Climate Resilient Adaptation Strategies for Litchi Production

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Abstract

Litchi is very fastidious in its climatic requirements. Its cultivation and commercialization globally has therefore been at slow pace due to this stringent requirement. It is observed that there is poor as well as erratic bearing pattern in trees in many important litchi-growing areas. The growth, panicle emergence time, flowering behaviour and flowering phase have been found to be influenced by the impact of climatic change. The productivity/yield and quality fruit production have also been found to be very much affected by environmental parameters like temperature, photoperiod/light intensity, moisture content in the soil and humidity in the atmosphere.

In an era of dynamic climatic changes, there is a strong need for adaptation strategies to be implemented with efficient water-nutrient management, canopy management and integrated pest management (IPM). The present assessment is based on the study carried out at NRC for Litchi, Muzaffarpur, and Bihar where practice of nonselective corrective pruning and reiterative pruning has been adopted for canopy development and enhanced quality production as well as for rebuilding of canopy even in unproductive old senile orchards. Based on this success, proper and timely pruning and training techniques have been standardized for canopy development and influencing microclimate for successfully combating the variable climatic conditions. The resilient adaptation strategies for successful litchi cultivation interalia include use of (1) windbreakers for avoiding damage by heavy windstorm, (2) better root stocks, (3) canopy management, (4) girdling, (5) rejuvenation of old unproductive orchards, (6) mulching and (7) honeybees as potential pollinators. The skilful use of adaptation strategies at appropriate time is the key for successfully overcoming the ill effects of climatic changes.

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As litchi has very narrow genetic base, it provides an ideal opportunity for developing climate analogous software, which could be adopted for litchi cultivation in country's different climatic zones for benefit of the farmers. A start has already been made by developing IT-enabled "frost alert system" software which uses forecast system to mitigate the ill effects in litchi production owing to vagaries of climatic conditions.

8.1 Introduction

Litchi (*Litchi chinensis* Sonn.) is an important, evergreen subtropical fruit crop (family Sapindaceae) of India. Its production in this country has undergone substantial expansion in the past 50 years with plantations increasing from 9,400 ha in 1949 to 60,000 ha in 2008. Now this crop has attained the status of important commercial fruit crop of India. Fruits are available from early May to early July in different areas, with only a small quantity being exported in the last few years. The commercialization around the world has been slow due to specific climatic requirement for successful cultivation and poor as well as erratic cropping pattern in many areas. Litchi plantation is found concentrated mainly in eastern states like Bihar, W.B. and U.P., with less concentration in Jharkhand, Tripura, Orissa, Punjab, Haryana, H.P., Assam and the Nilgiris hills (20–27°N latitude). The productivity and quality fruit production in litchi are strongly affected by environmental parameters like temperature, photoperiod/light intensity and moisture content in the soil and humidity in the atmosphere.

8.2 Impact of Climate Change on Growth and Productivity

Litchi requires specific but mild climate for its successful production. The growing season, thermal time (temperature range), moderate winter, actual rainfall with its specific annual distribution pattern and several of the interaction variables considerably influence the phase change in the annual cycle of the plant (Menzel and Waite 2005). Variability in weather conditions, like increase in temperature and moisture stress conditions during critical stages of crop, causes heavy yield loss and adversely affects the fruit quality even under adequate management conditions.

Due to the climate change, the increase in temperature and variability in precipitation pattern could lead to the development of abiotic stresses like heat, drought and flooding (Boyer 1982). These stresses occur in varying intensities coinciding with different growth and development phases of the crops, finally determining the productivity and quality. The air temperature, heat waves and frost are decisive factors in plant growth and development in litchi. Similarly, an assessment of the impact of elevated CO_2 in conjunction with increasing temperature needs to be studied for this specific crop (Menzel and Waite 2005).

In India, the salubrious climatic conditions for litchi cultivation is found restricted in the foot hills of Himalayas from Tripura to Jammu Kashmir and plains of Uttar Pradesh and Madhya Pradesh, though commercial cultivation have been found confined mainly to Bihar, West Bengal and Uttaran-chal. Globally, the ideal climatic condition for litchi wrt production and productivity varies considerably (Rai et al. 2001). The unusual impact of climate change has been witnessed in litchi production system as noted in flowering pattern (shifted early), fruit growth and harvesting period. The occurrence and the extent of damage by physiological disorders and resurgence of pests are very much dependent on the temperature and humidity variations in the atmosphere. The aberrant weather and extreme events may damage the crop completely.

The imbalance in climatic parameters, threatening the sustainability and the adverse effect/impact needs public intervention and also preparedness to face the challenges. It is required to have quick and clear understanding of impacts of climate

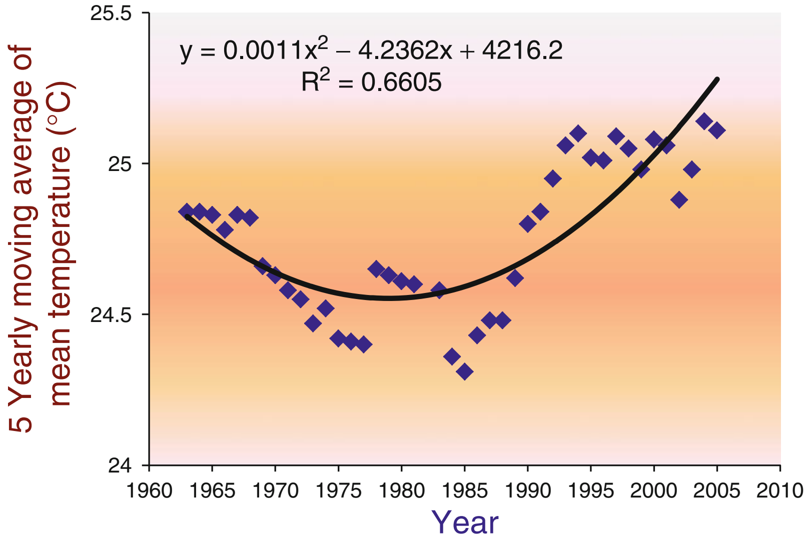

Fig. 8.1 Temperature trend at Samastipur (Bihar) (Source: Agro-meteorology division, RAU, Pusa, Bihar, India)

change on litchi crop for making sound action plan. The evergreen perennial litchi as sole crop or litchi-based farming systems also has very high potential for sequestering carbon for mitigation of climate change.

8.2.1 Temperature

The effects of temperature on growth and productivity for various litchi-growing areas have been extensively studied (Menzel et al. 1989; Menzel and Simpson 1995). As litchi is adapted to the warm subtropics and all the phenological changes are associated with certain specific temperature (range) requirements. The variation usually influences the fruit size and maturity as well as quality. Cropping is best in climates with hot humid summers and dry cool winters. Flower initiation in litchi is best below 20°C, while the optimal temperature for leaf and fruit growth is about 30°C. Temperature below 2°C damages new leaves, while below 0°C can kill the trees (Menzel and Waite 2005). There is a rapid period of shoot elongation and leaf expansion followed by a period of leaf maturation before the next period of shoot growth. The duration and interval of growth have been found to be related to temperature. The environmental adaptability of this crop has confined commercial production mainly to subtropics, where annual temperatures vary markedly across this range of latitude (regions). In major litchi-growing regions of the country (Bihar, W.B. and Uttaranchal), the less dependable is flowering, this is because cool temperatures are necessary for floral induction. The processes influencing floral initiation and bloom in litchi are elucidated by Davenport (2000) through a model proposing reproductive induction by vegetative and floral promoters (phytohormones) governing the type of shoot initiation, which is very much influenced by the environment mainly temperature. Better fruit set, fruit development and yields occur when temperature approaches from low (restricting vegetative phase) to warmer days and nights (allowing flower development and pollination), then again the higher range for fruit development and maturity (Davenport 2003).

Global warming will have negative impact on subtropical regions, as the prevailing temperatures during the season are shifting towards higher side. Characterization of temperature trend over Bihar (Pusa, Samastipur) was done over a database for 50 years (1960–2010) having monthly mean and minimum temperatures (Fig. 8.1). This clearly indicated an increasing trend over this place with a clear indication that local climate is undergoing change (Sattar 2010). The observed temperature trend in the region of litchi production (Bihar) showed a general increase in temperatures in order of 2–3°C over the base period of 50 years, while the reports are available that an average increase of 1–2°C could affect the phenology of this crop by influencing the degree days and it may respond differently, as occurrence of abnormal temperature has been a recurring phenomena in recent years, which certainly affects the prospect of litchi production and productivity.

8.2.2 Light Intensity and Photoperiod

The litchi crop is very much responsive to the light intensity and photoperiod for quality fruit production. The varied level of net CO_2 assimilation was recorded in various leaf growth stages as (1) in soft red green leaves 0.3 μmol/m²/s, (2) in red green leaves 1.6 μ mol/m²/s, (3) in light green leaves 2.7 μmol/m²/s, (4) in dark green leaves 5.8 μmol/m²/s and (5) in fruit growth to maturation 10.0–3.0 μmol/m²/s. These differences in CO_2 fixation were associated with higher concentrations of chlorophyll in older leaves than in the younger leaves. The presence and absence of fruits on the tree can influence the rate of leaf photosynthesis (Menzel and Waite 2005). Clearly, the amount of CO_2 fixed by plants depends on environmental conditions and the physiology of the leaves. The distribution of light and leaf nitrogen within the tree is usually a good indication of potential photosynthesis. Interaction effect of light, temperature, partial pressure of CO_2 water vapour and leaf water status influences photosynthesis by affecting the opening and closing of the stomata or leaf chemistry. Light used for CO_2 fixation is usually referred to in terms of photosynthetic photon flux density, PPFD or the number of photons from 400 to 700 nm.

Light may limit flower development in dense orchard. In litchi, high sunshine hours are expected to be correlated with fruit quality. Ultraviolet rays play an important role in the development of colour; more of UV rays reach the plants when atmosphere is free from dust. These help to develop anthocyanin pigments to a greater extent (Singh 2009). Heavy shade for 1 week increases fruit drop. Overall, the productivity is driven by the amount and distribution of light and nitrogen in the tree, along with water supply and temperature. Thus, it is inferred that variation in solar radiation may cause adverse effect on overall quality production and productivity.

8.2.3 Rainfall and Humidity

In litchi, an adequate amount of rainfall is necessary just after the harvest of fruits for proper initiation of new shoots, as current season shoots after proper maturity bear panicle and fruits. The delay in shoot emergence may cause unfruitfulness even in the coming season. Rains during the full bloom period cause washing off of pollens and restrict activities of pollinating insects, which may lead to poor fruit set and fruit yield. The database of monthly rainfall for 20 years (1971–2001) (Fig. 8.2) showed that the maximum rains occur in main monsoon period (July to September) and the rest of the periods were not dependable. The monsoon period mainly coincides with the period of active growth of litchi (Sattar 2010), but premonsoon showers prior to harvest time destroy the quality of ripening fruits. High rainfall and humidity induce good growth, and the average annual rainfall is considered to be around 1,250–2,000 mm for litchi. It is generally observed that abundant rainfall or irrigation and the resulting high soil moisture level encourages vegetative flushing. In India, there are areas where annual rainfall is less than 1,000 mm, but litchis are cultivated on a commercial basis. A dry autumn and winter are important to prevent vegetative growth and making essential condition for good flowering (in south China). A certain degree of water stress is needed for flower initiation. Fruit set in litchi is climate dependent and profoundly affected by humidity in conjunction with other climatic factors. Cloudy weather with increased humidity in the atmosphere encourages the incidence of pests and diseases and interferes with the activity of pollinating insects, thus adversely affecting fruit set. Overall, the optimum rains are conducive for production of quality litchi fruits, but sometimes early and continuous monsoon affects the quality

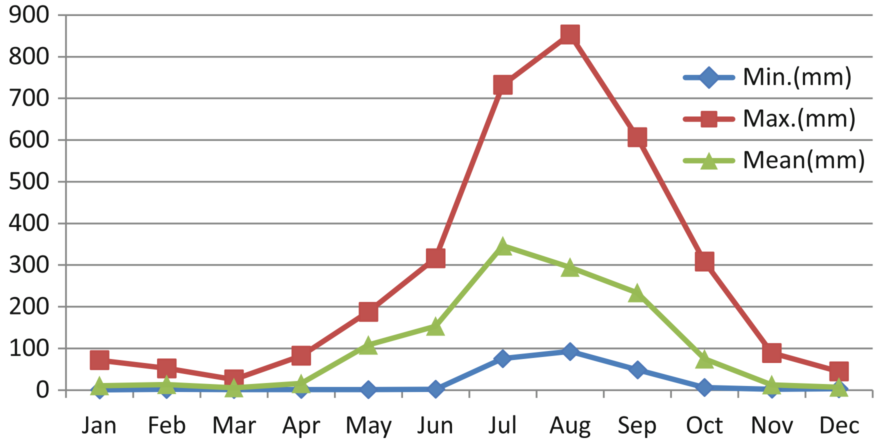

Fig. 8.2 Characteristics of monthly rainfall, Pusa, Bihar (1971–2001)

due to severe attack of fruit borer and some rots. High humidity and heavy rain during aril growth period of fruit development lead to excessive absorption of water by aril (fruit) and may aggravate many disorders like fruit cracking and fruit drop.

8.2.4 Wind

Like other important fruit crops, the initial establishment, proper growth and performance of litchi have been affected by nature of winds. Litchi plantations at initial stages experiencing hurricanes/high windstorms hamper establishment. The dust storm and squalls up to 60–80 km/h experienced in between the period of February to June damage the crop right from panicle development to whipping off of flower and fruits may cause complete crop loss. Heat waves during summer have an adverse effect both on fruit and foliage growth, which is more so in the areas adjacent to open fields that are not fully protected with windbreaks. Wind also leads to a loss of vigour and, consequently, slower growth. The high-speed windstorm or cyclones during fruit-bearing period, more particularly at harvesting time, may cause serious damage. Fruit drop at initial stages of its growth can be noticed due to high wind velocity. Various measures may be taken to limit the damage, but the most recommended is perhaps the raising of thick and strong windbreaks around the litchi orchard.

8.2.5 Fog and Frost

Fog definitely curtails light supply and reduces photosynthesis, while spring frosts are particularly harmful to litchi plants. Frost may either kill the reproductive organs of the flower or completely destroy the blossoms, thereby influencing the fruit set and ultimately the fruitfulness. Litchi young plants are extremely sensitive to cold and require frost protection. Frost has been regarded as one of the important factors responsible for causing drastic effect on bearing behaviour and even leading to mortality of the plants/trees. The extent of damage by frost depends upon age of the tree, moisture content of the soil, condition of growth, actual timing of frost occurrence and severity and duration of the frost. It has been found devastating for litchi, growing in areas/places having mild tropical and subtropical climate. Moist soil or irrigated soil raises the soil temperature and provides protection against mild frost.

8.3 Resilient Adaptation Measures

The resilient adaptation strategies to address the adverse impact of climate change on litchi production and productivity need immediate attention. The adaptation strategies should be planned to increase water and nutrient use efficiency, soil amendments and cultural practices by using modifying the canopy architectural design and use of integrated pest management practices.

Like other commercial fruit crops, litchi too has substantial carbon sequestration potential and strengthens the system ability to cope up with adverse impacts of changing climatic conditions. The influence of prevailing climatic conditions and the ill effects on overall productivity and quality of litchi due to climatic aberrations during the season can be nullified to a great extent by practicing region-specific adaptation measures, which can be (1) root stocks, pruning and canopy management including rejuvenation of old senile orchards, (2) growing intercrops and need-based intercultural operations, (3) use of mulching and recommended type of mulching material, (4) nutrient management with more emphasis on organic farming, (5) water management for enhancing water use efficiency and (6) use of integrated pest management practices.

The use of rootstocks and scion for vigour control and deep root system for litchi needs attention. The seedling rootstocks affect growth and yield of scion cultivars, also influence the photosynthetic efficiency and fruit quality.

8.4 Canopy Management

Canopy manipulations in litchi deserve more attention and importance. Training is practised in litchi mainly to give an open umbrella or semicircular shape of canopy to build a strong framework and induce maximum surface area to bear crop of good quality. The aim of utilizing the available space and sunlight is also fulfilled. Most orchards were planted at aspersing of 10 m × 10 m, i.e. low density and the trees were left to develop into large canopies. However, now the technology of canopy development is spreading fast and new orchards are planted under high densities and are pruned regularly. The technology adoption is increasing but with a slow pace.

Prolonged periods of overcast weather, extremes of temperature and droughts can reduce photosynthesis and productivity of many orchards in growing areas, but the timely pruning and training operation for canopy management have resulted increased productivity with quality production. The efforts to develop pruning and training strategies for high-density orchards with the intention to maximize light interception have given good response. The studies on the effect of pruning intensity on microclimate modification, time of panicle emergence, sex ratio, pest incidence and number of panicles emerged in litchi trees under high-density planting have been found to give higher percentage of healthy panicle emergence, flowering and fruit set as compared to unpruned trees. Maximum fruited panicles appeared at middle portion of the outer canopy than at the top; hence, the technique of centre open as well as nonselective pruning adopted to reduce the height and enhance the canopy spread. Pruning intensities modified microclimate, and the temperature variation observed was to the tune of 2.5°C inside the canopy in unpruned trees in August and March months. The field observations on the flushing time, flowering and fruit set were found better in case of trees received nonselective pruning just after the harvest of fruits. The likely created open canopy increased the pace of vegetative growth and panicle emergence leading to flowering. Reports also suggest that pruning or defoliation stimulates shoots initiation as such treatments not only remove the source auxin production but also increase cytokinin concentrations in Xylem sap (Goren and Gazit 1996; Olesen et al. 2002). Responses of external application of auxin at different time of vegetative flushes in late summer and early winter were found inconsistent, suggesting the need of timely operation of pruning and training.

The unmanaged orchards may develop senility and become unproductive. The rejuvenation of old senile orchards through reiterative pruning and required training for good canopy development can bring back to give quality yield like young orchards with more efficient and optimum input utilization in sustained manner. There have also been some efforts to determine the relative contribution of photosynthesis by examining the effects of light and temperature on CO_2 fixation in the single leaf, leaves and whole tree. These factors are main environmental variables during canopy photosynthesis with increased canopy surface bearing area. Girdling, defoliation and fruit thinning have been used to study the relationship between yield, photosynthesis and stored reserves (Menzel and Waite 2005).

8.5 Water Management

Water functions through both biophysical and biochemical activities in fruit plants and like in litchi too. The sound production strategies like improved water use efficiency under hot and dry conditions should be developed for litchi at its region-specific basis based on the fact that redistribution of organic compounds from source to sink and meristematic regions through movement and circulation of water at its critical stages. Like other fruit plants, the water use efficiency in litchi also varies with phyllo-taxonomic arrangement, ratio of chlorophyll fractions and size and frequency of guard cells in the leaves and ability of water-absorbing organs and also interactions of many other factors. Providing irrigation during critical stages of crop growth and conservation of soil moisture reserves are the most important interventions for bearing behaviour and quality production in litchi. The crop management practices like mulching with crop residues and plastic mulches help in conserving soil moisture. In some instances, excessive soil moisture due to heavy rain and untimely rain becomes major problem, and it could be overcome by growing intercrops, light intercultural operations and raised basin making. Drought has been used to manipulate autumn vegetative flushing and to improve flowering and yield of litchi in Israel (Goren and Gazit 1996).

8.6 Conclusion

Litchi grows well in mean annual temperature ranging from 20°C to 25°C and average annual rainfall of 1,500 mm (uniformly distributed). Having proper and desirable temperature during panicle emergence is crucial for a good harvest. Cool temperature in the range of 8–10°C favours good inflorescence development and flowering in litchi. However, litchi can withstand temperature as high as 44°C during the period of fruit development and maturity. Higher temperature, good sunshine and adequate soil moisture in the rhizosphere aid improved fruit size and quality. The aberrations in weather like prolonged cloudy weather and rains during the full bloom abetting normal cross-pollination (due to diminished activities of pollinators which are mainly honeybees) and fruit set in litchi sometimes may cause total crop failure. In addition, moist weather leads to severe attacks of mites and other insects as well as promotes incidence of lichen growth on the trunk and branches causing bark splitting, leading to other fungus infestation in the litchi crop. Pre-harvest low-intensity sunshine due to cloudy weather reduces the content of ascorbic acid and sugar in the fruit.

As on date information on effect of raised CO_2 levels in the atmosphere and rise in temperature is lacking in India. This aspect needs to be addressed urgently by gathering statistical data from related studies carried out in other litchi-growing countries and extrapolating the same based on Indian conditions for making projections both at regional and national levels. Past adverse climatic change occurrences such as droughts and cyclones have severely affected the litchi fruit yield. The studies undertaken abroad on the litchi simulation-model-based projections indicate the adverse influence of climate change on litchi cultivation. Quality of the produce is also likely to be affected with changes in physiochemical characteristics. Soil moisture conservation needs to be given paramount importance for crop production in water-limiting scenarios for the future. The carbon sequestration potential of these evergreen plantation/trees with dense foliage needs to be exploited for acquiring carbon credits for the overall benefits of farmers.

The influence of prevailing climatic conditions and its ill effects on overall productivity and quality in litchi due to climatic aberrations during the season can be nullified to a great extent by practicing region-specific adaptation measures like (1) pruning and canopy management including rejuvenation of old senile orchards and use of rootstocks, (2) growing intercrops and need-based intercultural operations, (3) mulching and mulching material, (4) nutrient management with more emphasis on organic farming, (5) water management strategically for enhancing water efficiency and (6) integrated pest management practices.

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