132%, while dry weight increased from 0.09 to 0.13 g, or by about 44%. In the two-genotype experiment of Altuntas et al. (2018), Si application increased shoot dry weight by approximately 5.5%-19.7% under 75 and 150 mM NaCl. When these five directly comparable treatments were considered as exploratory effect units, the median increase was approximately 12.4%. This estimate is considerably more conservative than the near-doubling effects reported in some individual experiments and better reflects the variation among studies.

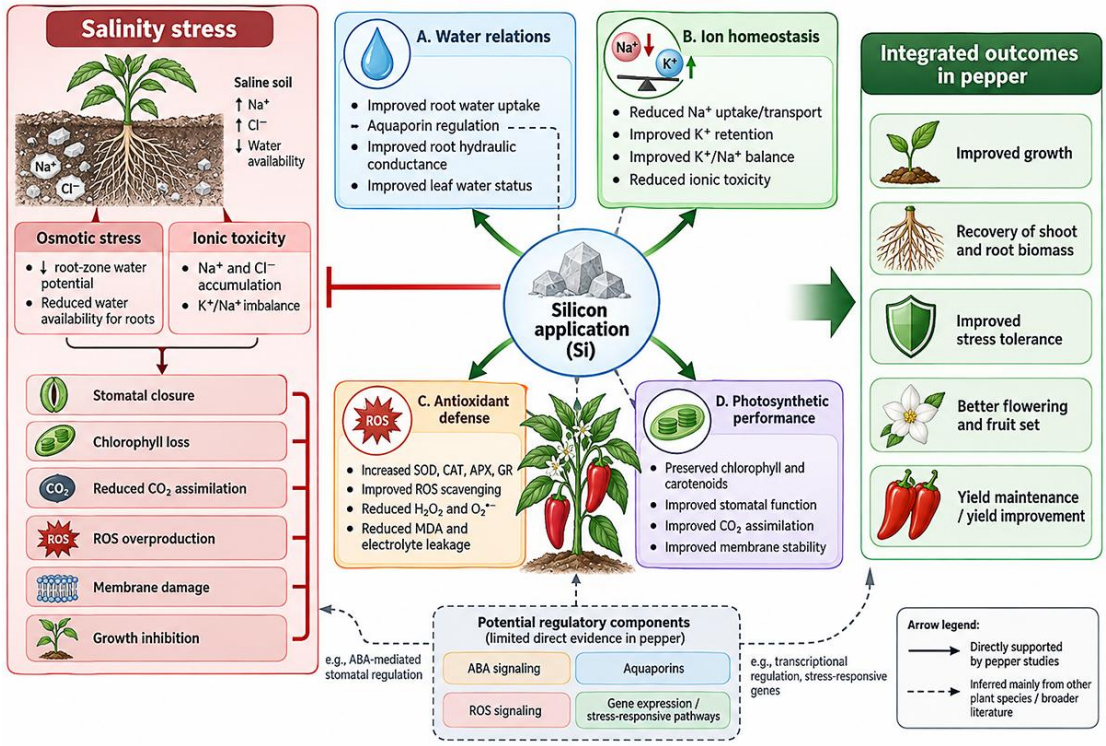


Figure 1 Proposed physiological framework of silicon-mediated salinity tolerance in pepper

Image caption: Salinity stress induces osmotic limitation, Na^+ and Cl^- accumulation, oxidative damage, and photosynthetic inhibition in pepper. Silicon application may alleviate these effects by improving root water uptake and leaf water status, maintaining ion homeostasis, enhancing antioxidant defense, stabilizing cellular membranes, and supporting photosynthetic performance. Solid pathways represent responses directly supported by pepper studies, whereas dashed pathways indicate mechanisms mainly inferred from evidence in other plant species

3.2 Root growth responses

Root responses show considerably greater variability. In 'Bugwang', individual root length was lower under the combined Si + salt treatment than under salt stress alone, whereas root number increased from 23.2 to 43.2, an increase of approximately 86%. This suggests that root system architecture may shift from a small number of relatively long roots toward a greater number of lateral roots. In the experiment of Altuntas et al. (2018), Si increased root dry weight by approximately 5%-39% across different genotypes under salinity stress. By contrast, Badem and Söylemez (2022) observed only a nonsignificant increase in root dry weight. Taken together, these results are more informative when changes in overall root system development are considered rather than root length alone.

Under saline conditions, roots are responsible for both water and mineral acquisition and are also the first organs directly exposed to NaCl. Si deposition and regulation of aquaporins may help root tissues maintain water uptake under high osmotic stress. At the same time, enhanced antioxidant capacity in roots may reduce membrane lipid damage and thereby help preserve selective ion uptake. Studies in other plant species have shown that Si can influence root hydraulic conductance and ABA-mediated regulation, providing a plausible explanation for the recovery of root biomass observed in pepper. However, direct measurements of root hydraulic parameters in pepper remain limited (Rios et al., 2017).