different ponding depths. For example, a calibrated CERES-Rice model successfully reproduced grain yield, evapotranspiration, irrigation volume, and leaf area index across AWD and controlled irrigation-drainage schemes, then used long-term meteorological scenarios to compare water-saving and yield responses among treatments (Gao et al., 2023). Similarly, AquaCrop-based simulations under drying-wetting cycles in paddy soils and fixed-interval irrigation in direct-seeded rice quantified how changes in irrigation frequency alter evapotranspiration, percolation, and soil moisture dynamics, revealing that current stress coefficients may overestimate water deficit under certain conditions and should be revised for rice-specific hydrology (Elsadek et al., 2023).

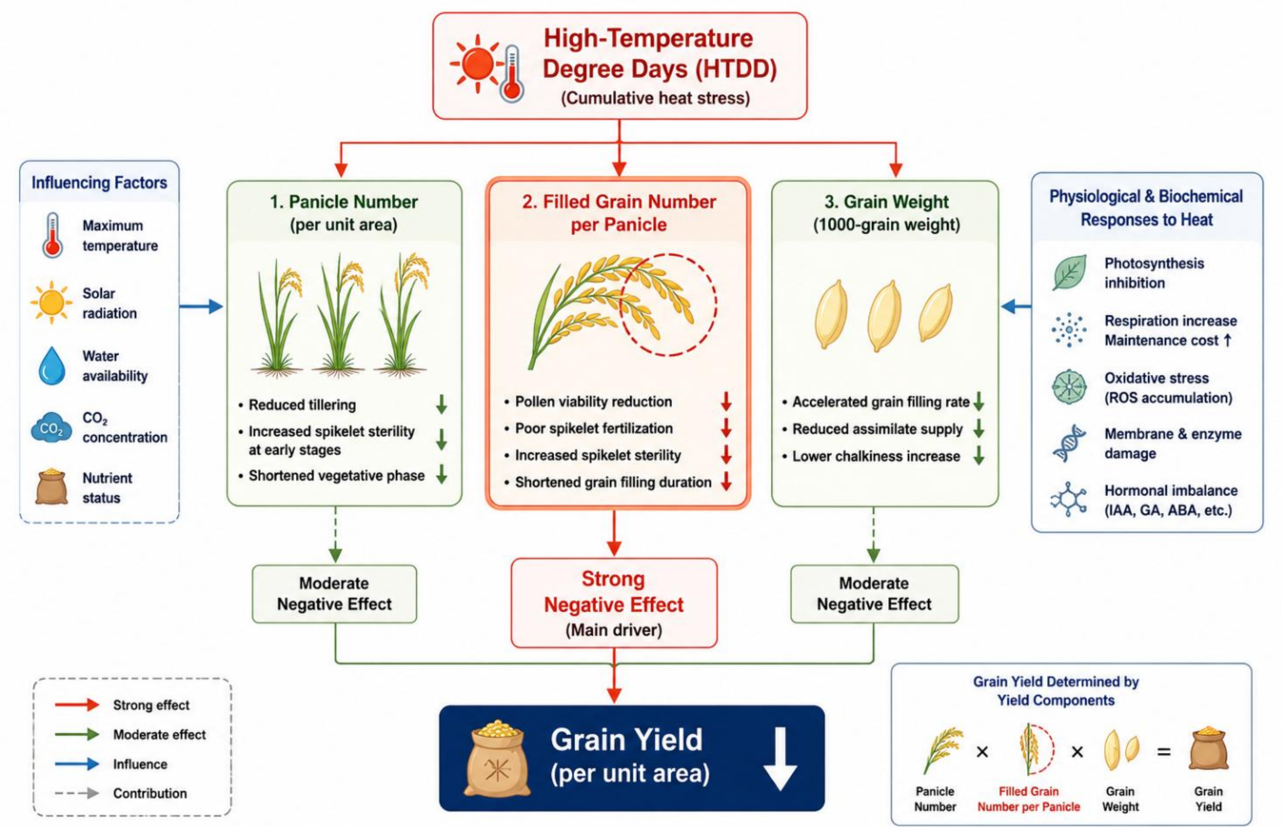

Figure 2 presents the pathways through which high-temperature stress affects rice yield formation. Among the yield components, reductions in filled grain number per panicle contribute most strongly to negative yield responses under warming conditions

5.3 Calibration and validation of models

Accurate representation of temperature and water effects in yield models depends on rigorous calibration and validation of both genetic and environmental/management parameters. In DSSAT-CERES-Rice applications, cultivar-specific coefficients (e.g., phenology, tillering, grain filling, spikelet number, temperature tolerance) are estimated using multi-year field experiments with contrasting genotypes, establishment methods, and nitrogen levels; evaluation against observed yields and phenology has shown low normalized RMSE and realistic sensitivity to ±1 °C temperature changes, confirming that calibrated models can capture both baseline performance and climate sensitivity (Islam and Hasan, 2021). For upland rice, detailed documentation of coefficients such as P2R (photoperiod sensitivity), P5 (grain-filling duration), G1 (spikelet number), G3 (tillering), and G4 (temperature tolerance) illustrates how parameter sets encode cultivar adaptation to different temperature regimes and allow tested models to simulate flowering and maturity across controlled temperature treatments.

Validation must also address parameter uncertainty and model robustness across sites and years. A cross-validation study with ORYZA (v3) generated multiple feasible parameter sets for a high-yielding variety under limited data and showed that several sets produced satisfactory simulations of biomass components and total aboveground biomass when tested with independent datasets, implying that non-uniqueness of calibrated parameters should be explicitly recognized (Nurulhuda et al., 2022). At larger scales, DSSAT-based studies have