Nash-Sutcliffe efficiency 0.65 and R 0.80. These simulations captured changes in fruit size (diameter, length, and average fruit weight) and yield under water-saving practices, supporting their use as scenario tools for fruit weight formation under constrained irrigation (Gebeyhu and Markos, 2023).

7.3 Model-based optimization of watermelon cultivation management (irrigation, fertilization, and temperature control)

Model outputs linked to irrigation strategies allow optimization of water allocation while maintaining fruit weight. In Mediterranean open fields, staged deficit-irrigation experiments quantified how applying 75%-50% of crop water requirement at vegetative, fruit development, or ripening stages reduces average fruit weight, fruit number, and marketable yield, with ripening identified as the least sensitive stage to water shortage. Similarly, Heliyon-based AquaCrop simulations for Ethiopian mulched systems showed that straw mulching plus 50% deficit irrigation with suitable varieties (e.g., Green Pearl) maximized land and water productivity while maintaining competitive average fruit weights, guiding irrigation scheduling and variety choice under scarcity (Gebeyhu and Markos, 2023).

Fertilization and coupled water-nutrient management can also be optimized using regression and structural approaches informed by model results in related cucurbits. Under rain-shelter watermelon, regression trendlines indicated that a 25% increase above standard NPK (125%) maximized fruit weight and vegetative growth under fertigation, suggesting that fertigation-based models should include fertilizer rate as a continuous decision variable in protected systems (Hafiz et al., 2024). For melon, structural equation modeling under varied water and fertilizer levels identified photosynthetic rate and total dry mass as key intermediates by which water and nutrient inputs control yield and quality, implying that watermelon fruit weight optimization models should similarly treat growth and photosynthesis as mediating variables when evaluating combined irrigation-fertilization strategies across arid and semi-arid environments (Yang et al., 2023).

8 Discussion and Outlook

Most existing watermelon fruit weight models are empirical and developed under narrowly defined conditions, limiting their transferability to other farms and seasons. For example, a tillage-based yield model was fitted using soil physical properties and simple plant traits, achieving very high R^2 (0.98) but relying on linear and weakly nonlinear relationships derived from only two seasons in a semi-arid Nigerian environment. Similarly, mixture models relating poultry, cow, and goat manure rates to fruit weight produced statistically significant quadratic equations, yet they describe only manure effects and do not explicitly account for weather, irrigation scheduling, or pest pressure that commonly constrain yield in practice. Non-destructive image-based models reach high fitting accuracy but also reveal important limitations. A U-Net plus machine-learning approach predicted watermelon weight from image features with $R^2 \approx 0.91$, but training relied on controlled image acquisition at fixed distances and backgrounds, conditions that are rarely met in commercial fields or heterogeneous greenhouses. Furthermore, the authors noted that prediction success is influenced by the diversity and complexity of products in the images, implying that substantial recalibration or retraining would be required when moving from experimental datasets to large-scale, multi-variety production systems.

Watermelon fruit weight responds to interacting environmental drivers rather than isolated factors, which complicates modeling. A three-way factorial experiment in northern Tanzania showed that extra irrigation or fertilizer alone did not increase fruit weight, while pollination strongly affected the probability of setting a second marketable fruit and improved sugar content, with complex higher-order interactions among water, fertilizer, and pollination on fruit initiation. Supplemental hand-pollination across 13 farms increased average fruit weight by 1.3 kg while responses to soil moisture varied with treatment, demonstrating that both biotic (pollinators) and abiotic (soil carbon and water) factors jointly regulate fruit set, abortion, and final weight. Greenhouse experiments further highlight strong water-nitrogen-CO_2 interactions on growth and yield. Under elevated CO_2, increased irrigation improved dry matter accumulation, photosynthesis, and yield, while higher CO_2 partly compensated for low nitrogen, shifting optimal N rates relative to ambient CO_2 scenarios (Hong et al., 2022). The interaction of irrigation and nitrogen significantly affected key physiological indicators such as net photosynthetic rate and