Seedling growth and flowering stages are sensitive to low temperature, frost, heat stress, drought, and strong wind. In particular, common buckwheat often shows increased empty grain rates and yield reduction when high temperatures, continuous rainfall, or insufficient pollinator activity occur during flowering (Penin et al., 2021). The physiological advantages of Tartary buckwheat are mainly reflected in its adaptation to high-altitude, cool, and nutrient-poor environments. Its relatively stable grain production under these conditions is associated with its shorter growth cycle, stronger root nutrient uptake ability, and higher secondary metabolic activity.

2.3 Genetic diversity and germplasm resources

Because common buckwheat is cross-pollinated and self-incompatible, natural populations usually maintain high heterozygosity and abundant genetic variation. Although Tartary buckwheat is mainly self-pollinating, long-term cultivation in mountainous regions, ethnic communities, and different altitudinal environments has also resulted in substantial ecological differentiation and the formation of diverse local landraces.

The wild ancestral form *F. esculentum* ssp. ancestrale is closely related to cultivated common buckwheat and provides valuable material for studying domestication traits such as larger seed size, reduced seed shattering, altered flowering behavior, and adaptation expansion. Similarly, the wild ancestral type *F. tataricum* ssp. potanini is important for understanding high rutin accumulation, bitter taste formation, and mountain adaptation in Tartary buckwheat. Compared with cultivated forms, wild buckwheat relatives usually show stronger seed shattering and seed dormancy. Although these traits are unfavorable for direct cultivation, they may contain genes related to stress tolerance and ecological adaptation.

2.4 Adaptation to marginal environments and climate resilience

Buckwheat is often considered suitable for marginal land cultivation, but this conclusion depends on environmental conditions and species differences. Both common buckwheat and Tartary buckwheat have relatively short growth periods and low nutrient requirements. They can therefore play important roles in areas with poor soil fertility, short frost-free seasons, or high risks for major cereal production. In mountain agricultural systems, buckwheat can function as a supplementary grain crop, a rotation crop, a nectar source plant, and an ecological landscape crop. Compared with high-input crops such as maize, wheat, and rice, buckwheat depends less on chemical fertilizers and irrigation, making it suitable for resource-limited agricultural regions.

However, the climate resilience of buckwheat should not be oversimplified. Although it shows relatively strong tolerance to poor soils and cool climates, it is still sensitive to salt stress, heat stress, drought, and frost. For example, Zhang et al. (2023) investigated the effects of salt stress on root morphology, carbon and nitrogen metabolism, and yield formation in Tartary buckwheat. Their study showed that increasing salt concentration inhibited root growth, disrupted carbon-nitrogen metabolic balance, and ultimately reduced grain yield.

Tartary buckwheat is generally better adapted to high-altitude and cool environments than common buckwheat, which corresponds closely with its long-term geographical distribution. Tartary buckwheat is widely cultivated in Liangshan Yi Autonomous Prefecture, the Yunnan Plateau, mountainous regions of Guizhou, and parts of the Himalayan region. It can complete reproductive development within a short growing season while accumulating high levels of flavonoids in the grain. This may be related to adaptation to strong ultraviolet radiation, large day-night temperature differences, and environmental stress conditions. In comparison, common buckwheat is more suitable for temperate and cool regions, but its flowering and seed setting are strongly influenced by weather conditions and pollinator activity. Under the increasing frequency of extreme climate events, breeding programs for common buckwheat need to pay greater attention to seed-setting stability, heat tolerance, and flowering regulation.

3 Nutritional Composition

3.1 Carbohydrates, proteins, lipids, and dietary fiber

Buckwheat grains are mainly composed of carbohydrates, but their nutritional profile differs from many traditional cereals because the starch matrix is accompanied by relatively high-quality proteins and dietary fiber components. Studies comparing common buckwheat (*Fagopyrum esculentum*) and Tartary buckwheat