Effects of Temperature and Water Stress on Leaf Growth and Flowering of Litchi (Litchi chinensis Sonn.)

Rupali Kumari

Assistant Professor Dept. of Botany M.S.K.B College Muzaffarpur, Bihar, India
Email ID: *rupali.jnu[at]gmail.com*

Abstract: ***The litchi is one of the most environmentally sensitive fruit tree restricted to few a countries in the world and in few states in India. Recently, it has been reported that litchi is performing well in Southern parts of India. Lychee or litchi (Litchi chinensis Sonn.) is most popular fruit of South-East Asia, produces leaf flushes, flowers and fruits on terminals of new growth. The stress factors like water stress, cold winter are the triggering factors to induce dormancy which promotes flowering. Soil moisture, permanent wilting point (PWP) and soil temperature at the depth of 5 and 15 cm revealed extreme soil dryness and high temperature, relatively less under orchards receiving FYM or, pond sediment. Soil moisture in the orchards was near the PWP where as soil temperature (5 cm) in open was 40 to 41˚C. Very poor rainfall (5.8 mm) between Oct 2021 to April 2022, shallow soil, extreme dryness led break in capillarity between upper soil and lower sand layer, elevated soil temperature coupled with moisture stress were established as reasons for drying of Litchi trees. Under similar soil depth, no drying of trees was observed from the orchards in which either FYM was applied on annual basis or incorporation of pond soil in root zone was routine practice which was corroborated in terms of better moisture and temperature conditions during April, 2022. Climate change projections under representation concentration pathways (RCPs) 8.5 indicate rainfall reduction of about 76% in November to April, though annual rainfall is Zero likely to increase by 36%.***

Keywords: Litchi, Temperature Water stress, Flowering, Leaf & Shoot maturity

1. Introduction

India is the world's largest producer of Litchi after China. Litchi (Litchi chinensis Sonn.) is an evergreen subtropical fruit tree and important member of family Sapindaceae having more than 400 species. The litchi is one of the most environmentally sensitive fruit tree restricted to few a countries in the world and in few states in India. Recently, it has been reported that litchi is performing well in Southern parts of India. Litchi commenced flowering during February-March in Bihar condition and intensity of flowering depends on the previous year's fruiting, temperature during floral bud differentiation, phenol content and age of plants. A single panicle produced hundreds to thousands of flowers and success of fruit set depends on the pollen grain received from male parents. The litchi fruit ripens during summer when the atmospheric temperature is high. Nowadays, quality is very important than quantity to attract the consumer. The position of fruit on tree has influence on the quantity and quality of fruit.

Litchi is an important fruit crop of the country with tremendous domestic market and export potential. At present, the area of this fruit under cultivation is 95,000 hectares and production is 727,000 metric tonnes (NHB, 2018-19). The productivity of litchi is although better in India in comparison with its native country but still wide gap exists between present productivity level (7-8 tonnes/ha) and realizable potential productivity (14-15 tonnes/ha). The export of litchi from India is however meagre (108 tonnes). Litchi contributes significantly to the growers' economy in Bihar, West Bengal, Assam and Jharkhand states of India that accounts for 78% of the total production in the country. Bihar produces 43% of total litchi and occupies nearly 35% of the area in India.

About 300 thousand metric tonnes of litchi is being produced from 32 thousand hectares area in Bihar of which nearly 12,000 hectares of orchards are in Muzaffarpur. The other districts where the fruit grows in abundance are Vaishali, Samastipur, Champaran, Begusarai, and their neighbouring areas. Litchis are also grown in Uttar Pradesh, Uttarakhand, Punjab, Himachal Pradesh, and West Bengal. The ICAR-NRC on Litchi has the mandate to address the productivity gap through basic and strategic research in areas of crop improvement and genetic enhancement, development of sustainable production technologies, integrated pest management systems, and post-harvest management and value addition.

The litchi from Bihar, referred to as Shahi litchi is the fourth product from the state to receive the Geographical Indication (GI) tag, thereby becoming an 'exclusive brand' in national and international market. A GI tag is given to products that have a specific geographical origin and possess qualities of a reputation that are due to that origin.

Litchi is a subtropical fruit by origin and natural abundance. Litchi being cultivated on the fringe of tropics and subtropics in India is very sensitive to further warming. The event of drying of litchi tree in some orchards in Muzaffarpur district of Bihar, India during 2022 warranted the need to explore management options to induce climate resilience. Litchi orchards including those where drying of litchi tree was observed were identified and grouped based on different management practices.

Litchi, or (Lychee chinensis Sonn.) is a well-known and significant fruit crop in South-east Asia, but it has only recently been made available commercially in other parts of the world. Orchards planted in many producing nations are hampered by inconsistent flowering and poor, variable fruit set. The majority of the research on this species' relationship to temperature and water has been done in Muzaffarpur Bihar.

Increase in temperature increases photosynthetic activity and root conductance to certain extent, but further increase inactives enzymes thereby reduces the plant ability to cope with heat stress. The ratio of photosynthesis and respiration must be high in order to achieve high growth and yield (Moretti et al., 2010).

Warm humid summer and cool dry winter are considered best for good quality litchi production. Water stress is major limitation for commercial cultivation of Litchi in India. Soil moisture near to field capacity or higher than 50% of field capacity is must for quality production. Warm and dry spell during flowering are often encountered in traditional belt of litchi in India which often desiccate pollen, reduces bee activities and result in poor fruit set (Kumar and Nath, 2013). A well distributed annual rain fall of 1200 mm is sufficient for good production but under skewed distribution of rainfall, irrigation is required for successful commercial production (Singh, 2012). Mean temperature range for optimum growth and fruiting of litchi has been reported 15 to 25°C (Menzel,1989), however being perennial and adapted to warmer climate it can tolerate more than 45°C for a short period. The variation in weather is likely to increase under climate change condition. Though litchi has been commercially grown successfully in the warmer climate mostly on the fringe of tropics and subtropics, by the origin and natural abundance, it is subtropical. In warmer climate, flowering is believed to be induced by moisture stress unlike to the cold stress in subtropical condition. To induce flowering there is practice of minimizing irrigation during late winter to early summer (Dec to Feb). Contrary to that, abundant flowering has been observed in Muzaffarpur district of Bihar, despite of rainfall during this period. It seems cool winter in this fringe zone between tropics and subtropics is probably sufficient to induce flowering in litchi. Heat and water deficit are two common stresses for litchi mainly during fruiting season.

Being grown on fringe (warmer) climate in India, litchi is vulnerable to further warming under climate change conditions. Irrigation has been traditionally used for microclimate modification under extreme heat stress. Though pollen desiccation, sun burn, fruit drop because of heat stress are common observed phenomena, there were reports of drying of full grown tress in some orchards during end of April, 2022 which was a rare occurrence. During the same period there were full bloom orchards in the proximity. This paper systematically investigates the reason for drying of litchi trees and recommendations for better climate resilience.

Water shortages may not directly affect flowering, numerous studies have demonstrated the significance of temperature on the process. Number and sex of flowers are dependent on climatic conditions. Drought can be used to control shoot growth and hence flowering in areas that have dry periods during autumn or winter. Similar data suggest that moderate droughts after flowering can increase fruit production, although these gains are at the expense of fruit size. Severe droughts at this time reduce fruit set and yield, and can lead to fruit splitting. Well-grown trees on good soils can extract water down to 1.0 m or below. This reduces the need for frequent watering in commercial orchards. Watering every two to three weeks is probably sufficient for trees grown on sandy loams, and every three to four weeks on clays. Irrigation is best applied by monitoring changes in soil water levels. Further research is required to determine the benefits of irrigation in different growing areas, and the best way to apply water. Fruit production is greatest in warm subtropical areas, with cool, dry winters. In hot, moist tropical locations, the trees grow but do not flower. It is now grown commercially between latitudes 17–32 °N. This paper is one of a series in which an attempt is made to collate information on the temperature, water relations and irrigation needs of fruit crops grown in tropical and subtropical regions.

Aim of this study

The aim of this study was to determine the "Effects of temperature and water stress on growth and flowering of litchi (Litchi chinensis Sonn.)" in Muzaffarpur Bihar.

2. Materials and methods

Plant physiology and phenology were studied in the field during different seasons in four lychee production sites in Muzaffarpur, considering the following stages: Temperature and water stress on flowering, fruit formation, fruit development and ripening.

Higher day temperatures in the shoot (constant 20°C or 30°C day/10°C night or 30°C day/25°C night compared with 15°C day/10°C night) and high root temperatures (constant 27.5°C compared with constant 12.5°C or 15°C day/10°C night) promoted vegetative growth and reduced or eliminated flowering in Litchi chinensis Sonn.). Higher temperatures also promoted the production of leaf of litchi plant. Leaf water potential in most treatments during the day ranged from –0.3 to –1.5 MPa with warm days, cool nights and cool roots generally increasing tree water stress. A combination of warm shoots (30°C day/25°C night) and cool roots (constant 12.5°C) induced lower leaf water potentials (–1.0 to –2.0 MPa) and totally suppressed growth. Terminal buds grew out as vegetative shoots within two weeks when leaf water potential was increased (–0.3 to –1.5 MPa) by increasing the root temperature to 25–30°C. Starch levels were generally low (<5.0%) in mature leaves and roots, except for flowering plants at 15°C day...

3. Result & Discussion

Soil moisture, permanent wilting point (PWP) and soil temperature at the depth of 5 and 15 cm revealed extreme soil dryness and high temperature, relatively less under orchards receiving FYM or, pond sediment. Soil moisture in the orchards was near the PWP where as soil temperature (5 cm) in open was 40 to 41˚C. Very poor rainfall (5.8 mm) between Oct 2021 to April 2022, shallow soil, extreme dryness led break in capillarity between upper soil and lower sand layer, elevated soil temperature coupled with moisture stress were established as reasons for drying of Litchi trees.

Under similar soil depth, no drying of trees was observed from the orchards in which either FYM was applied on annual basis or incorporation of pond soil in root zone was routine practice which was corroborated in terms of better moisture and temperature conditions during April, 2022. More events of extreme dryness during October to April were witnessed in post the year 1980 in historical weather data. Climate change projections under representation concentration pathways (RCPs) 8.5 indicate rainfall reduction of about 76% in November to April, though annual rainfall is Zero likely to increase by 36%. Temperature increase to the tune of 2.9 to 4.3 C by 2070, more during April coupled with reduced rainfall poses very high risk on litchi cultivation in traditional belt. Therefore soil manipulations including regular application of FYM, incorporation of pond sediment in orchards on shallow soil, litchi leaf mulching, early irrigations are recommended for moisture and thermal buffering thus greater climate resilience in litchi.

Leaf gaseous exchange

Temperature is most important for Photosynthesis of any plant, and Photosynthesis is one of the most fundamental metabolic processes in plants, is directly related to the abundance of chlorophylls, which absorb light energy that drives carbon- fixing reactions. Hence, leaf greenness may be closely related to photosynthetic performance. There is a sigmoid growth pattern of leaf expansion and an exponential pattern of net CO_2 assimilation (*A*) and stomata conductance with leaf age. The fruit are mainly dependent on current photosynthesis. Photosynthesis in the leaves behind the fruit cluster is more important than photosynthesis in older shaded leaves (Hieke *et al.* 2002a, b). Fullness of leaf expansion is another index of leaf development. However, litchi is a typical "delayed greening" tree, whose leaves are immature and accumulates chlorophylls when they are fully expanded (Hieke *et al.* 2002a, O'Hare 1989). Fruit set and final yield in most fruit crops can be described as a function of tree photosynthetic efficiency. Litchi's initial fruit set increased with leaf area. The fruit growth on adjacent branches is not hindered by the new leaves on one branch (Hieke et al.). 2002b). Leaves next to inflorescence are more important for yield than older leaves (Hieke *et al.* 2002a). Young litchi shoot has relatively low rates of photo assimilation until the leaves are fully expanded and dark green, and depends on assimilates from elsewhere in the plant. During leaf expansion, translocation of assimilates to the shoot occurs at the expense of the roots (Hieke *et al.* 2002c).The *A* of new leaves maintains below zero before they reach their 50% of full size (Hieke *et al.* 2002a). The light green fully expanded new leaves have *A* about 1/3 of the dark green fully matured leaves (Hieke *et al.* 2002c). Starch concentrations of the lower stem and roots decreases as the young red leaves expanded, and increased as the fully expanded leaves turned dark green.

Chlorophyll concentrations and net CO_2 assimilation rate are high in the fully expanded dark green leaves (Hieke *et al.* 2002c). The increase in *A* is associated with increased chlorophyll concentrations and higher stomatal conductance (*gs*), but lower internal CO_2 concentrations. The increase in *A* during leaf maturation was strongly related to changes in *gs* and chlorophyll concentration. Leaves close to inflorescences records lower rates of mitochondrial respiration (Rd) and net photosynthesis. *A* net and lower stomatal conductance (*g*s) and quantum efficiency of photosystem II under actinic light than vegetative shoot leaves. Leaf nitrogen concentration, (generally decreased from the beginning until the end of flowering), reduces, near to inflorescences than in vegetative shoot leaves.

Leaf nitrogen per unit leaf area (Na) remained nearly constant throughout the entire flowering period, with the exception of leaves close to panicles bearing set fruits, where these differences and changes were counterbalanced by an increase in the ratio of leaf mass to area. The decrease in electron flow in PS II, not changes in Na or Rubisco activity brought on by low gs, causes low A net in leaves close to inflorescences. According to Urban et al., this decrease is not directly linked to higher levels of starch or soluble sugar. 2004). Compared to older leaves on older flushes or woods that are located inside the canopy and contribute the majority of carbohydrate production, mature leaves on younger flushes located in the outer canopy had greater net CO_2 assimilation A CO_2, gs, and transpiration (E), but smaller internal CO_2 concentration (Ci). According to Chang and Lin (2007), leaves on the last flushes adjacent to fruit clusters had higher A CO_2, gs, and E levels than leaves on similarly situated de-fruiting shoots. While fruit can import assimilate from other branches, older leaves on the same shoot serve as the primary source of photosynthates for new leaves (Hieke et al.2002d).

According to Restrepo-Diaz et al.,(2010) a decrease in the relative water content (RWC) of the leaf initially results in stomatal closure, which in turn decreases the supply of CO_2 to the mesophyll cells and, as a result, the rate at which the leaf photosynthesizes. Changes in leaf nitrogen concentration or leaf mass-to-area ratio, as well as changes in one or more of the limiting biochemical factors of net photosynthesis, primarily ribulose-1,5-bisphosphate carboxylase/oxygenase (Rubisco) activity, ribulose bisphosphate (RuBP) regeneration, and mitochondrial respiration rate, can alter net photosynthetic assimilation in the presence of developing flowers, resulting in increases or decreases in net photosy 2004).

Litchi's apparent quantum yields (AQY), light compensation point (LCP), and light saturation point (LSP) indicated that it was a heliophilous plant (Zhang et al. 2014). According to Chang and Lin (2007), A CO_2 at a leaf temperature of less than 24°C is only half the maximum, indicating a potential lack of carbohydrate supply during the blooming season and early spring fruit set. According to Batten et al., the amount of fruit photosynthesis that contributes to reproductive growth ranges from 5 to 15 percent for many fruit trees. 1992). The moderately low photosynthetic productivity of litchi could add to its aversion to natural burdens (Menzel et al. 1995b). According to Chang and Lin (2007), younger flushes' leaf photosynthesis is greater than that of older flushes in shade. Instead of relying on stored carbohydrates, the fruit of Tai So litchi depends primarily on current CO_2 assimilation from the leaves (Roe et al.). 1997). accumulation of carbohydrates from tree reserves, canopy photosynthesis, or fruit photosynthesis (Hieke et al.) 2002a), is necessary for fruit growth. It appears that the bearing shoot is the primary source of carbohydrates for fruit growth, primarily through leaf CO_2 assimilation but also through its carbohydrate reserves when required (Menzel, 2005). Since the individual branches of litchi typically act independently and supply assimilates to fruit only when there is a severe local shortage of fixed CO_2. Under high irradiance and high ambient CO2 concentrations, litchi's net CO_2 assimilation increased at high K application rates.

4. Conclusion

Although low temperature appears necessary for lychee floral induction, there is a strong connection between flowering and shoot development. When shoots are mature enough, flush maturity has a significant impact on how they develop, but phasic changes are disrupted by minute temperature and rainfall patterns. In the subtropics, synchronous flowering has been successfully induced by harvesting fruits with few leaves, post-harvest cincturing, the application of paclobutrazol or KNO_3, and the exogenous application of kinetin (applied after dormancy). In a litchi flowering management program, foliar and leaf tissue analyses should serve as a foundation for fertilization. Foliar nitrogen levels shouldn't surpass 1.7% to beat vegetative flushes during winter down. Outfitted with the essential data gave here, cultivators can oversee blooming to happen at any ideal seven day stretch of the year. The expected responses may be affected by local environmental conditions, but thorough examination of all factors should result in consistent success. The unfavorable climate conditions, such as climatic disturbances, which could have a negative impact on lychee cultivation in Muzaffarpur Bihar.

References

[1] Batten, D. J., Lloyd, J. and McConchie, C. A. (1992). Seasonal variation in stomatal responses of two cultivars of lychee (*Litchi chinensis* Sonn.). *Australian Journal of Plant Physiology* 19:317–329.

[2] Chang, J. C. and Lin, T. S. (2007). Gas exchange in litchi under controlled and field conditions. *Scientia Horticulturae* 114:268–274.

[3] Hieke, S., Menzel, C. M. and Lüdders, P. (2002a). Effects of leaf, shoot and fruit development on photosynthesis of lychee trees (*Litchi chinensis*). *Tree Physiology* 22:955–961.

[4] Hieke, S., Menzel, C. M. and Lüdders, P. (2002b). Effects of light availability on leaf gas exchange and expansion in lychee (*Litchi chinensis*). *Tree Physiology* 22:1249–1256.

[5] Kumar, R. and Nath, V. 2013. Canopy Management in a book "Climate Resilient Horticulture-adaptation and Mitigation Strategy".

[6] Lal N, Gupta AK, Kumar A, Nath V. Effect of age and strain of plants in litchi on flowering. Litchima 2018;4:46-8.

[7] Lal N, Gupta AK, Marboh ES, Kumar A, Nath N. Effect of pollen grain sources on success of hybrids in "Bedana" litchi. Int J Bio Resour Stress Manag 2019;10:241-45.

[8] Lal N, Gupta AK, Marboh ES, Kumar A, Nath V. Effect of pollen grain sources on fruit set and retention in "Shahi" litchi. Multilogic Sci 2019;9:152-6.

[9] Lal N, Marboh ES, Gupta AK, Kumar A, Anal AK, Nath V. Variation in leaf phenol content during flowering in litchi (Litchi chinensis Sonn). J Exp Biol Agric Sci 2019; 7: 569-73.

[10] Lal N, Singh A, Gupta AK, Marboh ES, Kumar A, Nath N. Precocious flowering and dwarf NRCL-29-a new genetic stock of litchi (Litchi chinensis Sonn). Chem Sci Rev Lett 2019; 8: 206-10.

[11] Lal N. Genetic Studies of Litchi Germ Plasm. Jabalpur, MP: Thesis, Submitted to JNKVV; 2018.

[12] Menzel, C. M. and Simpson, D. R. (1995). Temperatures above 20 °C reduce flowering in lychee (*Litchi chinensis* Sonn.).*Journal of Horticultural Science* 70:981–987.

[13] Menzel, C. M. and Waite, G. K. (Eds) (2005). *Litchi and Longan: Botany, Production and Uses*. Wallingford, UK: CAB International.

[14] Moretti, C.L., Mattos, L.M., Calbo, A.G., and Sargent, S.A. 2010. Climate Changes and Potential impacts on Post harvest Quality of Fruit and Vegetable Crops. A review Food Res. Int., 43: 1824-1832.

[15] Nath V, Kumar AA, Pandey SD, Tripathi PC. Litchi in winter season-away forward. Indian Hortic 2015; 59:26-7.

[16] Roe, D. J., Oosthuizen, J. H. and Menzel, C. M. (1995). Rate of soil drying and previous water deficits influence the relationship between CO_2 assimilation and tree water status in potted lychee (*Litchi sinensis* Sonn.). *Journal of Horticultural Science & Biotechnology* 70(1):15–24.

[17] Singh, G., Nath, V., Pandey, S.D., Ray, P.K. and Singh, H.S. 2012. The Litchi, Food and Agriculture organization of the United Nations, New Delhi, India, 219 p.

[18] Zhang, Y., Chen, W., Smith, S.L., Riseborough, D.W. and Cihlar, J. 2005. Soil temperature in Canada during the twentieth century Complex responses to atmospheric climate change.