4.3 Genotype×environment interaction effects

The formation of peach fruit quality traits is not determined by genotype alone. Genotype × environment interaction (G×E) is an important cause of variation and stability differences in quality traits. In actual production, different cultivars may exhibit different quality under the same environment, while the same cultivar may show significantly different quality performance across regions, years, and management conditions. This phenomenon is a direct manifestation of G×E interaction. Multi-environment trials have shown that traits such as fruit weight, fruit size, coloration, and SSC usually display significant G×E effects. In contrast, traits such as titratable acidity and ripening date often have relatively high heritability and lower G×E effects, whereas fruit weight and shape are more environmentally sensitive and require region-specific selection and management (Rawandoozi et al., 2020b). This indicates that not all quality traits respond to the environment in the same way: some are relatively stable and suitable for wide adaptation, whereas others are highly environment-dependent and require precise matching between cultivar and region.

At the molecular level, multi-environment genomic prediction models show that the G×E effect on SSC mainly originates from the polygenic background, whereas some major QTLs and dominance effects remain relatively stable across environments. This means that peach quality traits are controlled both by stable major genes and by numerous minor-effect genes and environmental signals. Environmental factors such as light, temperature, water, canopy microclimate, and exogenous treatments interact with cultivar-specific regulatory networks by affecting sugar and acid metabolism, pigment accumulation, and volatile compound formation, ultimately leading to different quality outcomes (Cao et al., 2024). For example, in 'Huangjin' peach, the color-change stage is a key period of transcriptomic and metabolomic change, and the timing and intensity of this stage are strongly regulated by temperature and light. When exogenous treatments such as glutamic acid, sucrose, or brassinolide are applied, different cultivars show markedly different responses in fruit weight, firmness, SSC, anthocyanin accumulation, and the expression of key genes (e.g., *PpPAL, PpF3H, PpDFR, PpUFGT, PpGST1, and PpMYB10.1)*, indicating that the effects of environmental or management signals are strongly genotype-dependent (Figure 6) (Kou et al., 2023). This suggests that the same management practice does not necessarily produce the same effect across cultivars, and quality regulation must be based on an understanding of cultivar-specific responses.

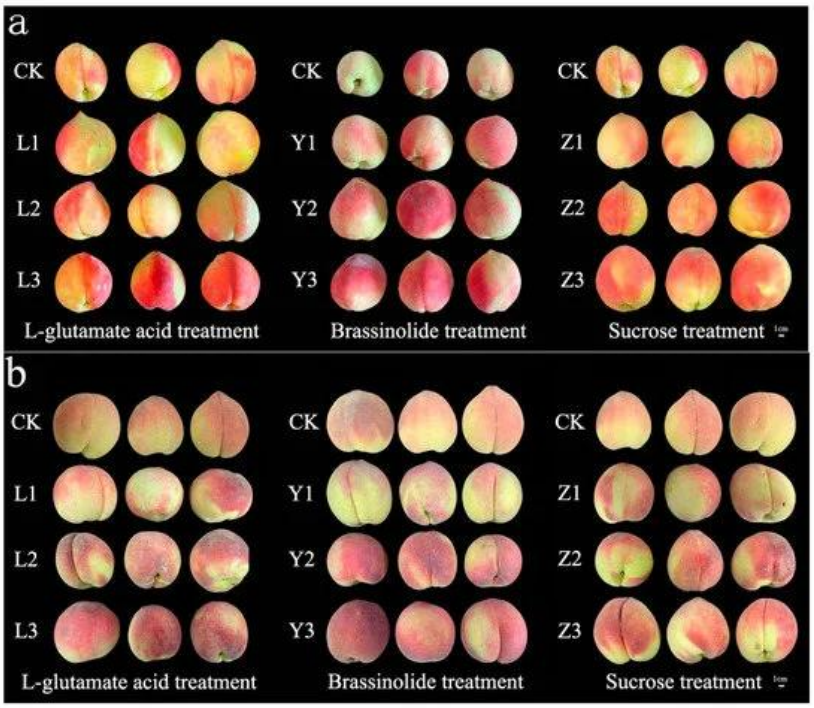

Figure 6 The ripening stage of the fruits of 'Baifeng' and 'Weiduanmihong' after treated with exogenous substances (Adopted from Kou et al., 2023)

Image caption: (a) is 'Baifeng'; (b) is 'Weiduanmihong' (Adopted from Kou et al., 2023)