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Litchi Under Stress: Understanding and Managing Nature's Impact on Growth and Fruit Quality

Balreet Kaur
M.Sc. Horticulture (Fruit Science), Punjab Agricultural University, Ludhiana- (141004), India.
Corresponding address: balreetkaur2712@gmail.com
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Introduction

Litchi (*Litchi chinensis* Sonn.) is an evergreen subtropical fruit crop belonging to the family Sapindaceae, with a chromosome number of 2n = 2x = 30. Botanically classified as a drupe with an edible aril, litchi is valued for its attractive appearance, pleasant flavour, and high nutritional content, particularly vitamin C, antioxidants, and essential minerals. Owing to these qualities, it is often referred to as the "Queen of Fruits." The crop is believed to have originated in South China and is now cultivated widely in countries such as China, India, Thailand, Vietnam, Israel, South Africa, Mauritius, Madagascar and the United States (Kumar 2015).

Litchi grows best in warm subtropical to elevated tropical regions characterised by warm, humid summers and cool, dry winters. It is however, highly fastidious in its climatic requirements, and its growth, flowering, fruit retention, and quality are strongly influenced by temperature, humidity, light intensity, and soil moisture (Menzel and Waite 2005). Even slight deviations from the optimum climate can adversely affect flowering behaviour and fruit development. In recent years, increasing climatic variability associated with climate change has intensified abiotic stresses such as heat, drought, cold, and erratic rainfall, leading to serious physiological disturbances including reduced photosynthesis, nutrient imbalance, fruit cracking, and fruit drop (Kumar 2016).

In addition to abiotic stresses, litchi is highly vulnerable to biotic stresses caused by fungal pathogens, insect pests, and occasional algal infections. These stresses collectively contribute to major pre- and post-harvest losses and significantly reduce marketable yield and fruit shelf life (Koul and Taak 2017). Therefore, understanding the effects of these stresses and adopting appropriate management strategies is essential for sustaining litchi production under changing environmental conditions.

Distribution Status of Litchi

Globally, litchi production is heavily concentrated in the Northern Hemisphere, which contributes nearly 96% of total world production. China is the largest producer, followed by India, Thailand, Vietnam, Bangladesh, Nepal and parts of the United States. These regions provide the cool winter temperatures required for floral induction along with warm summers suitable for fruit growth (Kumar and Nath 2013). The Southern Hemisphere contributes only a small share of global production with cultivation in Australia, South Africa, Madagascar, Mauritius, Reunion and Brazil, where favourable microclimates permit commercial litchi cultivation.

In India, litchi cultivation is mainly concentrated in the Indo-Gangetic plains. Bihar is the leading litchi-producing state, followed by West Bengal, Uttar Pradesh, Jharkhand, Assam, Tripura, Punjab, Haryana, Uttarakhand and Himachal Pradesh (Lal *et al* 2019). These regions are characterised by fertile alluvial soils, cool winters, and humid summers that favour vegetative growth, flowering, and fruit development. Recently, high-altitude regions such as Wayanad in Kerala have emerged as promising new litchi-growing areas due to their cooler winters, moderate summers, and high humidity. This shift highlights the increasing dependence on favourable microclimates to sustain litchi production under warming climatic conditions.

ECO PHYSIOLOGY OF LITCHI IN RELATION TO VARIABLE CLIMATIC FACTORS (Lal *et al* 2022a)

Process / Stage	Optimum / Required Conditions	Adverse Conditions / Effects
Vegetative Growth	25–35°C, high soil moisture; adequate light; RH 70–80%	Below 15°C slows growth; above 40°C limits growth
Dormancy Induction (Pre-flowering phase)	Mild water stress + cool winter (10–15°C)	No dormancy if continuously moist and warm (>20°C)
Floral Initiation	Low temperature: 10–15°C (day), 4–10°C (night); frost-free	>20°C suppresses flowering
Inflorescence Development	Cool, dry winter; soil moisture moderate	High soil moisture promotes vegetative flushes, reducing flowering
Anthesis (Flower Opening)	18–22°C for optimal pollination; low humidity	<15°C slows pollen tube growth; >27°C reduces fertilization
Pollination and Fertilization	19–22°C	<15°C inhibits pollen tube elongation
Fruit Set	Moderate day/night temperature (20/15°C)	>25°C or high heat after panicle emergence → poor fruit set
Fruit Growth and Development	21–37°C (India); adequate humidity (70–80%) and irrigation	>38°C with RH <60% → fruit cracking, sunburn, fruit drop

Ripening and Quality Development	Warm (30–35°C), humid (RH 80–90%)	Hot dry wind (>38°C), low humidity → cracking, sunburn

Nature's Impact and Stress Factors

Abiotic Stress Factors

- Abiotic stresses are among the most important constraints limiting litchi productivity. Studies estimate that various abiotic stresses can reduce crop yield by nearly 70% (Acquaah 2007). Temperature stress plays a dominant role in determining flowering and fruiting behaviour. Heat stress during flowering and fruit development restricts photosynthesis, disrupts membrane stability, and reduces fruit set and quality. Temperatures above 38–40°C, particularly when combined with low relative humidity, result in sunburn, fruit cracking, and excessive fruit drop (Menzel and Simpson 1988; Lal *et al* 2022b). Conversely, inadequate winter chilling leads to poor floral induction and erratic bearing, while temperatures below 0°C can cause severe damage to foliage and developing panicles (Rai *et al* 2001).

Water stress is another critical factor affecting litchi growth and productivity. Drought stress reduces plant vigour, shoot extension, leaf expansion, stomatal conductance, and CO_2 assimilation, leading to reduced flowering and fruit yield (Menzel 2005). Mild water stress before flowering may promote floral induction, but severe drought during flowering and early fruit development drastically reduces fruit set, fruit size, and increases fruit drop (Mitra and Pathak 2010). On the other hand, excessive rainfall and waterlogging reduce soil aeration, weaken root systems, and promote vegetative growth at the expense of flowering, besides increasing the incidence of fruit cracking and fungal diseases (Kumar and Nath 2013).

Other abiotic stresses such as wind, light imbalance, salinity, and nutritional stress also adversely affect litchi. Strong winds during flowering and fruiting cause physical damage, reduce pollinator activity, and result in heavy fruit drop (Kumar and Nath 2013). Excessive light and heat cause sunburn, while dense canopies or prolonged cloudy weather reduce flowering and fruit colour development (Menzel and Waite 2005). Litchi is highly sensitive to salinity and alkaline soils, which impair nutrient uptake, reduce photosynthesis, and ultimately lower yield and fruit quality (Saxena and Gupta 2006).

Biotic Stress Factors

Litchi is affected by a wide range of biotic stresses, including fungal diseases, insect pests, and occasional algal infections. Fungal diseases cause the most severe losses, both before and after harvest. Major diseases include anthracnose, fruit rot, dieback, stem canker, leaf blight, and root rot, which weaken trees, deteriorate canopy health, and reduce fruit marketability (Koul and Taak 2017). Algal diseases such as red rust and green scurf appear during the rainy season and further reduce photosynthetic efficiency.

Insect pests pose an even greater threat to litchi production. Important pests include fruit borers, nut borers, leaf rollers, bark borers, mites, scale insects, and stink bugs. These pests damage both vegetative and reproductive parts, causing heavy fruit drop, internal fruit damage, and quality deterioration. Many pest and disease infections initiated in the field continue during storage, leading to serious post-harvest losses and shortened shelf life (Anonymous 2024).

Stress Management and Mitigation Strategies

Effective management of litchi under stress requires an integrated approach combining cultural, nutritional, physiological, and plant protection measures. Proper orchard establishment with suitable site selection, well-drained soils, and windbreaks helps minimise environmental stress. Balanced nutrition through timely application of NPK, organic manures, and essential micronutrients such as Zn, B, and Mg strengthens tree vigour and improves stress tolerance (Singh *et al* 2021). Efficient water management is crucial for stress mitigation. Regulated irrigation, drip irrigation, mulching, and moisture conservation practices help reduce drought stress and fruit cracking, while avoiding excessive irrigation prevents waterlogging-related problems (Mitra *et al* 2014). Canopy management through pruning improves light penetration, reduces disease incidence, and enhances fruit colour and quality. Use of plant growth regulators such as NAA, GA_3, and potassium nitrate has been shown to improve flowering, fruit retention, and yield under stress conditions (Kumari *et al* 2021).

Biotic stress management relies on orchard sanitation, timely removal of infected plant parts, use of resistant or tolerant cultivars, and integrated pest and disease management practices. Pre-harvest fruit bagging reduces pest infestation, sunburn, and cracking, while post-harvest practices such as sulphur dioxide fumigation, antioxidant dips, and hygienic handling help reduce pericarp browning and extend shelf life (Koul and Taak 2017).

Conclusion

Litchi production is severely constrained by multiple abiotic stresses such as heat, drought, cold, salinity, wind, and light imbalance, which induce adverse morphological, physiological, biochemical, and molecular changes in the plant (Kumar 2016). Biotic stresses caused by fungal pathogens and insect pests further reduce yield, fruit quality, and shelf life. However, effective orchard management practices, including balanced nutrition, regulated irrigation, canopy management, use of windbreaks, plant growth regulators, and integrated pest and disease management, can significantly reduce the impact of these stresses. A thorough understanding of stress responses in litchi is essential for developing climate-resilient production systems capable of sustaining yield and fruit quality under changing environmental conditions.

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