

Weather extremes and plantation crops in the humid tropics

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सार – पिछले 60 वर्षों (वार्षिक / मानसून वर्षा के साथ 40-60 वर्षों की चक्रीय प्रवृत्ति भी देखी गई) से केरल राज्य में मानसून वर्षा में कमी आई जबकि तापमान में वृद्धि देखी गई। बेशक, वनों की कटाई के कारण पर्वतों की ऊँचाई में (उगाए जाने वाली इलायची, कॉफी और चाय के स्थानों में) तापमान में वृद्धि की दर हानिकारक रही। कुछ हद तक यह सही भी है कि समुद्र की सतह के वायु तापमान में वृद्धि के कारण तट (निचली भूमि) के साथ-साथ 1981-90 का दशक शुष्क और सबसे गर्म दशक था। वर्ष 1987 पूरे केरल के लिए सबसे गरम वर्ष था। पूरे राज्य में आर्द्र जलवायु (थॉटवेटस जलवायु वर्गीकरण के अनुसार B4-B3) के साथ आर्द्रता से लेकर सूखा व्याप्त था। मौसम की चरम घटनाओं में गर्मियों में सूखा, मानसून बाढ़, प्रबल पवनें (पूरे राज्य में चक्रवाती पवन के अलावा नवम्बर से फरवरी तक पालघाट गैप की हवाएँ) ओलावृष्टि, असामान्य वर्षा, भूस्खलन और उष्णता वृक्षारोपण फसलों के उत्पादन और इसकी गुणवत्ता को प्रभावित कर सकता है। लू और शीतलहर आर्द्र कटिबंधों के तहत वृक्षारोपण फसलों के संदर्भ में संगत नहीं हैं। नारियल की पैदावार में ग्रीष्मकालीन सूखे का प्रभाव 1983, 2004 और 2013 में देखा गया। कॉफी के मामले में यह प्रतीत होता है कि तापमान और जलवायु परिवर्तन में वृद्धि के कारण हाल ही के वर्षों में फसल जल्दी परिपक्व हुई है। कॉफी और काली मिर्च, नारियल और काजू की गुणवत्ता भी भूमंडलीय उष्णता और जलवायु परिवर्तन की वजह से प्रभावित कर रहे हैं। काली मिर्च के मामले में 1983, 2004 और 2013 की गर्मियों में देखे गए लंबे समय तक ग्रीष्मकालीन सूखे के कारण काली मिर्च की बेलों के नष्ट होने की दर अत्यधिक पाई गई है। मिश्रित फसल / एकीकृत खेती का अनुमान जलवायु परिवर्तन के परिदृश्य के तहत लंबे समय तक प्रतिकूल मौसम के खिलाफ फसल की आय को बनाए रखने का सुझाव दिया गया है।

ABSTRACT. Monsoon rainfall across the State of Kerala was declining since last 60 years (cyclic trend of 40-60 years is also noticed with annual/monsoon rainfall) while rise in temperature is evident. Of course, rate of increase in temperature was alarming across the High ranges (where cardamom, coffee and tea are grown) due to deforestation. It is also true to some extent along the Coast (low land) due to increase in sea surface air temperature. The decade 1981-90 was the driest and warmest decade. The year 1987 was the warmest year across Kerala. The State as a whole was moving from wetness to dryness within the Humid Climate ((B4-B3 as per the Thornthwaite's climate classification). Among weather extremes, summer drought, monsoon flood, strong wind (blows in Palghat Gap from November to February, other than cyclonic wind across the State), hailstorms, unusual rains, landslides and warming may adversely affect plantation crops' production and its quality. Heat wave and cold waves are not relevant with reference to plantation crops under the Humid Tropics. The effect of summer drought on coconut yield was noticed in 1983, 2004 and 2013. In the case of coffee, it appears that crop matures early in recent years due to increase in temperature and climate change. The quality of coffee and black pepper, nut size in coconut and cashew are also influenced due to global warming and climate change. In the case of black pepper, the mortality rate is high in young pepper vines due to prolonged summer drought as noticed in summer 1983, 2004 and 2013. Mixed cropping/integrated farming is suggested to sustain crop income against adverse weather on long run under projected climate change scenario.

Key words – Cardamom, Arecanut, Humid tropics, Extreme weather.

1. Introduction

The biotic and abiotic stresses are the two major components in environmental stress under which the plantation crops are grown. The influence of weather factors on biotic stress due to incidence of insect pest and diseases, epiphytes, weeds, rodents and grazing animals is

indirect rather than direct. Under abiotic stress, crop management practices play an important role in deciding crop output. Rainfall, air and soil temperatures, photosynthetically active radiation (PAR), soil moisture, wind, humidity and evapotranspiration play a predominant role if the other factors are not limiting under the abiotic stress. It is a complex phenomenon to understand the

TABLE 1
Mean annual surface air temperature (°C) across Kerala at different locations

Name of the station	Maximum temperature	Minimum temperature	Mean temperature	Temperature range	Seasonality (Summer-Southwest Monsoon)
Thiruvananthapuram	30.4	23.7	27.1	6.7	31.9 - 29.6
Punalur	32.9	22.3	27.6	10.6	35.2 - 30.8
Alappuzha	31.2	24.0	27.6	7.2	32.9 - 30.0
Kottayam	31.9	23.1	27.5	8.8	33.8 - 30.8
Cochin(Kochi)	31.0	24.1	27.6	6.9	32.4 - 29.5
Palakkad	32.4	23.2	27.8	9.2	35.9 - 30.2
Kozhikode	30.8	23.8	27.3	7.0	32.7 - 28.9
Pattambi	32.4	22.5	27.5	9.9	35.2 - 29.7
Ambalavayal	27.3	17.3	22.3	10.0	30.1 - 25.1
Pampadumpara	24.9	17.4	21.2	7.5	28.3 - 23.3
Average	30.5	22.1	26.3	8.4	32.8 - 28.8

influence of weather and climate on plantation crops under rainfed and irrigated conditions due to nature of crop and its response to the environment. For example, coconut is grown in vast areas across the East and West Coasts of the Country in different agroclimatic zones. It gives reasonably better yield in terms of quantity and quality in the Humid Tropics under rainfed conditions. However, the coconut yield scenario is totally different when the crop is irrigated. The altitudinal sequence of crops in Kerala is a classic example to understand the influence of temperature on crop distribution within the Tropics. The distinct feature is that the crops which are grown in the high ranges like cardamom, coffee and tea are not grown in the lowlands and midlands while coconut is absent across the high ranges on commercial scale. Cashew and rubber are seen cultivated in mid-and-high lands. The altitude of high ranges where tea, coffee and cardamom are grown is of the order of more than 900 m from the above mean sea level, indicating a temperature decrease of 2 °C as per the lapse rate.

2. Data and methodology

The surface air temperature data at different locations across the State of Kerala were collected from the India Meteorological Department (IMD) for the period from 1956 to 2009 and the statistical analysis was carried out. The temperature projections were highlighted through linear trend analysis. The onset of monsoon data from time to time was updated from the published data of the IMD and the research papers published by various authors from 1870 to 2015. The time series analysis was carried out including trends using the data of monsoon onset. Similar exercise was done in the case of rainfall too for the State of Kerala. The climate shifts were worked out using the moisture index as per the Thornthwaite's classification (Thornthwaite, 1948; Thornthwaite and

Mather, 1955 and Subrahmanyam, 1982). Tri-decadal analysis was carried out to understand the climate shifts over Kerala since last 145 years. Crop-weather analysis was carried out using the statistical analysis and graphical techniques in plantation crops such as coconut, cashew, cocoa, cardamom, rubber, black pepper, coffee, tea and areca nut based on secondary data and experimental data wherever it was possible.

3. Results and discussion

3.1. Temperature distribution over Kerala

The annual maximum temperature is high at Punalur (32.9 °C), followed by Palakkad and Pattambi (32.4 °C) and Kottayam (31.9 °C). It is low at Thiruvananthapuram (30.4 °C), Kozhikode (30.8 °C), followed by Cochin (31.0 °C). It reveals that the annual maximum temperature across the State of Kerala, predominantly known as the Plantation State, varies from 30.4 °C to 32.4 °C with an average of 30.5 °C (Table 1). However, it shoots to 40 °C occasionally in the Palghat-Thrissur region during peak summer. In the case of minimum temperature, it ranges from 22.3 °C to 24.1 °C across the State with an average of 22.1 °C. Mild winter prevails across low and midlands. From extreme temperatures, it can be understood that the occurrence of cold wave and heat wave in the above region is practically zero. The annual mean temperature varies between 27.1 °C and 27.8 °C across the State with an average of 26.3 °C. In the case of temperature range, it varies between 7.5 °C and 10.6 °C with an average of 8.4 °C. Being the Coastal State, the temperature range is relatively low, revolving around 6-7 °C in majority of the locations except at Punalur, Kottayam, Palakkad, Pattambi and Ambalavayal. The High ranges (Pampadumpara and Ambalavayal) across the Western Ghats within the State of Kerala experiences a maximum temperature of 24.9 °C

to 27.3 °C and a minimum temperature of 17.3-17.4 °C. The annual mean temperature varies between 21.2 and 22.3 °C, with temperature range of 7.5 °C at Pampadumpara (South of Kerala) and 10 °C at Ambalavayal (North of Kerala). The plantation crops like cardamom, coffee and tea are predominant in this region since temperate environment is conducive within the Humid Tropics. However, the night temperature across the High ranges goes below 5 °C and touches sometimes 0° C.

3.2. *Temperature projections*

Warming Kerala is real as the trend in temperature was increasing significantly since 1980s. Within the State, the rate of increase in temperature was high across the High ranges, followed by the low lands while moderate increase along the midlands. It could be attributed to alarming deforestation across the High ranges and the effect of increase in sea surface temperature along the Coast. At the current rate of increase in temperature, it is projected that increase in maximum temperature is likely to be around 1.6 °C by 2100 A.D. while 0.3-0.4 °C in the case of minimum temperature. Increase in mean surface air temperature is likely to be less than 1 °C by 2100 A.D. The decade 1981-90 was the warmest and driest decade in Kerala during which the plantation crops' production was adversely affected to a considerable extent. The year 1987 was the warmest year across the State of Kerala. The low and midlands experience increase in night temperature in recent years and flowering of fruit crops is adversely affected. It is more so in the case of mango. Fruit drop in mango and flower drop in other crops are common when hailstorms hit the crop, which are not uncommon during summer across the High ranges.

3.3. *Onset of monsoon*

The monsoon directory of Kerala indicates that the onset of southwest monsoon is on 1st June with +/- 7 days, indicating that it varies from 25th May to 8th June in majority of the years. However, the earliest monsoon was recorded on 11th May in 1918 while belated monsoon on 18th June in 1972. The trend analysis since 1870 indicated that the onset of monsoon is stable and it tends to be around 1st June. Though the trend analysis indicates that the onset of monsoon is likely to be on or before 1st June over Kerala, the fact file in recent years appears to be different since the onset of monsoon in 2011 was on 29th May and it was 5th June in 2012 and again on 1st June in 2013, 6th June in 2014 and 5th June in 2015. It indicates that inter-annual variations are expected within one standard deviation in majority of the years. It is also understood that the monsoon set may be early (before 25th May) or late (8th June) occasionally during which the monsoon rainfall is likely to be below normal or normal,

indicating that the chances of excess rainfall in such years (early or late monsoon years) are likely to be less. Floods are common in low-lying areas during the monsoon and post monsoon periods due to single/two day heavy wet spells. It may not be a threat to plantation crops since they grow mostly on elevated lands/slopes. However, waterlogging is noticed in coconut gardens/homesteads in heavy rainfall zones across the State during the monsoon season.

3.4. *Rainfall over Kerala*

The annual rainfall of the State of Kerala as a whole is close to 3000 mm. It is very high (5883 mm) at Nariamangalam (Ernakulam District) and low (651 mm) at Chinnar (Idukki District). Rainfall increases from 1479 mm at Parasala in the South to 3562 mm in the North of Kerala. Similarly, it increases from the Coastal belt to the foot hills and then decreases on the hill tops. The monthly rainfall over Kerala appears to be bi-model due to the influence of both southwest and northeast monsoons. The influence of Northeast monsoon is more significant towards South of Kerala, indicating that rainfall is uniformly distributed towards South when compared to that of North of Kerala. It is one of the influencing factors for better crop yields towards South. It is very true in the case of coconut and rubber. The Northern Districts, Kasaragod and Kannur, experience uni-model rainfall, indicating that a prolonged dry spell is noticed from November to May if pre-monsoon fails. To some extent, it is true in the case of Palghat and Thrissur Districts also. A strong dry wind also blows across the Palghat Gap, commencing from mid- November to mid-January, popularly known as 'Vrichika Kattu' in local language. It has tremendous negative impact on plantation crops. The other regions within Kerala are free from strong winds during the above said period. The long period average annual rainfall over Kerala is around 2828 mm with a coefficient of variation of 14.3 per cent. It indicates that the annual rainfall is stable and at the same time, rainfall during winter and summer months is not dependable. That is the reason, why, the plantation crops' production is also variable depending upon the receipt of rains in both the monsoon seasons. Rainfall during the monsoon season (June-September) contributes 68% of the annual rainfall. It is 15.7% during post monsoon (October to November) while 13.9% in summer (March to May). It is insignificant (2.3%) in winter.

3.5. *Rainfall trend*

A decline in monsoon rainfall while increase in post monsoon is the trend across the State though cyclic trends of 40-60 years were noticed in annual rainfall. Of course, the decline in annual rainfall is evident since last 50-60

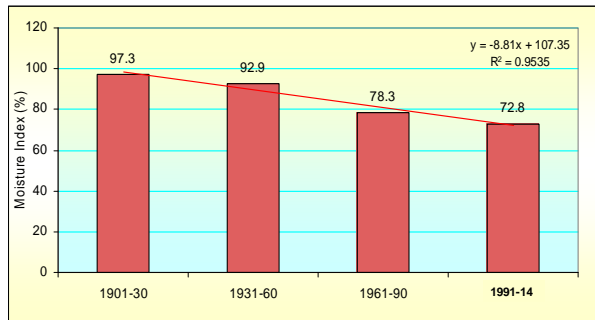


Fig. 1. Climate shifts in Kerala from 1901 to 2014

years. It also reveals that the percentage contribution of rainfall in monsoon season to the annual rainfall was declining while increasing during the post monsoon season. However, increase in post monsoon rainfall may not compensate rainfall decrease in monsoon season. Interestingly, there was a shift in climate as a result of changes in thermal and moisture regimes over the State of Kerala. The State of Kerala as a whole was moving from wetness to dryness within the Humid Climate from B₄ to B₃ since last 100 to 150 years (Fig. 1). One of the major factors could be due to alarming deforestation that took place during the above said period across the Western Ghats within the State of Kerala. The State level trends of Climate Change across the Country were highlighted by Rathore *et al.* (2013) and Climate Change over India by Shukla *et al.* (2002).

3.6. Coconut

Coconut palms in Kerala not only experience severe soil moisture stress during summer but also subjected to waterlogging due to heavy rains during monsoon periods in low and mid lands. The above situation is more predominant in the northern districts of Kerala where a unimodal rainfall pattern is seen. The primordium initiation, ovary development and button-size nut development in coconut are sensitive to soil moisture availability. The crop performs better under irrigated conditions during summer in traditional and non-traditional areas. Of course, coconut cannot come up and yield economically if irrigation is not provided throughout the year in non-traditional coconut areas like in Tamil Nadu, Karnataka and Andhra Pradesh. High temperature that prevails during summer adversely affect nut size in coconut and thereby oil content per nut in non-traditional areas. At the same time, coconut comes up well in Kerala even under rainfed conditions due to heavy rainfall and less dry spells except in summer. However, nut yield per palm is relatively low in Kerala since crop is mostly grown under rainfed conditions. However, the quality of copra and oil content are much better in Kerala when compared to that of other coconut growing states. The

same may not be true in Wayanad District (High Ranges) within the State of Kerala due to very low prevalence of temperature. The copra content is less and also not well formed in some locations and thereby less oil content with poor quality in high ranges.

3.7. Summer drought and coconut yield

The coconut production of Kerala suffered to a great extent during 1983-84 due to unprecedented drought that occurred during summer 1983, followed by 2004 and 2013. The effect of high rainfall from June to September and prolonged dry spell during summer adversely affect the coconut production in the following year. The decline in coconut productivity due to severe drought during summer could be seen in the following year under rainfed conditions. Similarly, summer showers influence coconut yield positively in the subsequent year. The effect of summer drought on monthly nut yield at various locations across Kerala indicated that the effect commences in the seventh, eighth or ninth month after the drought period is over by May or June, depending upon the receipt of pre-monsoon showers or onset of monsoon. The decline in monthly nut yield due to drought continued for 12 months, reaching to its maximum decline in 12th/13th month after the drought period is over. The percentage decline in the subsequent year due to summer drought varies depending upon the yield group. In higher nut yield group (greater than 100 nuts per palm per annum), it revolves around 29-30% while around 10% in poor yielders (yield group of 40 and 60 nuts per palm per annum). It is intermediary (24.5%) in group III, producing 60 to 80 nuts per palm per annum. On an average, the decline in nut yield due to drought in the subsequent year is 23.7% and it varies based on the yield group (Rao, 2002b).

Good planting material, high yielding coconut cultivars and coconut hybrids, good agronomic practices, floor crops, intercropping with several suited crop combinations and scarce water management practices and integrated pest management alleviate the ill effects of abiotic and biotic stresses to a large extent in coconut. Under projected climate change scenario, crop combinations may be better suited rather than mono crop to withstand against adverse weather conditions. Deep drainage facility under the field condition is a solution to avoid lack of aeration in the root zone of plantations, especially so in the case of coconut during heavy rainfall periods. It will be having beneficial effects on crop yields in plantation crops.

3.8. Cocoa

The biotic events such as flowering, chelle production and pod set in cocoa are seen throughout the year with significant variation seasonally. However, the

flowering appears to be very low during the rainy season (June to September). It normally initiates in October/November depending upon rainfall distribution from June to September and reaches to its peak by May. Similar trend is seen in the case of cherelle production and pod set. The above biotic phenomena is true only under rainfed conditions in the Humid Tropics, where heavy rainfall is noticed from June to September, followed by prolonged dry spell. Profuse flowering is also noticed during summer months if one or two good showers are received 15 days prior to commencement of flowering in cocoa. Interestingly, the number of flowers appears to be more under open conditions when compared to shade due to better availability of sunlight under good crop management practices. The number of cocoa (cacao) pods is high during summer, but pod weight is low. A harvest of five pods during October/November may be equal to eight/nine pods harvested in summer, showing superiority in cocoa pods harvested in October/November. The maximum temperature from January to March influences cocoa yield to a considerable extent. A prolonged dry spell from November to May with high maximum temperature adversely affects the pod yield to the tune of 40 per cent depending upon the crop management. In good and bad yield years, the difference in cocoa yield is more evident during the rainy season. High rainfall versus cocoa yield showed inverse relationship, indicating that high rainfall during rainy season may not be conducive in the case of cocoa due to water logging and lack of soil aeration. Overall, it reveals that high maximum temperature during summer, followed by heavy rains during the Southwest monsoon may not be conducive for obtaining good yield in cocoa under the Humid Tropics. High rainfall has a malevolent effect in places where the crop is grown under waterlogged conditions, while summer rainfall has benevolent effect on pod yield. On augmenting the dry season's rainfall by the use of irrigation, the results have not always been improved because the water lost from the leaves is so high with low humidity that the roots cannot match the loss. Crop yields are very low with heavy shade and increases with increasing light up to the 50% level. Cocoa yield is affected by the presence or absence of fertilizer if the level of light is above 50%. With added fertilizer, yields increase almost up to full light, whereas in the absence of fertilizer the yields fall off. The theory has therefore been advanced that the light regime for optimum yield of cocoa is a function of its mineral nutrition. The loss of apical dominance in cocoa is seen constantly at a temperature of above 32 °C. The loss of apical dominance implies the development of side shoots of the plant. High maximum temperatures (> 36 °C) during February and March, 2004 resulted in low pod yield in cocoa over the central region of Kerala. Cocoa is grown as an intercrop in coconut or part of homestead garden. Both the crops cocoa and

coconut respond identically with reference to weather and climate under the Humid Tropics. Of course, the phenology of both the crops is totally different.

In crops like cocoa, mango and cashew the flowering period is very much influenced by the geographical co-ordinates such as latitude, longitude and altitude of the crop growing regions and appears to follow the famous Hopkins Bio-climatic Law (Hopkins, 1938). It states that "A biotic event in North America will, in general, show a lag of four days for each one degree of latitude, five degree of longitude and 400 feet of Altitude, northward, eastward and upward in spring and early summer". In the case of mango, the flowering period across the Country, in general, followed the above said Hopkins Bio-climatic Law (IMD, 1957).

3.9. *Cardamom*

A sharp decline in area under cardamom was noticed across the cardamom tract of the Western Ghats in recent decades. However, the production and productivity of small cardamom were increasing. The important physiological stages like panicle initiation and subsequent growth (forwarding) depend on receipt of showers from January to May. The failure of showers during this period results in poor growth and crop yield. The unprecedented drought in summer 1983 adversely affected the growth and yield of cardamom in Coorg district, and the same trend prevailed in other cardamom-growing tracts of South India. The drought that prevailed during 1982-83 resulted in as high as 50% mortality in some of the cardamom estates. In the Palni hills of Tamil Nadu, both panicle and flower production are seen in October and November, during which northeast monsoon rains are received. It indicates that both panicle and flower production in cardamom are commensurate with the rainfall pattern of the cardamom tract. There is a close relationship between cardamom production and rainfall distribution during summer. Summer rains during March, 2008 have benefited the cardamom crop of 2008-2009 up to 20-30%. Therefore, summer rains have significant positive influence on cardamom. The length of crop growing season was more over Tamil Nadu (327 days), followed by Kerala (265-274 days) and the least (223- 237 days) over Karnataka across the cardamom tract of the Western Ghats. The duration and intensity of water deficit period were comparatively low at Thandikudi (90 mm), followed by Pampadumpara (141 mm). It was maximum at Sakleshpur (424 mm). Madikere and Mudigere recorded a water deficit of 258 mm and 269 mm, respectively. With all the environmental factors taken into account, the zone I (South Kerala and Tamil Nadu) is relatively better in terms of cardamom production, followed by Wayanad Region and the

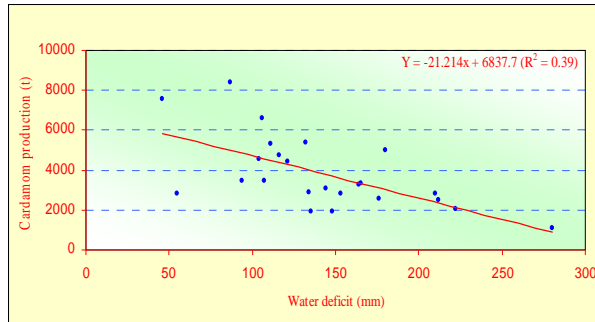


Fig. 2. Water deficit during summer (Dec-May) and cardamom production over Kerala

Karnataka Region (Zone III) the lowest cardamom yields. There exists a strong relationship between the water deficit during summer and cardamom production (Fig. 2). The cardamom production is high if the water deficit is low during summer and *vice-versa*. The studies on crop weather relationships of cardamom indicates that rainfall from December to May, annual temperature range and temperature range during southwest monsoon could explain the variability in cardamom production up to 78 per cent.

3.10. Coffee

The blossom and backing showers are very important in the case of coffee. Coffee yield is very poor in the absence of either of them. The growth of coffee appears to be affected when exposed, and hence it requires a certain degree of shade for better performance. Arabica prefers high altitudes when compared to that of Robusta. Arabica is more sensitive to weather when compared to that of Robusta. Of course, the quality of Arabica appears to be better. It is more so when processed as “Monsooned Malabar Coffee”, which is a speciality coffee preferred by the people who like black coffee and it fetches high premium in the international market. If monsoon is weak during the monsoon season in which coffee beans are processed, the quality of coffee appears to be poor. The quality of “Monsooned Malabar Coffee” is better if monsoon is heavy and continuous during July and August over the Malabar Region, where the coffee beans are processed. Continuous clouds with heavy rainfall and its better distribution, high atmospheric water vapour content, moderate surface air temperature and gentle sea breeze would lead to better moisture content in coffee beans if processed during the monsoon period. Probably, active monsoon period within the monsoon season may be more conducive for such processing of coffee beans. It is one of the factors leading to superior quality in addition to other genetical and environmental factors. Vapour pressure deficit and night temperature had significant relationship with moisture content of coffee beans. Due to increase in temperature, maturity of crop appears to be early and

weight of beans is also less. Irrigation/rainfall during October and November may be beneficial to coffee for next crop since it reduces the length and intensity of dry spell before blossom showers occur. Coffee with black pepper may be a better crop combination to cope up adverse weather conditions.

3.11. Cashew and its environment

Cashew flowering is highly erratic and depends on many environmental factors. Tea mosquito incidence is a menace along the West Coast while cyclone is a threat along the East Coast. Irrigation is practiced in cashew by the farmers along the East Coast while not so in Kerala. Cashew is mostly grown in mid lands along the West Coast while in plains along the East Coast. Cashew is cultivated on commercial line in non-traditional areas while not so in traditionally cashew growing tracts. The author travelled the cashew tract along the West and East Coasts of India extensively during various phases of cashew and interacted many scientists working in cashew to understand the time of flowering and its behavior in connection with the testing of Hopkins Bioclimatic Law (Hopkins, 1938). Rao (2002a) revealed that the above phenomenon is true in the case of cashew under the Humid Tropics. Therefore, the Hopkins Bio-climatic Law can be very well tested in case of several other fruit (perennial) crops across the Country since it has tremendous operational value for better management of crops under the field conditions and obtain good yields.

3.12. Black pepper

Black pepper requires a warm and humid climate. An annual rainfall of 2500 mm is ideal for proper growth of the crop. Rainfall is believed to be the chief pollen vector in pepper. The flowering process in pepper is initiated by the application of water equivalent of 70 mm or more rainfall within the period of three weeks, followed by a dry spell. Rainfall influences the flower bud differentiation process. Spike elongation and berry development in pepper may be ceased if there is prolonged dry spell immediately after good summer showers. Hence, good summer showers followed by a dry spell may be detrimental to black pepper production. Moderate and continuous rainfall till berry initiation may be favourable to black pepper. It may not come up well in high ranges, where low temperature prevails throughout the year. The green berry weight varied significantly with soil moisture depletion. Its weight was maximum when vines were irrigated at 50% soil moisture depletion. It recorded the lowest green berry weight when irrigated at 75% soil moisture depletion. The Oleoresin and Piperine contents of the berries followed the similar trend of weight of the green berries in response to the soil moisture depletion. In contrast to coconut, cardamom and cocoa,

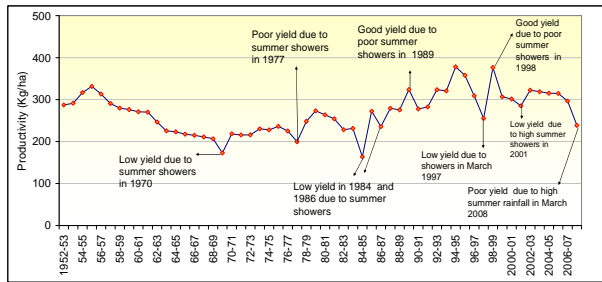


Fig. 3. Effect of summer showers on black pepper productivity

black pepper thrives to some extent under prolonged dry spells during summer (Fig. 3). The yield of black pepper declines if summer showers are received and followed by dry spell. It is true in the case of cashew also. The quality of cashew nut becomes poor and fruit drop is noticed when pre-monsoon showers or summer showers are noticed since they coincide with nut development and maturity during which dry weather is very important. Of course, mortality rate is high under poor management conditions in prolonged dry spell conditions in the case of young black pepper vines. It was the reason why, black pepper gardens were wiped out in Wayanad District during summer 2004. Another important aspect is that whenever black pepper yield is low the coffee yield is better. It is true in 2003 and 2008 when dried coffee beans were high the yield of dry black pepper was low. In 2006 and 2000 when dried coffee beans were low the yield of black pepper was high. Therefore, mixed cropping of coffee with black pepper is better against prolonged dry spell during summer rather than allowing to grow mono crop. Coffee fails to yield if blossom and backing showers fail in coffee growing areas. That is why coffee growers invariably prefer sprinklers or drip irrigation facility to manage coffee yields better.

3.13. Tea

Two growth periods are seen in tea (mid-March to mid-June and mid-August to mid-November). Night temperature and relative humidity are the most important factors which determine the productivity of tea in addition to rainfall. In Anamalai, night temperature occasionally drops below 5 °C and humidity is below 10% when the dry atmosphere is prevalent. This situation leads to tea production at lower levels. In tea, there is a time lag between the physiological function of tea bush and the vegetative harvest. It is about five weeks in the pruning year and four weeks in other years. As such the weather conditions of the previous month are generally correlated to the current month's harvest. Irrigation during cool dry season (mid-January to mid-March) will not produce the desired effect on production as temperature is the limiting factor during the period. Irrigation during the hot and dry

period (March to September) that occurs frequently in Nilgiris will be beneficial in crop production. The occurrence of heat wave during March 2004 adversely affected tea crop up to 50 per cent over Himachal Pradesh. Heat wave is not seen in tea belt in the Humid Tropics.

3.14. Rubber

Rubber is grown extensively across the midlands of Kerala. It can thrive well and produce better in the midlands of Kerala where the thermal environment is conducive to its growth. The mean annual maximum temperature across the midlands is 32.6 °C while it is 22.8 °C in the case of mean annual minimum temperature. The mean maximum temperature in the midlands of Kerala where the crop is grown extensively varies between 29.2 °C in July and 36.7 °C in March. In the case of minimum temperature it varied between 21.3 °C in January and 24.4 °C in April. The thermal environment in Kerala in general, midlands of the State in particular is conducive for the growth and development of rubber. The rate of increase in rubber productivity was affected during 1959-63 (-24.3%), followed by 1979-83 (-8.3%), 1984-88 (2.2%), 1999-03 (13.5%) and 2004-08 (18.9%). The percentage decline in productivity of rubber could be attributed to the adverse weather situations prevailed during that period. 1961 was severe flood year as far as Kerala is concerned. Severe flood due to continuous rainfall and more number of rainy days led to low productivity, though it was not very evident from the productivity chart. Continuous rainfall adversely affects rubber production. Tapping is adversely affected in the event of heavy rainfall and extended number of rainy days. Similarly, during 1979-83 and 1984-88 there was a decline in the rate of increase of yield. 1981-90 was the warmest and hottest decade in Kerala, which might have influenced adversely the rubber yield during that decade. Rise in temperature may not have much role in determining rubber productivity as the thermal regime of rubber is not subjected to frequent fluctuations even during summer. It is rainfall - its quantum, distribution and number of rainy days which determine the yield decline in rubber. Rubber growing areas in south Kerala suffered due to heavy rainfall which extended up to December 2010. Good quality planting material having tolerance to drought and pest and disease attack are to be used extensively to combat the changes in weather in the contest of climate change and global warming to sustain rubber production in the country. In short, it revealed that rubber yield is not affected due to long term changes in temperature, but is likely to be affected due to short term monsoon uncertainties like prolonged rain during monsoon, followed by extended rain during post monsoon as seen in 2007 and 2010. Similarly, prolonged dry spells during summer may adversely affect rubber yield under

rainfed conditions. Therefore, detailed studies in these directions are to be taken up with experimental data systematically collected for this purpose.

3.15. *Areca nut*

The areca nut palm is capable of growing under a variety of climatic and soil conditions. It grows well from almost sea level up to an altitude of 1000 m in areas of abundant and well distributed rainfall or under irrigated conditions. Arecanut is mostly grown in valleys under profuse irrigation in summer. Arecanut may not come up well under waterlogged conditions. The climatic requirements of arecanut appear to be similar to that of coconut, but it is relatively more sensitive to soil moisture stress and waterlogging. Due to waterlogging, areca nut is susceptible to yellowing, which is a dreaded disease. Most of the arecanut palms were affected with yellowing after heavy rains in 2014 in Wayanad District. The area under areca nut was decreasing very fast due to various reasons. The quality of arecanut has also come down. It is attributed to global warming and climate change. In Wayanad District, rainfall decline and increase in temperature are noticed in tune with global warming and climate change. Rate of increase in temperature across the Wayanad District is alarming. Warm nights are noticed. Hailstorms are also not uncommon during summer in some parts of Wayanad District. Fruit drop is common during hailstorms in fruit crops like mango and flowering in coffee is also adversely affected. Areca nut or banana or combination of both require large amount of water for irrigation to grow successfully. Paddy fields/wet lands were replaced by the above crops, leading to prolonged drought during summer since the water resources are dried up. Wet lands act as water sink during rainy season and water source during summer/lean season. Replacing such wet lands with other heavy water consuming crops is detrimental.

4. Conclusion

In the absence of northeast monsoon and summer showers, prolonged dry spell results to summer drought, which adversely affects plantation crops' production to a large extent. It is more so in the case of coconut, areca nut, cocoa, cardamom, tea, coffee and black pepper. Such severe summer droughts were noticed in 1983, 2004 and 2013 and huge crop losses were noticed and the State's economy was badly hit. Interestingly, the ill effects of weather extremes on perennial crop production are seen not only in the same year but also in subsequent years depending upon the phenology of crop. Increase in temperature, aridity index, number of severe droughts during summer, rainfall decline and moisture index are the major climate factors responsible for a marginal decline or

stagnation in coconut productivity in recent tri-decade when compared to the tri-decade of 1951-80. Climate change in the form of climate variability is a major threat to plantation crops' productivity. Recent findings indicate that the climate change effects not only crop output but also commodity quality and price. The current hike in coconut price could be attributed to last year's summer drought in addition to the crop suffered in neighbouring coconut growing states. Therefore, it is high time that the government agencies and policy makers to be proactive with short term and long term strategies to mitigate the ill effects of weather related disasters with the people's participation and minimize the losses against the weather related disasters. In this respect the work done by Rathore and Maini (2008) with the co-operating centres of Agrometeorological Field Units (AMFUs) is of paramount importance to mitigate the ill effects of climate variability on various crops.

References

- Hopkins, A. D., 1938, "Bio climates, a science of life and climate relations", U.S. Department of Agric. Misc. Pub., p280.
- IMD (Indian Meteorological Department), 1957, "Agricultural Meteorology in India Meteorological Department: A Review", Issued in commemoration of silver jubilee of Agricultural meteorology, Division of India Meteorological Department, p42.
- Rao, G. S. L. H. V. P., 2002a, "Climate and cashew", Kerala Agricultural University, Thrissur, Kerala, India, p100.
- Rao, G. S. L. H. V. P., 2002b, "Climate variability and coconut production in the humid tropics", Kerala Agricultural University, Thrissur, Kerala, India, p38.
- Rathore, L. S. and Maini, P., 2008, "Economic Impact Assessment of Agrometeorological Advisory Service of NCMRWF", Report NO. NMRF/PR/1/2008, NCMRWF, MoES, Govt. of India, New Delhi, p160.
- Rathore, L. S., Attri, S. D. and Jaswal, A. K., 2013, "State Level Climate Change Trends in India", Meteorological Monograph No. ESSO/IMD/EMRC/02/2013. India Meteorological Department. Ministry of Earth Sciences, Govt. of India, New Delhi, p147.
- Shukla, P. R., Sharma, S. K. and Ramana, V. P., 2002, "Climate Change and India - Issues", Concerns and Opportunities, Tata - McGraw-Hill Publishing Company Ltd, New Delhi, p314.
- Subrahmanyam, V. P., 1982, "Water balance and applications with special reference to India", Andhra University, Waltair, No. 173:102.
- Thornthwaite, C. W., 1948, "An approach towards a rational classification of climate", *The Geographical Rev.*, **38**, 55-94.
- Thornthwaite, C. W. and Mather, J. R., 1955, "The water balance", *Publications in Climatology*, **8**, 104.