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EFFECT OF CLIMATE CHANGE ON FCV TOBACCO PRODUCTIVITY AND QUALITY TRENDS DURING THE LAST TWO DECADES IN SOUTHERN TRANSITIONAL ZONE OF KARNATAKA

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Flue Cued Virginia (FCV) tobacco is an important commercial crop grown under rainfed conditions in the Southern Transitional Zone (STZ) of Karnataka which is typically characterized by a sub humid to semi-arid climate with a bimodal rainfall pattern. Even though FCV tobacco is regarded as a hardy and drought tolerant crop and produces better quality leaf in light soils of Karnataka, continuous monocropping, lack of crop diversity/crop rotation practices coupled with erratic / uneven rainfall and unpredictable rains during recent times is greatly affecting the production and quality of this export-oriented crop with unsustainable productivity and farm income. The analysis of two decades of rainfall (for the period from 2002-03 to 2022-23) has indicated rainfall variability with a high coefficient of variation of 27.8%. Further, the month of July considered to be very critical for moisture stress showed a wide variation of 42.3% in terms of the quantum of rainfall and number of rain events (C.V.26.9%). Regarding the other weather factors analyzed, the photoperiod (sunshine hours/day) showed comparatively higher variability (13.8%) compared to the average mean temperature (5.7%) during the crop growing season indicating minimum sunlight period for optimum productivity level. The average productivity level over two decades was observed to be 1123 kg/ha with a variation of around 12.0%. However, in 60% of the years the productivity was below normal. Anything above >450 mm during the crop period was detrimental to productivity. Optimum rainfall is observed to be around 370-450 mm during the cropping season with July (critical period) month rainfall not falling below 50 mm (and also not exceeding 120 mm) with better sunlight intensity (minimum of 4.0 hours/day and above) for optimum productivity and quality of FCV tobacco in KLS.

Flue Cued Virginia (FCV) tobacco is an important commercial crop grown under rainfed conditions in Southern Transitional Zone (STZ) of Karnataka in an area of 0.75 to 0.80 lakh ha. The STZ zone is typically characterized by sub humid to semi arid climate with bimodal rainfall pattern occurring right from April to November (*Mahadevaswamy and Giridhar, 2003*) and tobacco crop is raised in early *kharif* season followed by various pulses/ ragi/ maize during late *kharif* / *rabi* season. The rainfed tobacco produced in Karnataka Light soils (KLS) zone is considered as superior neutral filler with high export demand in the international market due to mild and smooth aroma, balanced leaf chemistry, TSNA levels below detectable level and low levels of heavy metals. The FCV tobacco growing soils in this transitional zone are generally red sandy to sandy loam in texture, well drained with slightly acidic to neutral in reaction and found highly suitable for quality tobacco production. However, the major limitations are diminishing soil fertility over the years, poor water and nutrient retention capacity. Even though FCV tobacco is regarded as hardy and drought tolerant crop and produces better quality leaf in light soils, continuous mono-cropping, lack of crop diversity and poor soil fertility management practices coupled with erratic and unpredictable rainfall during the recent years is greatly affecting the production and quality of this export-oriented crop often resulting in unsustainable productivity and farm income. Dry land agriculture in arid and semi-arid regions where 40% of the world's

Key words: FCV tobacco, climate change, rainfall variability, crop productivity, KLS

population live is more vulnerable to risks of climate change and rainfall variability, drought in particular (*Sivakumar, 2012*).

Being a rainfed production system, the sustainable leaf productivity and cured leaf quality / chemistry is largely influenced by climate changes and prevailing weather situations during the crop growth period. The timely onset of monsoon and the availability of moisture during the critical stage of crop growth is the most important factor for successful FCV tobacco production in this zone. The productivity of rainfed farming is always uncertain due to long temporal and spatial variation in the rainfall apart from the productive capacity of the land. In recent years the large-scale variations in climatic factors in terms of rainfall pattern, rainfall intensity and variability, coupled with varied temperature regimes and photoperiodism have been found to be greatly associated with the basic soil characters/ properties in turn affecting water and nutrient availability and its uptake, pests/disease outbreak resulting in poor and unsustainable productivity and quality of FCV tobacco grown in this zone. Any strategy to increase agriculture production on a sustained basis should take explicit account of the complementarily of the agro-meteorology and development (*Biswas, 1994*). The large-scale variations in productivity as well as the leaf quality parameters from year to year have negatively impacted the export potential and farm economics. In this paper, an attempt was made to analyze productivity trends and variations as affected by rainfall variability and other weather parameters during the last 2 decades and to understand optimum weather factors required in general for optimum productivity and quality in KLS.

MATERIAL AND METHODS

The two decades of rainfall (for the period from 2002-03 to 2022-23) and the temperatures regimes (maximum and minimum), and the photoperiod (sunshine hours per day) were collected for 20 years from the agro meteorology observatory situated at ICAR-Central Tobacco Research Institute Research farm, Hunsur, Mysore District, Karnataka. The agro-weather station is situated at an altitude of 826 MSL with latitude of 12^0 to 18^0 N and Longitude of 76^0 to 81^0E with a long-term average rainfall of around 850 mm. The mean temperature was worked out by summing up maximum and minimum temperature values and divided by 2. The variability (C.V. %) in various weather parameters were calculated based on the formula (Standard Deviation divided by Mean value and multiplied by 100). The number of normal RF years, Excess RF years and Deficit RF years were worked out as per IMD classification (Excess: +20% and above, Normal: +19 to -19%, Deficit: -20 to -59% and Scanty: -60% and less). The Productivity levels along with the leaf quality parameters of KLS zone were obtained from Tobacco board, Mysore. The year-to-year RF variability and weather data were interpreted and the optimum RF and weather parameters required in general for maximizing the productivity/and quality of FCV tobacco were inferred.

RESULT AND DISCUSSION

Rainfall trends and Climatic variability

The analysis of the latest 20 years RF data (2003-2022) has indicated rainfall variability in the annual rainfall with a coefficient of variation of 23.7%. The annul RF ranged from 583.4 to 1461.8 mm with a mean value of 884.0 mm, while the RF during the crop season (May- Aug) ranged from 229.9 mm to 812.8 mm with the mean value of 439.8 mm. Out of the 20 years rainfall analyzed, 13 years fall under the Normal category (+19 to - 19%), three under Deficit years (-20 to - 59%) and four under Excess RF years (+20% and above) indicating that in 35% of the years, the rainfall was not normal for successful production of FCV tobacco-based farming in this zone (**Table 1**).

Normally the RF in this agro climatic of Karnataka (STZ No.7) commences from the second fortnight of April and continues up to middle of November facilitating double cropping system with FCV tobacco in the *kharif* season (May- Aug) followed by pulses/ragi/maize in the succeeding *rabi* season (Sept.- Nov/Dec). However, the rainfall distribution is unpredictable and erratic resulting in unsustainable productivity /quality of the crop as indicated by high coefficient of variation in rainfall intensity and rainy days. FCV tobacco planting generally commences from the month of May and ends by Aug during which period the

Table 1: Total Annual RF, rainfall pattern, temperature & sun shine during the crop growing period

Year	Total RFmm	RF mm during crop season (May-Aug)	RF mm during July	No. of Rainy days during crop period (May-Aug)	Average Temp (May-Aug)	Sun shine Hrs./day (May-Aug)
2003-04	724.0 (N)*	346.3	95.0	32 (10) *	23.91	4.00
2004-05	751.7 (N)	371.4	78.4	36(9)	22.17	4.06
2005-06	1013.0(N)	486.0	140.6	47(16)	22.41	4.36
2006-07	764.8 (N)	383.0	72.0	44(12)	24.01	4.90
2007-08	884.0 (N)	472.3	114.6	39(10)	24.03	4.00
2008-09	718.9 (N)	393.0	104.0	34(11)	24.07	4.40
2009-10	1025.9 (N)	514.6	223.8	41(17)	24.06	4.00
2010-11	1016.0 (N)	479.0	85.6	45(14)	23.97	3.50
2011-12	1064.3 (E)	451.0	101.8	43(13)	22.83	3.70
2012-13	583.4 (D)	229.9	32.6	26(5)	23.40	4.06
2013-14	770.8 (N)	347.0	109.7	36(15)	21.30	3.00
2014-15	733.0 (N)	412.6	84.6	44(14)	21.60	4.00
2015-16	1159.0 (E)	552.6	47.6	46(9)	21.20	4.50
2016-17	569.6 (D)	460.5	115.4	37(15)	21.50	4.30
2017-18	836.6 (N)	394.0	48.4	39(7)	21.91	4.10
2018-19	847.3 (N)	489.1	103.6	48(12)	20.51	3.90
2019-20	970.8 (N)	551.8	99.8	38(11)	23.40	5.80
2020-21	714.0 (D)	382.2	81.9	37((10)	21.41	4.10
2021-22	1072.0 (E)	265.6	83.3	38(14)	21.90	3.80
2022-23	1461.8 (E)	812.8	173.3	58(18)	19.85	4.15
Mean	**884.0**	**439.8**	**99.8**	**40.4(12.1) ***	**22.47**	**4.13**
C.V.%	**23.7%**	**27.8%**	**42.3%**	**16.9 % (26.9%)**	**5.7%**	**13.8%**

*N: Normal year, E: Excess year and D: Deficit year

** Figures in the parenthesis indicates the number of rainy days in the month of July

rainfall intensity, number of rainy days, availability of sun light period and temperatures regimes determines the crop performance and productivity levels. Planting during First fort night of May month has been identified as very beneficial as it results in highest farm income due to increased productivity and better bright grades rather than subsequent late plantings in KLS conditions (Devappa and Balbatti, 1981).

As per the crop physiology and growing period, the optimum water requirement for successful tobacco production is estimated at 400-450 mm during the tobacco cropping season (May to Aug) with well distributed 8-10 rainy days during each month. The low or excess rainfall during this period greatly affects the tobacco productivity and quality, as the crop is highly sensitive to soil moisture stress/deficit as well as water logged conditions. The long-term data of 20 years RF showed a high coefficient of variation of 27.8% during the cropping season is affecting the productivity levels from year to year.

Further, as July rainfall is identified as critical period as it coincides with the grand growth phase of the crop, amount of RF as well as distribution during July coupled with sun light intensity, plays an important role in crop growth, leaf expansion, leaf size & thickness as well proper ripening. The RF data clearly indicated that with climate change the RF during July month showed wide variation of 42.3% compared to the rainfall during the cropping season (27.8%) or the total annual rainfall

(23.7%). Even the RF distribution in terms of number of rain events showed high variability from year to year (C.V.26.9%). Regarding the other weather factors analyzed, the photoperiod (sunshine hours/day) showed comparatively higher variability (13.8%) than the average mean temperature (5.7%) during the crop growing season indicating minimum sun light period for optimum productivity levels. The cloudy days with the reduced sunlight and continuous drizzling that normally occurs during July/early August in this zone has been frequently observed which adversely affect the productivity and quality of the crop due to decreased photosynthetic activity / dry matter production apart from poor nutrient uptake by the crop.

In general, the variability in weather parameters during the crop growing the FCV tobacco production and quality in the order of Rainfall in July> rainfall during crop season> number of rain events in July > number of rain events cropping season (May -Aug) >Sunshine hours > average mean temperature. *Steven jerie* and *Ndabaningi*, 2011 studied the influence of different weather parameters and concluded that rainfall variability is a major factor influencing the yield and quality variations in tobacco under rainfed Zimbabwe conditions.

Production trends and leaf quality parameters over the years

The tobacco area, production, productivity and leaf quality parameters in KLS as observed during the last 20 years are presented in Table 2. The production trends indicated that the productivity during the last twenty years ranged between 945 and 1327 kg/ha with the mean productivity figure of 1123 kg/ha under rainfed tobacco gowning areas of KLS. Out of 20 years analyzed 12 seasons recorded below average productivity while in 8

Table 2: Area production and productivity and leaf quality trends in KLS for the last 2 decades

Year / season	Area (ha)	Production (m.kg)	Productivity (Kg/ha)	Average Cured leaf quality parameters		
				Nicotine %	Sugars %	Chlorides %
2003	69158	74.69	1079	1.79	19.80	0.30
2004	69680	90.35	1296	1.89	13.70	0.34
2005	73980	82.90	1120	1.05	24.00	0.32
2006	78162	96.98	1240	2.12	15.12	0.18
2007	85735	87.66	1022	1.96	16.26	0.11
2008	90175	114.00	1264	1.29	18.23	0.23
2009	106601	115.60	1100	1.66	20.20	0.23
2010	117924	127.85	1092	1.77	13.93	0.18
2011	106000	104.29	984	2.13	19.65	0.19
2012	93000	93.80	1008	2.38	23.90	0.99
2013	97760	102.01	1050	1.93	19.11	0.48
2014	85689	103.46	1207	2.00	15.87	0.80
2015	75837	71.95	945	1.50	22.65	0.51
2016	76088	98.72	1300	1.83	21.65	0.35
2017	81083	106.89	1320	1.94	19.50	0.64
2018	83696	85.08	1017	1.35	20.90	0.32
2019	81360	106.07	1327	1.67	19.85	0.39
2020	73234	88.40	1210	1.60	19.95	0.32
2021	71000	68.13	960	1.74	19.75	0.47
2022	66000	60.00*	909	1.44	19.41	0.36
Mean	-	-	**1123**	**1.75**	**19.17**	**0.38**
C.V.%	-	-	**12.0%**	**17.7%**	**14.9%**	**55.0%**

years the productivity was higher than the average figures of 1123 kg/ha. The coefficient of variation in the productivity was around 12% over the two decades. In case of the curd leaf quality parameters wider CV ratio of 55.8% was noticed in the chloride levels of the leaf followed by CV of 17.7% and 14.9% in case of leaf nicotine and sugars, respectively. Wide variation of chlorides once again is an indicative of the drought /excess rainfall years which can alter the irrigation water quality and the soil chloride levels. By and large the leaf quality parameter was still found to be in the normal acceptable range in KLS.

Productivity trends in relation to rains and weather parameters

In 12 out of 20 years, the productivity was below 1123 kg/ha (the average productivity of 20 years) and in remaining 8 years the productivity was found to be above the average values indicating that in nearly 60% of the years the productivity was below normal (Table 3). The interesting observation is that in the 12 low productivity years observed, the severe drought periods were only 4 years (2003,2012, 2013and 2021) and rest 8 years having excess rains during the crop period from May to August or in the month of July. ***Mahadevaswmy et al, 2017*** based on regression models of rainfall data of 34 years (1981-2014) inferred that productivity followed sigmoid curve with respect to July RF wherein much of the normal productivity points were concentrated at 100-120 mm rainfall range and rainfall in excess of > 120-150 mm was not conducive for leaf development and productivity decline was very much observed during excess RF years. It was observed that rainfall above >450 mm during the crop period is detrimental for productivity. Optimum rainfall observed to be around 370-450 mm during the cropping season with July (critical month) rainfall not falling below 50 mm and also not exceeding 120 mm. The productivity levels tend to decline when the average sunshine period during

Table 3: FCV Tobacco productivity trends (2003-2022) in relation to rainfall and weather factors

Year	Productivity Kg/ha	RF mm during July	RF mm during crop season (May-Aug)	No. of Rainy days during crop period (May-Aug)	Av. Sunshine hours/day during (May-Aug)	Average Mean Temp (May-Aug)
2003	1079	95.0	346.3	32 (10)	4.00	23.91
2004	1296	78.4	371.4	36(9)	4.06	22.17
2005	1120	140.6	486.0	47(16)	4.36	22.41
2006	1240	72.0	383.0	44(12)	4.90	24.01
2007	1022	114.6	472.3	39(10)	4.00	24.03
2008	1264	104.0	393.0	34(11)	4.40	24.07
2009	1100	223.8	514.6	41(17)	4.00	24.06
2010	1092	85.6	479.0	45(14)	3.50	23.97
2011	984	101.8	451.0	43(13)	3.70	22.83
2012	1008	32.6	229.9	26(5)	4.06	23.40
2013	1050	109.7	347.0	36(15)	3.00	21.30
2014	1207	84.6	412.6	44(14)	4.00	21.60
2015	945	47.6	552.6	46(9)	4.50	21.20
2016	1300	115.4	460.5	37(15)	4.30	21.50
2017	1320	50.4	394.0	39(7)	4.10	21.91
2018	1017	103.6	489.1	48(12)	3.90	20.51
2019	1327	99.8	551.8	38(11)	5.80	23.40
2020	1210	81.9	382.2	37((10)	4.10	21.41
2021	960	83.3	265.6	38(14)	3.80	21.90
2022	909	173.3	812.8	58(18)	4.15	19.85

the cropping period falls below 4.00 hours /day. So, the analysis indicates that the amount and distribution of rain fall in terms of quantity and the number of rain events during the cropping season as well as during July (critical period which coincides with the grand growth period) are very much deciding factors followed by availability of sun light duration during cropping season.

Future line of work

The higher coefficient of variation in rainfall and weather parameters observed during the last 2 decades in KLS due to climate change phenomena necessitates suitable climate risk management strategies and drought mitigation technologies through the development of planting techniques, rain water management, and suitable soil and crop management practices to optimize the productivity levels and maintaining the leaf quality and to reduce the year to year variation in production for sustaining the export potential and farm income and livelihoods in rainfed FCV tobacco zone of Karnataka. Further, the reliable forecast of the July month rainfall situation becomes very much relevant (as the variation is quite high) in determining not only yield estimates/ quality assessment, but also serves for planning possible climate mitigation preparedness or policies at the governance level and farm level. Integrated crop and site-specific soil management programmes may reduce the impact of climate variability to a greater extent to minimize the production losses in abnormal years. Building up of soil organic matter and integrated nutrient management practices and following ideal crop rotation practices may be very much likely to reduce the impact of climate change and crop production losses to a greater extent.

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