decrease in vitamin C content and locule number, while fruit firmness, Brix value, and β-carotene content tend to increase (Mahmoud et al., 2025).

Dual resistance to ToLCV and bacterial wilt can be combined with good processing traits, but it is necessary to maintain a balance of lycopene, total soluble solids (TSS), and acidity during parent selection (Acharya et al., 2018). In addition, hybrids with multiple resistance to Fol, TYLCV, and TSWV can meet market standards in terms of fruit firmness, TSS/acid ratio, and color. This indicates that if quality traits are included simultaneously in breeding selection, disease resistance does not significantly reduce fresh fruit quality.

Evaluation of diverse germplasm resources also found that some materials possess both ToMV resistance, high soluble solids content, and strong antioxidant activity. These can be used as important parental resources for simultaneous improvement of resistance and quality.

6.2 Agronomic measures supporting resistant varieties

Resistant varieties perform best under integrated disease management (IDM) systems. The IDM model that combines resistant or grafted plants with biological agents, pheromone traps, and need-based pesticide application not only increases yield but also significantly reduces pesticide use.

In areas with high incidence of bacterial wilt, integrated measures such as soil improvement, application of Bacillus subtilis, and intercropping systems can effectively reduce disease occurrence and improve input-output efficiency (Sheneka et al., 2025). In addition, studies on Fusarium wilt and late blight indicate that a single control method is not enough for long-term management. Instead, soil health management, crop rotation, and biological control should work together with resistant varieties to achieve sustainable control (Jehani et al., 2025).

6.3 Postharvest quality and shelf life

Disease resistance can also indirectly improve postharvest quality by reducing disease incidence, since healthy plants and fruits are less prone to decay. Breeding strategies that combine ToLCV resistance with delayed ripening traits have successfully developed hybrids with extended shelf life and stable yield (Manjunath et al., 2025).

Studies show that genotypes with higher fruit firmness have lower disease incidence during storage and can maintain a longer shelf life, thereby reducing market losses (Imali et al., 2025) (Figure 2). In addition, molecular improvement of gene loci related to fruit firmness and shelf life can delay fruit softening and enhance resistance to pathogens during transportation and storage.

7 Case Studies of Disease-Resistant Tomato Varieties

7.1 Breeding progress of TYLCV-resistant tomato varieties

Resistance to TYLCV (Tomato yellow leaf curl virus) is mainly achieved by introgressing Ty genes from wild relatives and combining gene-specific markers with linked markers for gene pyramiding. For example, commercial F1 hybrids such as ‘Brivio’, ‘Dania’, ‘SV8320’, and ‘Tyrmes’ commonly contain combinations of multiple resistance genes, including Ty-1/Ty-3, Ty-2, Ty-4, and ty-5. Under field TYLCV pressure, these varieties may show moderate or mild symptoms, but they can still maintain relatively good yield and fruit quality (Mahmoud et al., 2023). Studies have shown that pyramiding Ty-1/Ty-3 with Ty-2 using marker-assisted selection can significantly enhance resistance, confirming the synergistic effect of stacking multiple loci (Lee et al., 2020). In variety trials under natural TYLCV pressure in Georgia, USA, cultivars carrying Ty-1 or Ty-3/Ty-6 showed lower disease incidence and higher yield compared with susceptible controls, indicating good field resistance (Acharya et al., 2025). However, resistance based on Ty-1 may break down under high-temperature conditions, suggesting limitations in environmental adaptability of the current resistance system (Koeda and Kitawaki, 2024).

7.2 Fusarium wilt-resistant tomato hybrids

Resistance to tomato Fusarium wilt mainly comes from the I gene family introgressed from wild species (Chitwood-Brown et al., 2021). By crossing lines carrying the I-3 gene with commercial cultivars containing I-1 and I-2, the FOX hybrid series has been developed. Some of these materials show resistance to different physiological races of *Fusarium oxysporum* f. sp. lycopersici (Fol), but their agronomic traits still need