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Climate drives of growth, yield and microclimate variability in multistoried coconut plantation in Konkan region of Maharashtra, India

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सार – 32 वर्षों पुराने नारियल के पौधे (बौना x लंबा यानी COD x WCT) की वृद्धि और उपज पर बदलते मौसम प्राचलों के प्रभाव का अध्ययन करने के लिए क्षेत्रीय नारियल अनुसंधान स्टेशन, भाट्ये, महाराष्ट्र के प्रमुख नारियल उत्पादक क्षेत्र (कोंकण क्षेत्र) में दीर्घकालिक प्रयोग (2013-14 से 2018-19) किए गए। प्रयोग के वर्षों में मौसम प्राचलों की परिवर्तनशीलता की जाँच करने के लिए मौसम प्राचलों का समाश्रयण आधारित प्रवृत्ति विश्लेषण किया गया। अधिकतम तापमान (r2=0.034) में कमी और न्यूनतम तापमान (r^2=0.017) और वर्षा (r^2=0.393) में वृद्धि मौसम के प्राचलों में बदलाव का संकेत देती है। मौसम के प्राचलों और नारियल की वृद्धि और उपज के बीच परस्पर क्रिया को समझने के लिए सहसंबंध अध्ययन किए गए। अधिकतम तापमान का विकास पर (पत्तियों की संख्या और वार्षिक पत्ती उत्पादन के लिए -0.02 और -0.58) नकारात्मक प्रभाव पड़ा लेकिन उपज (गुच्छों की संख्या,बटनों की संख्या और नारियल की उपज के लिए 0.41, 0.64 और 0.63) पर सकारात्मक प्रभाव पड़ा। न्यूनतम तापमान का वार्षिक पत्ती उत्पादन (-0.88) पर महत्वपूर्ण नकारात्मक प्रभाव पड़ा और प्रति पौधा नारियल की उपज (0.95) पर सकारात्मक प्रभाव पड़ा। सापेक्षिक आर्द्रता (सुबह एवं शाम) का प्रभाव नगण्य था। वर्षा ने गुच्छों की संख्या (-0.10) और प्रति पौधा नारियल की उपज (-0.48) को नकारात्मक रूप से प्रभावित करके, बटनों की संख्या (0.08) को सकारात्मक रूप से प्रभावित करके फसल पर अपना प्रभाव डाला। इसके अलावा, बागान में सूक्ष्म जलवायु की तुलना खुले मैदान से की गई, जिससे खुले मैदान की तुलना में नारियल के बागान में निम्न अधिकतम और न्यूनतम तापमान (-3.4 और -3.1%) और सुबह और शाम की उच्च सापेक्ष आर्द्रता (1.6 और 1.9%) का संकेत मिला।

ABSTRACT. Long term experiments (2013-14 to 2018-19) were conducted in Regional Coconut Research Station, Bhatye, a representative location of major coconut growing region of Maharashtra (Konkan region) to study the impact of changing weather parameters on growth and yield of 32 years old coconut plants (dwarf x tall, *i.e.*, COD x WCT). Regression based trend analysis of weather parameters was conducted to check the variability of weather parameters over experimentation years. There was a decrease in maximum temperature (r^2=0.034) and increase in minimum temperature (r^2=0.017) and rainfall (r^2=0.393), indicating change in weather parameters. Correlation studies were carried out to understand the interaction between weather parameters and coconut growth and yield. Maximum temperature had a negative impact on growth (-0.02 and -0.58 for number of leaves and annual leaf production) but had a positive impact on yield (0.41, 0.64 and 0.63 for number of bunches, number of buttons and nut yield). Minimum temperature had significant negative effect on annual leaf production (-0.88) and had a positive effect on nut yield per plant (0.95). The effect of relative humidity (morning and evening) was non-significant. Rainfall had its influence on the crop by negatively affecting the number of bunches (-0.10) and nut yield per plant (-0.48), a positively affecting number of buttons (0.08). Further, microclimate in the plantation was compared to an open field, which indicated lower maximum and minimum temperature (-3.4 and -3.1 %) and higher morning and evening relative humidity (1.6 and 1.9 %) in the coconut plantation as compared to the open field.

Key words – Coconut, Microclimate, Multistoried, Crop-weather relationship.

1. Introduction

Coconut palm (*Cocos nucifera* L.), a crop in humid tropics, distributed between 23° North and 23° South of the equator and up to altitudes of about 600 m from the above MSL. The crop is grown at about 11.9 M ha in over 95 countries in the tropical belt of world, with an annual production of about 67.12 billion nuts and productivity of 5638 nuts ha^{-1}. Coconut plantations are grown mainly by resource poor farmers, with a major production being contributed by countries like India, Indonesia, the Philippines, Sri Lanka, Papua New Guinea and Vietnam. India, Indonesia and the Philippines together account for more than 74 per cent of the total world coconut production, India is being a leading coconut growing nation with a production of about 21.38 billion nuts from an area of 2.15 Mha with an average productivity of 9815 nutsha^{-1} (Anon., 2020), grown in 19 States and union territory, mostly contiguous the coastal region.

Maharashtra is being a major coconut growing state in the country with confines 27.18 thousand ha area ranked 7th place with a production of 209 million nuts ranked 9th place in national coconut production and productivity of 7687 nuts ha^{-1} (Anon., 2020). Konkan region of Maharashtra is a long narrow strip of 720 km, running north to south along the West coast of Maharashtra. The coastal districts, namely Sindhudurg, Ratnagiri, Raigad and Palghar cover the major coconut growing areas in the state. Within the state, these four districts occupy 94 per cent of the area under coconut plantation. It is characterized by hilly terrain receiving heavy rainfall ranging from 3000 to 4000 mm per annum during four months from June to September (Pulak *et al.*, 2020). With the climate is warm and humid almost throughout the year, multispecies and multistoried cropping system ensures maximum utilization of resources for the higher yield per unit area. Natural resources are not fully utilized in a sole crop of coconut under the spacing schedule 7.5 m × 7.5 m, indicating a need to design a high density multispecies cropping model suited to the given agro-climatic situation. Along with these, the model should be capable of generating enough biomass output, yields, more economic returns and higher total income, additional employment opportunities for family labours and meets the diversified needs of the coconut farmers (Maheswarappa *et al*., 2014).

Climate change is projected to increase global annual mean temperatures in the range of 1.8 to 4 °C, increasing the variability in rainfall and enhancing the frequency of extreme weather events such as heat waves, cold waves, droughts and floods (Anon., 2007). All these changes have proven potential influence on agricultural production, causing vulnerability of many production systems. In annual crops, the assessment of weather extremities and implications of amendment measures can be taken with ease due to their short lifespan. But, it will be difficult with perennial crops like horticultural and plantation crops. Coconut being a major plantation crop, mostly prone to climate change since one or many physiological aspects of its growth and productivity are influenced by the weather. For economic production in coconut, the crop requires well-distributed rainfall (130-230 cm year^{-1}), annual mean temperature of 27-29 °C and sunshine (about 2000 hrs or 250-350 Wm^{-2} SRAD in a year with at least 120 hrs month^{-1}) (Rajagopal *et al*.,1996).

There are numerous examples of the impacts of weather aberrations on various physiological aspects at different stages of the crop. Minimum temperatures above 10 °C trigger flowering and temperatures above 40 °C during April to July in the tropics decrease functional leaf area index, dry matter production and nut yield (Naresh Kumar *et al*., 2008). The rainfall of the previous year had the most influence on the total annual yield of coconut (Peiris and Thattil, 1998). But the occurrence of rainfall as well as its impact on the crop productivity is unpredictable (Abhinav *et al*., 2018). Coconut having a prolonged reproductive phase of 44 months from the initiation of inflorescence primordium to complete maturity of nuts, weather affects all stages of the long development cycle, extending to 44 months, and thus, there is likely to be extended predictability based on climate variability (Vishweshwar *et al*., 2020). This long period signifies the need to study the impacts of magnitude of weather aberrations and their impacts on crop productivity.

Keeping these points in view, long-term studies were carried out to understand the relationship between coconut growth and productivity with weather parameters for laying out a scientific basis for development of management practices under abiotic risks arising due to climate change. In addition, the changes in micro climate were studied in order to assess the impact of coconut

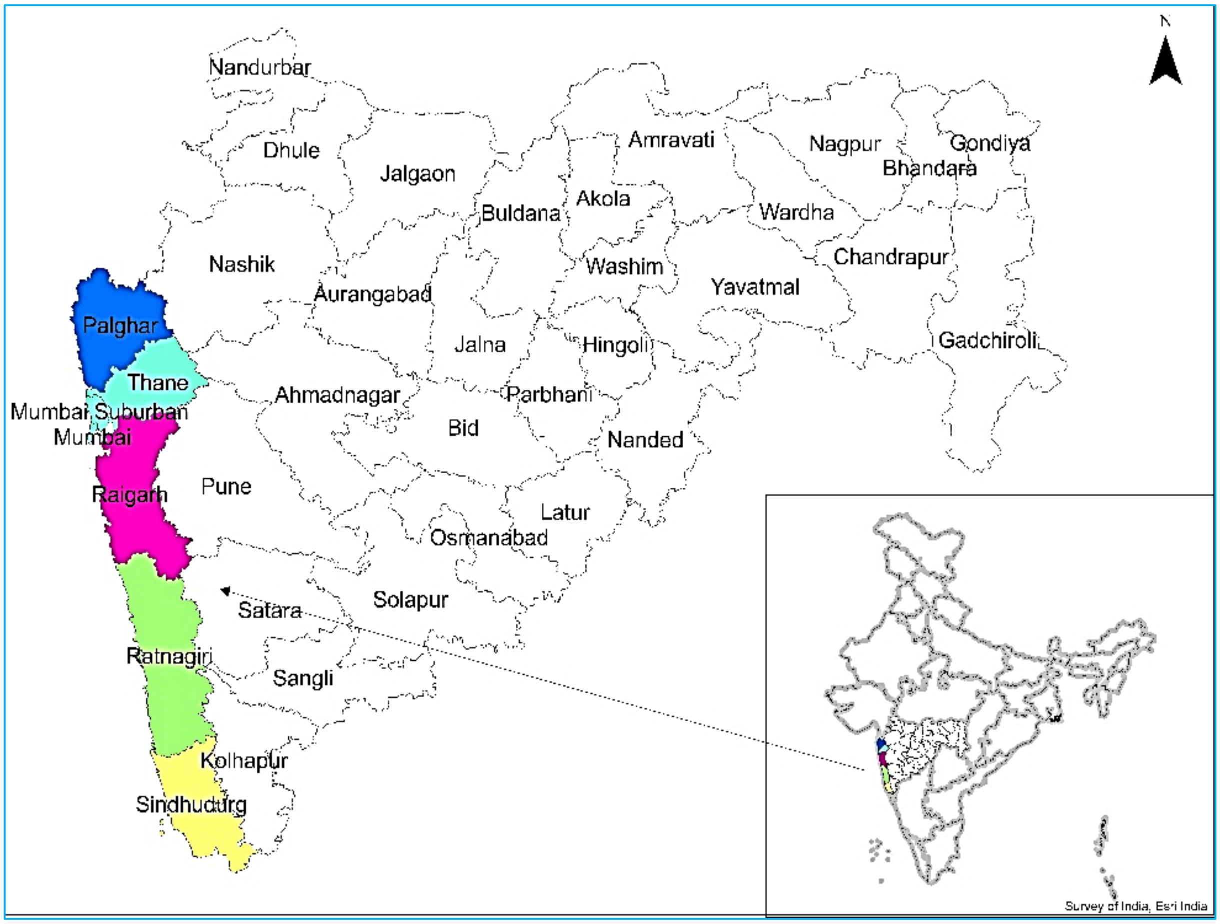

Fig. 1. Konkan region of Maharashtra: a major coconut belt where the experimental site was situated

plantation on it, to have an idea for deciding an ideal intercrop with a conformity of efficient use of natural resources.

2. Material and methods

2.1. *Study area*

The experiment was conducted from2013-14 to 2018-19 in Regional Coconut Research Station, Bhatye as a representative location of the Konkan region, a long narrow strip of 720 km, running north to south along the West coast of Maharashtra (15.67-20.20° N and 72.74 - 73.58° E, consisting of coastal districts, namely, Palghar, Thane, Mumbai, Raigad, Ratnagiri and Sindhudurg (Fig. 1). These districts cover the major coconut growing areas of the state (over 94 % of the total). The region is characterized by hilly terrain receiving heavy rainfall ranges from 3000 to 4000 mm per annum during the four months from June to September.

2.2. *Meteorological data*

Long term meteorological data (2013-14 to 2018-19) was recorded daily by the weather station located near the experimental plot and was obtained from Regional Coconut Research Station, Bhatye, Ratnagiri, India, under the ICAR-All India Coordinated Research Project on Palms. The daily weather data during the experimentation period was subjected to trend analysis, the linear trends were worked out for changes in weather parameters. Through regression analysis, magnitudes of change in weather parameters were worked out (Abdulsalam *et al.*, 2011). As far as productivity data is concerned, the trend analysis was done by following the best fit trends for a data series. Regression equations were used for finding the estimated value. Difference between estimated and measured values were used for calculating the change in a given parameter over time. Magnitude of change and correlation was calculated on a yearly basis.

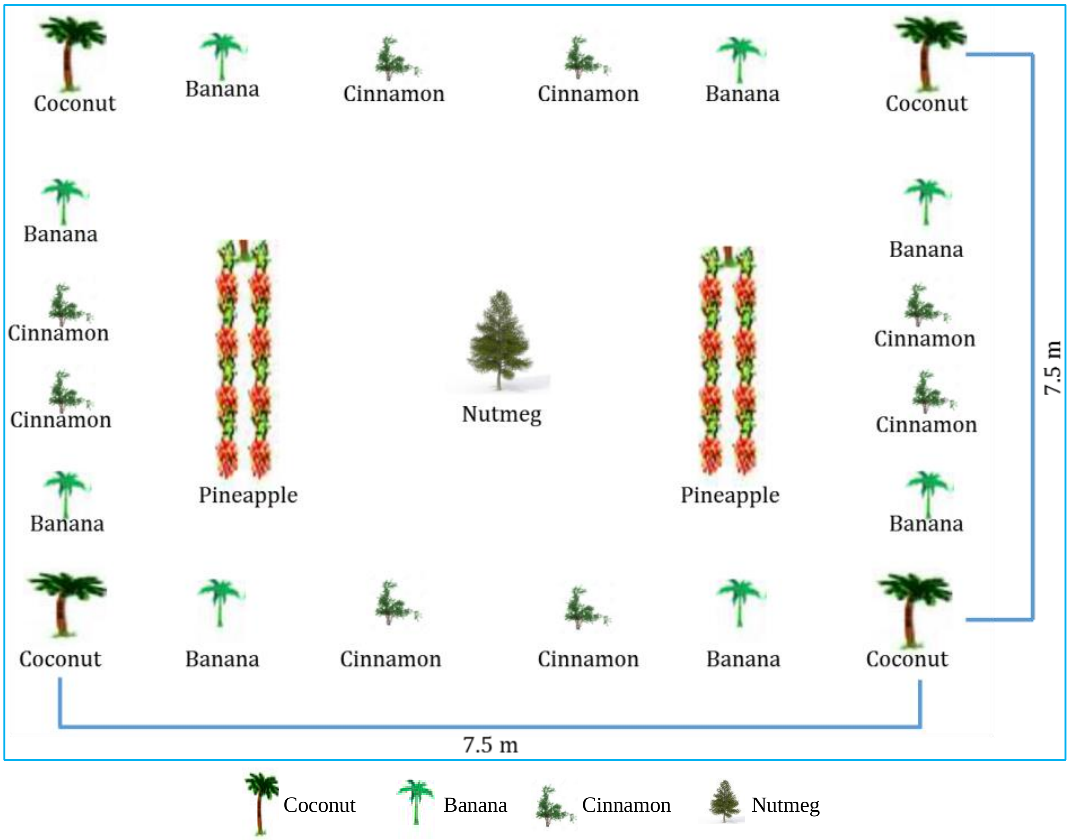

Fig. 2. Layout of a single plot representing the adjustment of intercrops in the plantation

2.3. *Experimental data*

The study was carried out on 32 year old (Dwarf x Tall *i.e*. COD x WCT) coconut plantation at Regional Coconut Research Station, Bhatye, Ratnagiri, India, under ICAR-All India Coordinated Research Project on Palms. The coconut main crop was intercropped with cinnamon, nutmeg, banana and pineapple and consisted of three INM treatments as follow,

Treatment	*Details*
T1	75% recommended NPK + 25% of N through organic recycling with vermicompost
T2	50% of RDF+50% of N through organic recycling with vermicompost + vermiwash application +bio-fertilizer application +in situ green manuring
T3	100% of N through organic recycling with vermicompost + vermiwash application + bio-fertilizer application + in situ green manuring and green leaf manuring (Glyricidia leaves) + composted coir pith, husk incorporation and mulching with the coconut leaves, were implemented in a coconut-based high density multi-species cropping system
T4	Control: monocrop of a coconut with recommended NPK and organic manure.

The experimental site was 3.2 m above MSL, located at 16°58’ N latitude and 73°17’ E longitude. The experimental site represented red sandy loam soil with anacidic pH (5.8) and electrical conductivity of 0.171dsm^{-1}, medium organic carbon content (0.62%) having medium fertility status (Nagwekar *et al*., 2014). The average annual rainfall received was 3500 mm, of which 82 percent is received during the four monsoon months (June-September). The mean temperature ranges from 21°C to 36 °C and the average relative humidity varies between sixty and ninety-five per cent. Coconut palms were laid out at a distance of 7.5 m × 7.5 m in a square system and were managed with the recommended package of practices. Experimental block of each treatment was laid out in 0.11 ha area (1100 m^2) and intercropped with spices (nutmeg and cinnamon) and fruit crops (banana and pineapple) as illustrated in Fig. 2.

For recording and interpretation of field data, annual leaf production was recorded from selected palms by marking a newly emerged leaf and later counting the number of leaves emerged above the marked leaves as leaf production/palm/year in each year. The numbers of spadices and buttons were timely recorded. Nuts were harvested at maturity stage palm-wise and average for the

Figs. 3(a-d). (a) Variability and trend in maximum temperature, (b) minimum temperature, (c) rainfall during experimentation years and (d) percent variation in microclimatic weather parameters of coconut plantation as compared to an open field

year was worked out. Growth and yield characters of component crops were recorded timely.

2.4. *Statistical analysis*

As the experiment was conducted over year, the weather parameters during the year influence the productivity of system over the years. In order to consider the influence of weather parameters over the years, year effect was taken as a fixed effect in the ANOVA table and treatment effect as error. The weather data were subjected to trend analysis wherein the linear trends were worked out for changes in weather parameters. Through regression analysis, magnitudes of change in weather parameters were worked out. Further, statistical analysis was performed using Statistical Analysis System 9.3 computer software (SAS Institute Inc., 1995). The Duncan's multiple range test (DMRT) procedure was used at p=0.05 level to determine the significance among treatments. Furthermore, as per productivity data are concerned, the trend analysis was done following the best fit trends for a data series. Regression equations were used for finding the estimated value. The difference between estimated and measured values was used for calculating the change in a given parameter over time. Magnitude of change and correlation was calculated on a yearly basis.

3. Results and discussion

3.1. *Temperature and rainfall during the experimentation years*

Temperature and rainfall are important weather factors that have great influence on the growth and productivity of palm. The highest mean maximum temperature of 33.06 °C occurred in 2018 and the lowest maximum temperature of 31.6 °C recorded in 2019 with mean maximum temperature of 32.6 °C and a standard deviation of 0.59 °C [Fig. 3(a)]. With respect to minimum temperature, during 2014, the lowest mean minimum temperature (21.54 °C) observed, whereas, a higher mean minimum temperature (22.73 °C) was observed in 2015 with a mean minimum temperature of 22.06 °C and the standard deviation of 0.41 °C [Fig. 3(b)]. Besides this observed short-term variability in weather parameters during study years, numerous previous studies have indicated the region's higher vulnerability to climate change. Investigations made by Todmal *et al*., (2021) indicated a rise in temperature by 1 to 2.5 °C in the parts of Konkan and Madhya Maharashtra sub-divisions. Their estimations also signify a marginal increase in annual mean temperature the post-2070 period. The annual maximum temperature does not show a considerable rise; however, the annual minimum temperature is expected to increase (by < 1.2 °C). Though many parts of the region have reported with increased rainfall during recent years, the distribution of rainfall throughout the year influence productivity of crops like coconut, mango, cashewnut, *etc*. Rainfall during *kharif* season also evinced significant increasing trend at some parts of Konkan (Suksale, Bhatsanagar, Karak and Mulde) and decreasing trend at some parts (Karjat). During *rabi* season significant increasing rainfall trend was observed in stations like Vengurla and decreasing trend at Harnai. Significant increasing rainfall trend was evinced at Wakawali during summer season while remaining stations did not observe any significant trend (Jedhe *et al*., 2018).

As per Vishweshwar *et al*. (2020), the response of temperature on productively of coconut was mainly attributed to variations in the current climate and plantation management across the region. These effects of the weather are mainly reflected by the yields, leading to complex to understand fluctuations. So, under non-limiting nutrient resources, the coconut yield variation is controlled mainly by the distribution of climatic variables (Talashilkar *et al*., 2008).

Moisture stress is the major constraint on coconut productivity in rainfed plantations in India as well as in other coconut-growing countries. The crop is being grown as a rainfed crop, the productivity is less than 50% of irrigated gardens because of the usual summer dry spells each year apart from the frequent moisture stress occurrence during drought years. In rainfed coconut production, nut yield is influenced significantly by the length of dry spells at critical stages and the dry spell during the primordium initiation, ovary development as the button size of coconut is largely influenced by moisture, which, indirectly influences nut yield (Rajagopal *et al*., 1996).

From Fig. 3(c), it can be observed that, there is an ascending trend of annual rainfall from 2014 to 2019. The total annual rainfall also varied from 2353.2 mm (2015) to 3878.0 mm (2019) during the experimental period, with the mean rainfall of 3013.3 mm and standard deviation of 734.67 mm. Extreme rainfall during the final years of experimentation resulted intense button shedding and heavy pest infestations in the plantations, leading to steep downfall in the production of coconuts in the concurrent year as well as the succeeding years. The longer duration between inflorescence primordial initiations (~44 months) to nut maturity with the pre-fertilization period (~32 months) is being longer than the post-fertilization (12 months) period. Hence, the impact of drought occurring during any of these critical stages of the development of inflorescence affects nut yield (Bhaskara Rao *et al*., 1991). The impact of dry spell is also of long duration in coconut. There are evidences that a longer dry spell affects the nut yield for the next four years to follow with a stronger impact on the fourth year, irrespective of the total rainfall (Naresh Kumar *et al*., 2008).

3.2. *Impact of weather parameters on growth and yield of coconut*

Annual coconut yields depend on several factors like edaphic and weather variabilities. Weather conditions, are being the major one, occurrence of weeds, diseases, and pests can result in yield fluctuations on the other hand (Hebbar *et al*., 2017). Since the impact of the former one is difficult to estimate, the impact of weather parameters can be estimated using statistical methodologies (Challinor *et al.*, 2014). Correlation analysis is major among these methodologies, widely used to estimate the dependence of yield (dependent variable) on weather parameters (independent variable). In our case, annual weather parameters were correlated with growth and yield parameters of coconut (Table 1).

3.3. *Temperature*

Maximum temperature had a negative impact on growth parameters like, number of functional leaves on crown (-0.02), annual leaf production (-0.58) and having a positive impact on yield parameters such as, the number of bunches (0.41), number of buttons per plant (0.64) and nut yield (0.63). While, minimum temperature has a negative correlation with the number of functional leaves on crown (-0.24), annual leaf production (-0.88*) and number of bunches per plant (-0.36) but was having a positive correlation with number of buttons per plant (0.13) and nut yield (0.95). Coconut, is being a crop sensitive to thermal variability during most of its lifecycle, more responsive at flowering time. Higher thermal regimes can impact the crop in both positive and negative directions. Negative impacts on low altitude coconut growing areas such as south interior Karnataka and Tamil Nadu are recorded in the form of added heat stress to the

TABLE 1

Correlation between growth attributes, yield attributes and yields of coconut with weather parameters

Parameters	Number of functional leaves on crown (nos./palm)	Annual leaf production (nos./palm)	Number of bunches (nos./palm)	Number of buttons (nos./palm)	Nut yield (nuts/palm)
T_{max} (ºC)	-0.02 NS	-0.58 NS	0.41 NS	0.64 NS	0.63 NS
T_{min} (ºC)	-0.24 NS	-0.88*	-0.36 NS	0.13 NS	0.95*
RH (morning) (%)	-0.32 NS	-0.45 NS	0.44 NS	0.80 NS	-0.04 NS
RH (evening) (%)	0.48 NS	0.12 NS	0.57 NS	0.30 NS	-0.02 NS
Rainfall (mm)	0.39 NS	-0.08 NS	-0.10 NS	0.08 NS	-0.48 NS

* correlation is significant at p=0.05. NS : Non-significant

plant, an increase in enzyme activity, *etc*. Regression analysis indicated an increase in minimum temperature increased the leaf emergence rate: the increase in maximum temperature increased the inflorescence emergence rate and nut retention rate. Frequent but short periods of temperature below 15 °C result in fruit abnormalities (Naresh Kumar *et al*., 2008). The higher temperature also may lead to a positive impacts in currently cold-limited high-latitude regions like Assam and West Bengal.

3.4. *Relative humidity*

Morning relative humidity had a negative impact on the number of functional leaves on crown (-0.32), annual leaf production (-0.45) and nut yield (-0.04). But, it was having positive impact on yield parameters like the number of bunches per plant (0.44) and the number of buttons per plant (0.80). While, evening relative humidity had a positive correlation with all the growth and yield parameters (0.48, 0.12, 0.57, 0.30 correlation coefficient with respect to the number of functional leaves on crown, annual leaf production, the number of bunches per plant, the number of buttons per plant) except nut yield per plant (-0.48). Even though, the air humidity has no direct influence on the growth and yield of coconut, the long term exposure of the crop to above and below the crop requirement may lead to yield reduction due to decrement in vegetative growth. Naresh Kumar *et al*. (2008) studied the impact of elevated morning and evening relative humidity, reported that the impact of relative humidity can be noticeable in two of three lag periods of growth.

3.5. *Rainfall*

Though coconut is grown in well managed conditions in India, but, in most of the times, the crop is taken care of up to the establishment stage, during later periods, the crop requires more resources and lack of adequate management leading to moisture stress. The primordial initiation, ovary development and button size nut stage are the very sensitive stages of crop growth to water stress. Except the number of functional leaves on crown annual leaf production (0.08) and the number of buttons per plant (0.08), all growth and yield parameters were negatively correlated with rainfall (-0.08, -0.10 and -0.48 with respect to annual leaf production, the number of bunches and nut yield per palm). Coincidence of drought with critical stages affects nut yield (Rajagopal *et al*., 1996, 2000). The affected crops not only suffer from stress for a year, the effect will be carried on to the subsequent 3 years, leading to perennial economic losses to the grower.

Due to the complex physiology of a plant's response to drought stress, the dynamics of soil water depletion and atmospheric water demand, the length and severity of stress have spatio-temporal variations. This response is multidimensional, starting at the cellular and intercellular level to the organ and phenological stage level varying with space and time. In western coastal India, hot, sub-humid and per-humid (Kasaragod, Kerala; Ratnagiri, Maharashtra); in the Western Ghats, hot, subhumid and per-humid (Kidu, Karnataka) and hot and semiarid (Arsikere, Karnataka); and in the eastern coastal plains, hot and subhumid (Veppankulam, Tamil Nadu; Ambajipeta, Andhra Pradesh), in India has indicated that the dry-spell was longer in Ratnagiri (216 days) and Arsikere (202 days) and shorter at Kidu (146 days), which differentially affected the nut yield (Naresh Kumar *et al*., 2008, Shinde *et al.*, 2019).

3.6. *Influence of intra-seasonal variations in weather parameters on growth and yield of coconut*

Among the different weather factors, rainfall and temperature are the major ones affecting the nut yield in coconut. Temperature has a critical role in various physiological processes; fluctuations in temperature

TABLE 2

Variations in microclimatic weather parameters brought about by the coconut plantation as compared to an open field

Period	T_{max} (°C)			T_{min} (°C)			RH I (%)			RH II (%)		
	Open field	Plantation	% Diff.	Open field	Plantation	% Diff.	Open field	Plantation	% Diff.	Open field	Plantation	% Diff.
1st SMW	28.6	27.5	-4	15.6	14.6	-6.3	85.6	87	1.6	43.8	44.1	0.7
24th SMW	32.7	32	-2.1	25.4	24.9	-2.2	87	88	1.1	75.8	77.1	1.7
52nd SMW	33.6	32.2	-4.1	19.8	19.5	-1.8	82.4	84	2	52	53.7	3.3
Average	31.6	30.6	-3.4	20.3	19.6	-3.1	85	86.3	1.6	57.2	58.3	1.9
SD	2.21	2.18		4.2	4		1.9	1.7		13.9	13.6	

% Diff. indicates the per cent change in weather parameters over an open field = [(open field-plantation)/plantation]*100

during different growth stages can significantly affect growth and yield. High-temperature stress during flowering and fruit development stages led to a significant reduction in coconut yield (Pathmeswaran *et al*., 2018). Conversely, optimal temperature ranges (27-29 °C) during the flowering period were associated with better nut set and higher yield (Hebbar *et al*., 2020).

Rainfall and soil moisture availability are crucial determinants of coconut growth and productivity, especially in regions with distinct wet and dry seasons. Extreme event like excessive/high intensity rainfall during the flowering or button shedding during the first four months subsequent to inflorescence opening period (Rajapakse *et al*., 2010). On the other hand, prolonged dry spells during the nut filling stage can result in smaller-sized coconuts and lower copra content (Rao, 2016). Proper water management strategies, including irrigation during dry periods, are necessary to mitigate the adverse effects of intra-seasonal precipitation variations.

Following temperature and rainfall, humidity and evapotranspiration play vital roles in coconut physiology. High humidity levels impart yield variability through their indirect impacts such as pest/disease development. Gopal *et al*. (2002) reported that higher humidity levels increased the incidence of diseases like wilt and pests like rhinoceros beetle, leading to reduction in quality and quantity of nuts.

3.7. *Variations in microclimate brought about by the coconut plantation*

The tall plant stature combined with wide venation structure and orientation of leaves in mature coconut plant makes a congenial environment for growing other short stature crops underneath. It is found out that in a mature coconut plantation, about 55% active radiation is permitted belowground (Nelliat and Padmaja, 1978), thus, is offering ample scope for intercropping with suitable perennial, biennial and seasonal crops. Even though ample solar radiation is available for cultivation, the suitability of other microclimatic parameters needs to be studied. In the present study, efforts were made to compare the microclimatic observations with those of an open field to have an understanding of microclimate suitability to component crops.

Fig. 3(d) depicts the variabilities brought about by coconut in the microclimate below the canopy. There was 3.4% decrease in maximum temperature in the plantation microclimate (30.6 °C) as compared to the open field (31.6 °C) with higher standard deviations in field temperatures (2.21) and less in plantation (2.18) indicating the reduction in maximum temperatures because of the coconut plantation (Table 2). This was due to poor penetration of solar radiation to the ground levels due to the obstructions caused by the expanded coconut leaves along with absorption and reflectance. And, a decrease in minimum temperature was observed (3.1 %) within the plantation (19.6 °C) over open field (20.3 °C). this reduction in the minimum temperature was due to the decrease in the maximum temperature itself entered in to the canopy (Balakrishnan *et al*., 1991).

Changes in morning and evening relative humidity were positive (1.6 and 1.9 % in morning and evening) indicating an increase in the relative humidity within the microclimate. This is mainly attributed to increased vapour content in the air caused by transpirational release of moisture from the plant's body by the help of stomata below the leaf surface (hypogeal). This type of stomatal arrangement helps in protecting the escape out of transpired moisture to the outer atmosphere there by containing it within the canopy (Abdul *et al.*, 2010).

These decrements in the variabilities in microclimatic weather parameters makes coconut canopy a congenial environment for growing intercrops of different height ratios (multistoried cropping). Although many crops can be grown well in coconut garden (Rethinam, 2001), profitability of growing various crops as intercrops under adult coconut garden has been reported by a few workers (Ghosh *et al*., 2017, Basavaraju *et al*., 2018, Rani *et al*.,2018). This stresses the need for location specific research studies on various crops as intercrops in major coconut growing areas.

4. Conclusions

The impact of various weather parameters has been proven on annual crops like field crops. But, the estimation of weather impact on the growth and yield of plantation crops is difficult because of the long lifecycle and difficulty in measuring the actual biological outcome generated by them. Here an attempt was made to estimate the impact of weather parameters on coconut using long-term experimentation data. Primary investigations into weather parameters indicated a decreasing trend of maximum temperature, increasing trend of minimum temperature and rainfall over the experimentation years. The relationship between weather parameters and growth and yield of coconut were non-significant (significant in certain parameters), indicating that the weather influence of the crop is slow and needs data from much more years to get a perfect estimate. Though climate change has proven its negative impact on crop growth and yield, the microclimate beneath it can be utilised for adopting component crops because of less temporal variability.

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