Most of the available evidence comes from nutrient solutions, pot experiments, perlite systems, or controlled greenhouse conditions. These designs are well suited to mechanistic studies because root-zone salinity can be maintained relatively uniformly. Field soils, however, show spatial variation in water availability, salinity, and plant-available Si, while temperature, fertilization, and soil texture introduce additional sources of variation. The study of Bushra et al. (2025) began to incorporate root responses and fruit yield into the evaluation, but overall, direct field evidence remains much more limited than controlled seedling experiments.

From a meta-analytic perspective, these interactions mean that future analyses should not focus only on the question of "how much Si improves performance on average". A more informative question is under which genotype, salinity level, and Si source the response is greatest. Existing studies already indicate interactions among genotype, salinity intensity, and Si treatment. The interpretation becomes even more complex when K, mycorrhizae, or NO are included (Altuntas et al., 2018). Therefore, simply pooling all treatments into a single overall mean effect may produce an apparently precise estimate with limited biological relevance.

8 Conclusions and Future Research Directions

Exogenous Si exerts beneficial effects on pepper under salinity stress, although the consistency of the response varies among traits. Among the biomass comparisons that could be quantified, the representative median increase in shoot dry weight was approximately 12%. Net photosynthetic rate increased by about 13%, while leaf water status improved by roughly 14%. Some individual studies reported much larger increases, particularly for fresh weight and plant height, but such values are not suitable as general conclusions when results are compared across experiments. Improvements in chlorophyll content, stomatal conductance, and transpiration rate were more consistent in direction.

Compared with growth-related traits, indicators of oxidative damage showed greater consistency. Representative comparisons indicated that Si reduced MDA by approximately 31% and electrolyte leakage by about 33%, while increasing the activities of SOD, CAT, APX, and GR. In sweet pepper, tissue Na^+ concentration declined by an average of approximately 45%. These responses form a physiologically coherent sequence: reduced Na^+ accumulation lowers oxidative pressure, while enhanced antioxidant capacity further limits membrane lipid peroxidation. At present, this constitutes one of the most complete lines of evidence for Si-mediated salinity tolerance in pepper. Positive yield responses have also been reported, and in some cases the magnitude was substantial. In one two-season sweet pepper experiment, Si increased total yield by approximately 56% and 44% under two salinity levels. By contrast, another study found no significant main effect of Si on marketable fruit yield. These findings are not necessarily contradictory. Rather, they indicate that production responses are strongly influenced by salinity level, genotype, application method, and experimental duration. A more appropriate conclusion at present is therefore that Si has clear potential to help maintain yield under salinity stress, but the available meta-analytic evidence in pepper is still insufficient to derive a stable overall yield effect size.

Existing studies have expressed salinity using 50-150 mM NaCl, ppm salt concentrations, or electrical conductivity in dS/m, while Si treatments have included conventional silicates, foliar Si formulations, and nanosilicon. Treatment duration has ranged from approximately two weeks to the full fruiting period. This methodological variation limits the applicability of rigorous variance-weighted meta-analysis. In particular, some studies report only treatment means or graphical results without complete information on SD, SE, or sample size. Pooling such data indiscriminately would create a false impression of precision. At present, data on chlorophyll, antioxidant enzymes, and MDA are much more abundant than data on fruit yield. This imbalance is important because a 50% increase in leaf SOD activity does not imply a 50% increase in yield. Physiological advantages can be translated into economic yield only if leaf area, photosynthetic activity, flowering, and fruit set are maintained throughout the crop cycle. Few pepper studies currently cover all of these stages simultaneously. Existing evidence has already shown that salt-tolerant and salt-sensitive genotypes respond differently, but the number of genotypes included in Si experiments remains limited. An "optimal Si concentration" derived from one or two commercial cultivars cannot be directly extrapolated to other pepper types. Transcriptomic evidence further indicates that cultivars inherently differ in ROS scavenging, SOS signaling, and hormonal responses.