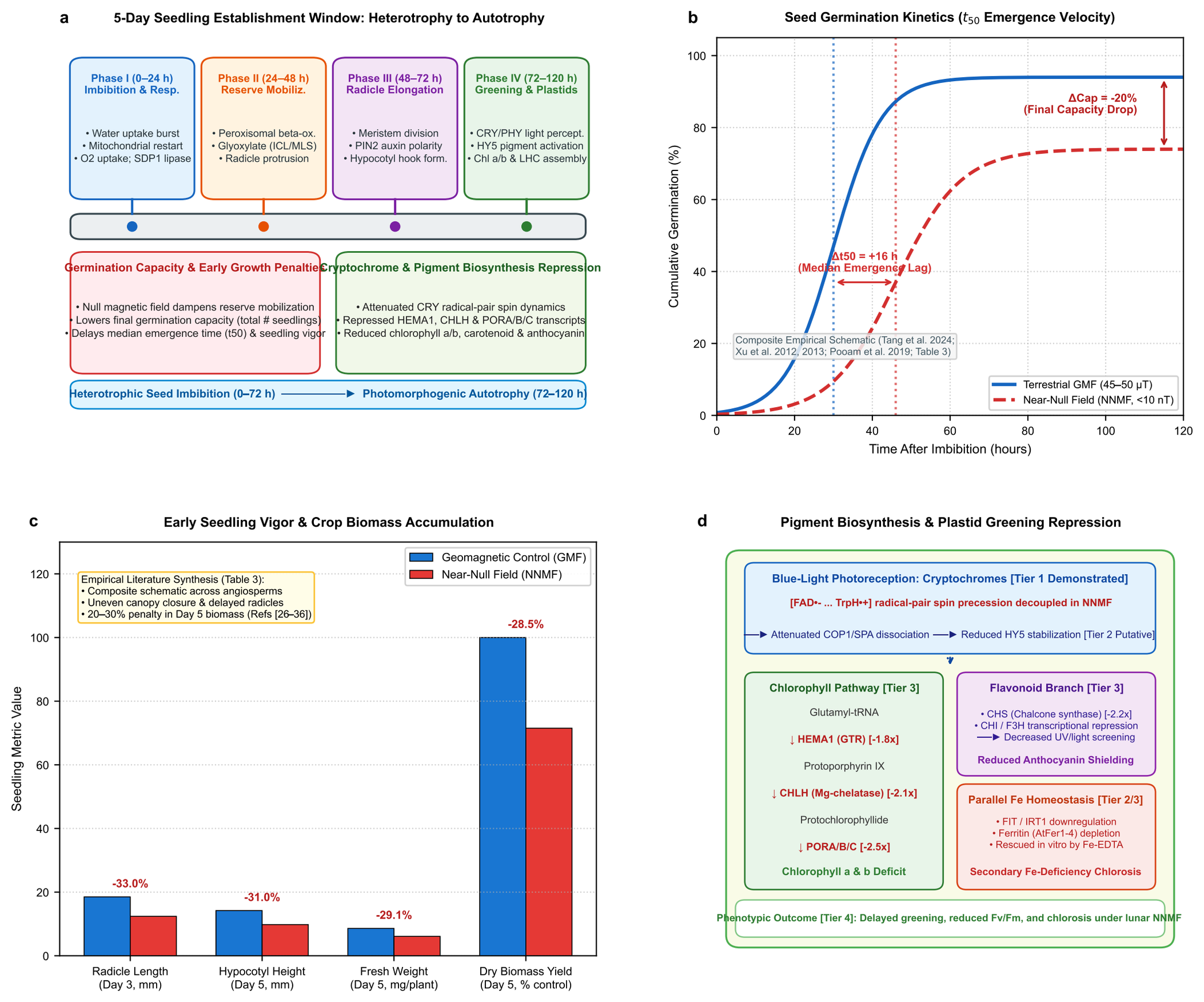

a
5-Day Seedling Establishment Window: Heterotrophy to Autotrophy
Phase I (0–24 h)
Imbibition & Resp.
• Water uptake burst
• Mitochondrial restart
• O2 uptake; SDP1 lipase
Phase II (24–48 h)
Reserve Mobiliz.
• Peroxisomal beta-ox.
• Glyoxylate (ICL/MLS)
• Radicle protrusion
Phase III (48–72 h)
Radicle Elongation
• Meristem division
• PIN2 auxin polarity
• Hypocotyl hook form.
Phase IV (72–120 h)
Greening & Plastids
• CRY/PHY light percept.
• HY5 pigment activation
• Chl a/b & LHC assembly
Germination Capacity & Early Growth Penalties
• Null magnetic field dampens reserve mobilization
• Lowers final germination capacity (total # seedlings)
• Delays median emergence time (t50) & seedling vigor
Cryptochrome & Pigment Biosynthesis Repression
• Attenuated CRY radical-pair spin dynamics
• Repressed HEMA1, CHLH & PORA/B/C transcripts
• Reduced chlorophyll a/b, carotenoid & anthocyanin
Heterotrophic Seed Imbibition (0–72 h)
Photomorphogenic Autotrophy (72–120 h)
b
Seed Germination Kinetics (t_{50} Emergence Velocity)
Cumulative Germination (%)
Time After Imbibition (hours)
ΔCap = -20%
(Final Capacity Drop)
Δt50 = +16 h
(Median Emergence Lag)
Composite Empirical Schematic (Tang et al. 2024;
Xu et al. 2012, 2013; Pooam et al. 2019; Table 3)
Terrestrial GMF (45–50 μT)
Near-Null Field (NNMF, <10 nT)
c
Early Seedling Vigor & Crop Biomass Accumulation
Seedling Metric Value
Geomagnetic Control (GMF)
Near-Null Field (NNMF)
Empirical Literature Synthesis (Table 3):
• Composite schematic across angiosperms
• Uneven canopy closure & delayed radicles
• 20–30% penalty in Day 5 biomass (Refs [26–36])
-33.0%
-31.0%
-29.1%
-28.5%
Radicle Length
(Day 3, mm)
Hypocotyl Height
(Day 5, mm)
Fresh Weight
(Day 5, mg/plant)
Dry Biomass Yield
(Day 5, % control)
d
Pigment Biosynthesis & Plastid Greening Repression
Blue-Light Photoreception: Cryptochromes [Tier 1 Demonstrated]
[FAD•- ... TrpH•+] radical-pair spin precession decoupled in NNMF
Attenuated COP1/SPA dissociation
Reduced HY5 stabilization [Tier 2 Putative]
Chlorophyll Pathway [Tier 3]
Glutamyl-tRNA
↓ HEMA1 (GTR) [-1.8x]
Protoporphyrin IX
↓ CHLH (Mg-chelatase) [-2.1x]
Protochlorophyllide
↓ PORA/B/C [-2.5x]
Chlorophyll a & b Deficit
Flavonoid Branch [Tier 3]
• CHS (Chalcone synthase) [-2.2x]
• CHI / F3H transcriptional repression
Decreased UV/light screening
Reduced Anthocyanin Shielding
Parallel Fe Homeostasis [Tier 2/3]
• FIT / IRT1 downregulation
• Ferritin (AtFer1-4) depletion
• Rescued in vitro by Fe-EDTA
Secondary Fe-Deficiency Chlorosis
Phenotypic Outcome [Tier 4]: Delayed greening, reduced Fv/Fm, and chlorosis under lunar NNMF