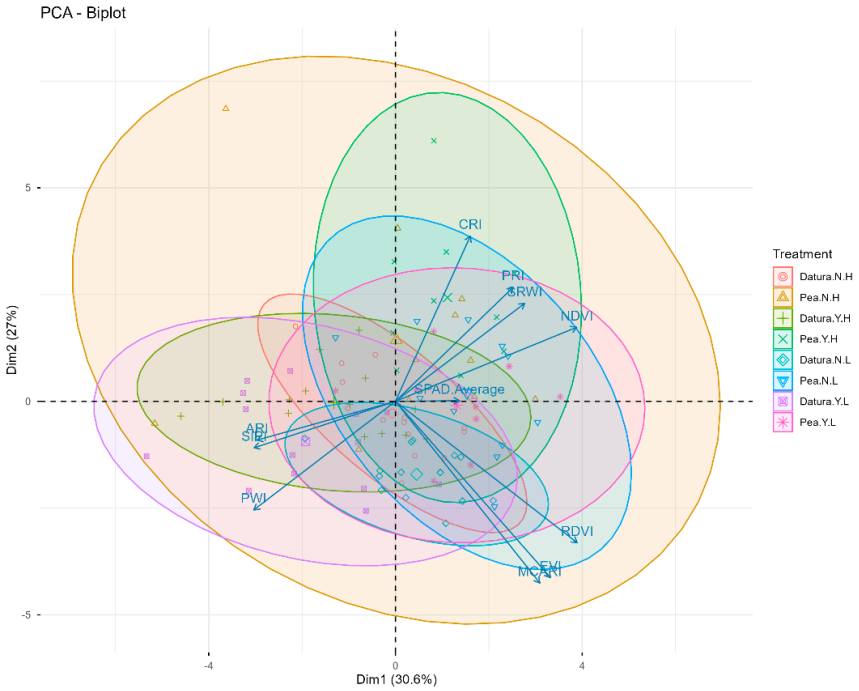


Figure S6. Principal component analysis (PCA) biplot showing the distribution of samples across treatment combinations (species × PPFD × far-red radiation) based on spectral and physiological indices. SPAD, Soil Plant Analysis Development chlorophyll index; NDVI, normalized difference vegetation index; RDVI, renormalized difference vegetation index; MSAVI, modified soil-adjusted vegetation index; EVI, enhanced vegetation index; PRI, photochemical reflectance index; CRI, carotenoid reflectance index; RWI, ratio water index; PWI, plant water index; ARI, anthocyanin reflectance index; SIPI, structure-insensitive pigment index.