

Spatial and Temporal Rainfall Analysis of the Bidi Tobacco Growing Areas of India.

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Abstract

The monsoon extremities, such as heavy rainfall, drought, and cyclones are becoming frequent across India and causing substantial damage to commercial crops. To predict/identify the trend in rainfall of Bidi tobacco growing areas were studied for variability, trend, and detection of any change in monthly rainfall over the years (1990-2020) using Mann-Kendall trend analysis and Sen's slope tests. Monthly rainfall in three unique Bidi production zones has shown distinct trends. A positive trend was observed in *March, April, August, September, November, and December* while negative trends were in June and July months in Gujarat. During the crop growth period, the trend is positive except in October, the magnitude of change was negligible. However, supplemental irrigation is to be planned during water deficit periods of the nursery (*June and July*) and critical crop growth periods. In Karnataka, a positive trend from February to October was observed while a negative trend during *November, December, and January*. The magnitude was high in *January (+) and September (-)* and significant. The period of negative trend has coincided with the harvesting hence, the crop may not get affected. However, high rainfall during the crop growth period causes a detrimental effect. To mitigate the inundation proper drainage facility should be created through field channels to flush out excess water to avoid saturation at the root zone as this crop is especially extremely sensitive to poor aeration and anaerobic conditions. A positive trend was observed in *January, February, March, June, August, and September* months in Andhra Pradesh, whereas a negative trend was high in October & November which coincided with crop growth and might significantly affect *Bidi* tobacco. The positive trend in rainfall during June is high and the same can be utilized for nursery during July-August through proper moisture conservation measures.



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Introduction

The largest commercial crop in India is tobacco, which is grown on 0.45 million hectares of land and yields 804 million kilogrammes yearly. Tobacco exports provide \$5,540 billion in revenue for the country's economy, and excise taxes generate 22,737 billion and 28,277 crores respectively. It also ensures the livelihood of 45.7 million people. The unique feature of Indian tobacco is that different tobacco types viz., Flue-Cured Virginia, Burley, HDBRG, Oriental, *Bidi*, Cheroot, Natu, Pikka, Lanka, Chewing, Cigar Wrapper & Filler, and Hookah. Indian tobacco enjoys a competitive advantage on the global market thanks to its low production costs and offers consumers more "value for money" and to the availability of several tobacco leaf varieties. Besides its conventional use, tobacco is also exploited for phytochemicals and other value-added products such as Solanesol, proteins from green leaf, and oil from the seed.

Among the several types of tobacco, *Bidi* tobacco is a smoking type that occupies an area of 1,80,759 ha and with a production of 3,72,220 tons, cultivated in Gujarat (89.84 %), Karnataka (3.93 %), and Andhra Pradesh (6.23 %). There was a surge in *Bidi* tobacco cultivation from the year 2010-2011 i.e. $\approx 60\%$ increase in area and production. (Fig. 1 and 2) because of an increase in demand for its various end uses. About 68% of the land in India is used to grow crops, which provide food for 60% of the country's animals and 40% of its people.¹ Monsoon adversities, such as heavy rainfall, drought, and cyclones are becoming frequent with varying intensities across India and causing crop damage.

Extreme deviations from the typical monsoon pattern can have an impact on the economy, livelihoods, and food production. Unlike other commercial crops, tobacco leaf is the economic part, and its productivity is in danger to weather aberrations, and change in climate associated with raise in temperature, CO₂, and changes rainfall distribution. In the recent past, extreme weather events such as prolonged drought, erratic rainfall, and unprecedented heavy rains led to floods posing a serious threat to *Bidi* tobacco production. The present investigation was taken up to study the variation and trend in rainfall, its impact on crop growth or yield to formulate suitable strategies and research initiatives to mitigate /overcome its impact on the *Bidi* tobacco productivity.

To understand the hydro-meteorological aspects of a region or the entire world, climate trend analysis is used. Numerous studies,^{2, 3, 4, 5, 6} were conducted to assess rainfall distribution and trend spatially and temporally throughout the world, and various regions in India.^{7,8,9,10,11,12} Parametric and non-parametric techniques were employed to analyse trend of the rainfall. The non-parametric test is appropriate for independent datasets with outliers while the parametric test presupposes that the data are normal. Slope estimator (Sen's test - SSE)¹³ and the Mann-Kendall trend test^{13,14} are employed to analyse local & regional rainfall trends.¹⁵ The local level rainfall dynamics especially is unique and novel approach which helps in developing strategies to prove production while escaping the stress due to moisture in season.

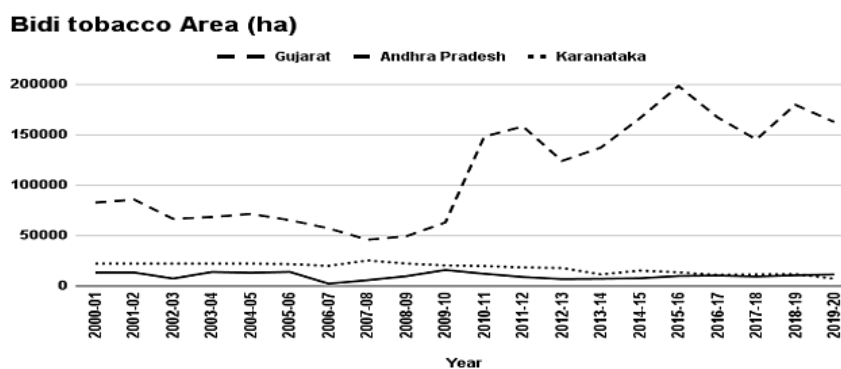


Fig. 1: Bidi tobacco area trends in India.

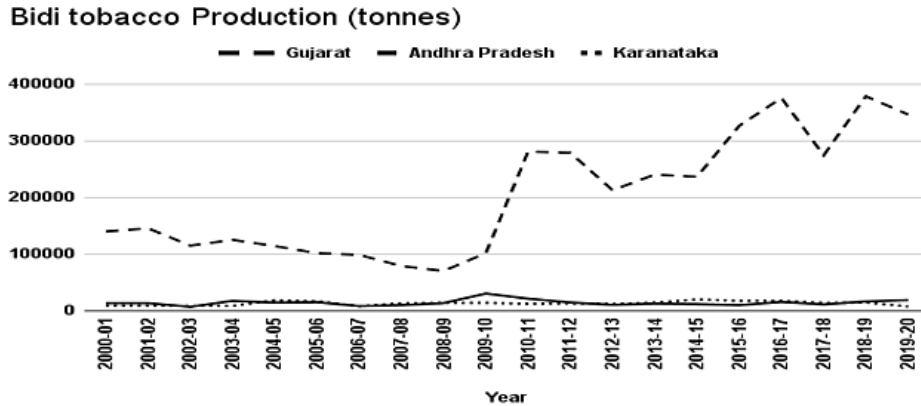


Fig. 2: Bidi tobacco production trends in India

Materials and Methods

The trend in regular rainfall of *Bidi* tobacco growing areas of Gujarat, Andhra Pradesh, and Karnataka was studied for detecting any aberration over the years. The statistical methods employed were *Mann-Kendall* analysis to establish or detect trend and Sen’s technique for assessing the slope in a rainfall trend. The data sets of monthly rainfall from a time series of 1990 – 2020 (30 years) and 1980-2020 (40 years) were collected from the research centres *Nandyal, Anand* and *Nippani* situated in *Bidi* tobacco growing regions of Andhra Pradesh, Gujarat and Karnataka, respectively.

Trend Analysis of Rainfall

Periodical rainfall data from the above mentioned three *Bidi* tobacco growing areas was analysed to detect the dynamics. The Mann–Kendall technique was employed to identify the presence of any rainfall trend in a time series¹⁶ and to establish the magnitude of change the Sen’s slope method was employed. 90, 95 and 99 % confidence levels ($p < 0.10$, $p < 0.05$ and $p < 0.01$) were tolerance levels to categorise the significance of +ve and -ve rainfall variation. Numerous scholars employed this approach to find variations in temporal hydrological data (groundwater level), rainfall and stream flow, etc.^{17,18,19, 20, 21,22,23,24,25,26,27,28}

The ranks that every data point received were used in the test. The initial and final values of Mann-Kendall statistic’s (S) is the result derived from deviations increases and decreases^{29, 30}

$$S = \sum_{i=1}^{n-1} [\sum_{j=i+1}^n \text{sgn} (R_j - R_i)]$$

Signum function (sgn) (x) = 1 for x > 0; Signum function (x) = 0 for x = 0; Signum function (x) = -1 for x < 0. The z-statistic = | S | / s 0.5. A positive value of S implies an increasing trend while a negative value a decreasing trend.

Test significance (z) was compared with table values at confidence intervals 99 % (2.576), 95 % (1.960), and 90 % (1.645), respectively.

The real magnitude of change per year of an existing trend estimated using Sen’s slope³¹ following formula:

$$f(t) = \text{Slope} (Q) t + B(\text{Constant}) \quad \dots(1)$$

Determined slopes of each pair of data to get the slope estimate(Q): When $j > k$, $Q = x_j - x_k / j - k$: If the time series has n values for x_j , then the number of $N = n(n-1)/2$, and slope estimations Q_i are obtained.

The average of N readings of Q_i serves as Sen’s estimate of the slope. Q_i (N values) is ranked from smallest to highest.

The Sen’s estimator calculated using the formula given as under

$$Q = \text{if } N \text{ number is odd then it is } Q [(N + 1) / 2]$$

(or else)

$Q = \text{if } N \text{ number is even then it is } \frac{1}{2} (Q [N / 2] + Q [(N + 2)])$

Results and Discussion

Periodical rainfall of three distinctive *Bidi* production zones of Gujarat, Karnataka, and Andhra Pradesh, where *Bidi* tobacco is grown have shown different trends.

Rainfall Analysis of *Bidi* growing regions of Gujarat

Monthly rainfall distribution in *Bidi* tobacco growing areas of Gujarat was depicted graphically (Fig. 3) taking the percentage of total monthly rainfall against the years from 1990 to 2020. The maximum rainfall

is observed throughout *June, July, August, and September* whereas lowest rainfall was observed during *January, February, March, April, November, and December*.

Based on Mann-Kendall trend analysis, it was observed that a positive trend was obtained in *March, April, August, September, November, and December*, in other months negative trends were observed. The -ve trends in June and July will affect the nursery raising. During the crop growth period, the trend is mostly positive except in *October*, the magnitude of change was negligible. However, alternative supplemental irrigation is essential and is to be planned during water deficit periods of October. (Table 1, Fig. 4 -5).

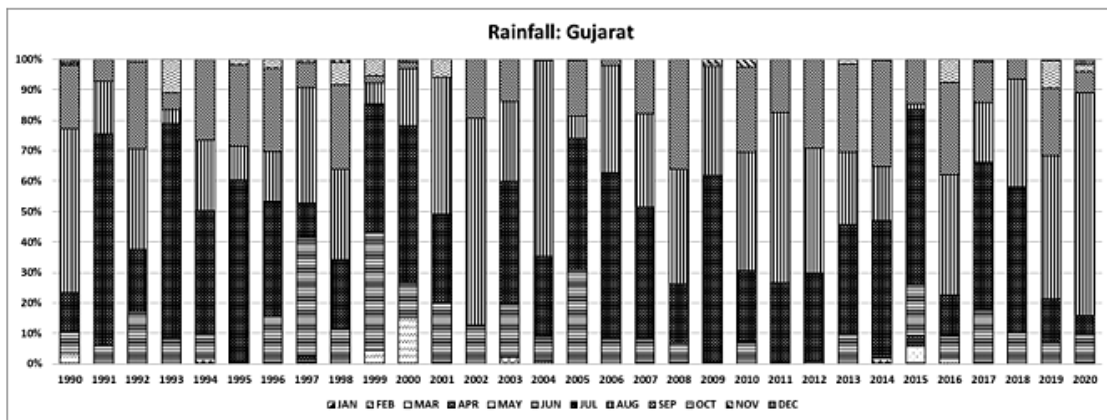


Fig. 3: Monthly distribution of rainfall in *Bidi* tobacco growing areas of Gujarat.

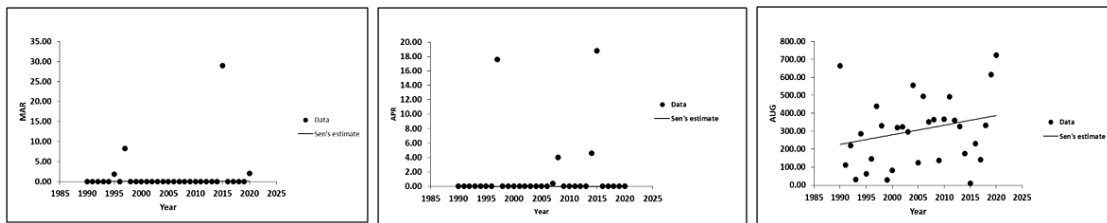


Fig 4: Rainfall (mm) trend in March, April, and August months over 31 years at *Bidi* tobacco growing centre Anand, Gujarat.

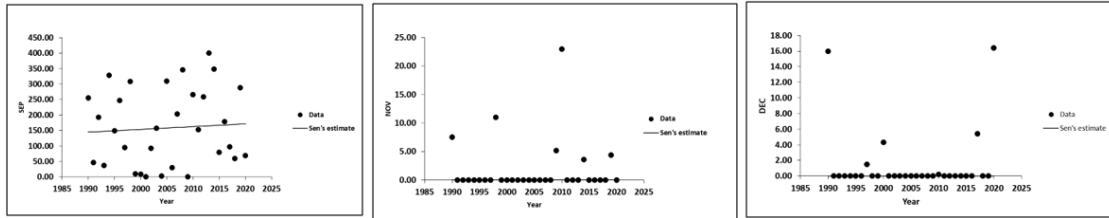


Fig 5: Rainfall (mm) trend in September, November, and December months over 31 years at Bidi tobacco growing centre Anand, Gujarat.

Table 1: Rainfall trend and Slope estimates of regular rainfall (1990-2020) at Bidi tobacco growing centre Anand, Gujarat.

Month	Starting Year	End Year	Mean (mm)	Standard Deviation (n-1)	Z value for Mann-Kendall Trend (S)	Q (Estimate)	B (Constant of Sen slope) (mm per year)
JAN	1990	2020	1.6	4.9	-0.65	0.000	0.00
FEB	1990	2020	0.8	4.2	-0.44	0.000	0.00
MAR	1990	2020	1.3	5.4	0.25	0.000	0.00
APR	1990	2020	1.5	4.6	0.59	0.000	0.00
MAY	1990	2020	5.0	14.0	-0.36	0.000	0.00
JUN	1990	2020	108.0	112.8	-0.44	-0.600	104.80
JUL	1990	2020	309.0	183.0	-0.03	-0.321	254.27
AUG	1990	2020	295.0	190.7	1.56	5.336	226.94
SEP	1990	2020	161.9	124.0	0.42	0.900	144.50
OCT	1990	2020	15.8	28.8	-0.51	0.000	0.80
NOV	1990	2020	1.8	4.7	0.24	0.000	0
DEC	1990	2020	1.4	4.1	0.17	0.000	0

Note: * Confidence interval for level of significance is at 99 %.

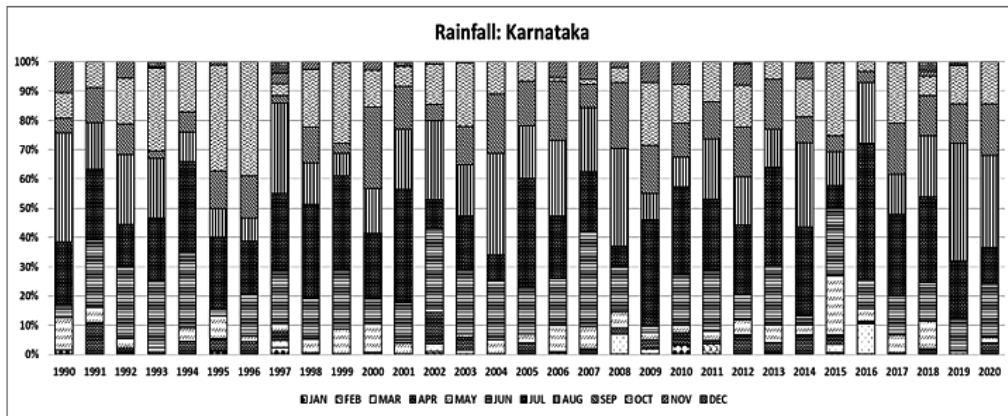


Fig. 6: Monthly distribution of rainfall in Bidi tobacco growing areas of Karnataka

At the harvesting stage i.e., from January to April the Mann-Kendall constants (Z) were negative during January and February, however, they are not going to influence significantly as the magnitude of change was zero.

Rainfall Analysis of the Bidi growing Region of Karnataka

The monthly distribution of rainfall in Bidi tobacco growing areas of Karnataka was analyzed and illustrated graphically (Fig. 6) by taking the percentage of total monthly rainfall against the years from 1990 to 2020. The maximum rainfall was observed in *June, July, August, September*, and *October* whereas lowest rainfall was observed in *January, February, and December*

The Mann-Kendall analysis (Z-test) detected a positive trend from *February to October* and negative during *November, December and January*. The magnitude of the negative trend was high in *January* while the positive trend was high in *September* and significant. (Table.2., Fig.7 & 8). The period of negative trend has coincided with the harvesting and hence the crop may not be affected significantly. However, high rainfall during the crop growth period causes a detrimental effect on crop growth. To mitigate the inundation proper drainage facility should be created through field channels to flush out excess water to avoid saturation at the root zone of the plant as this crop is extremely sensitive to poor aeration and anaerobic conditions.

Table 2: Rainfall trend and Slope estimates of regular rainfall (1980-2020) at Bidi tobacco growing centre Nipani, Karnataka.

Time series	First year	Last Year	Mean (mm)	Standard Deviation (n-1)	Z value for Mann-Kendall Trend (S)	Q (Estimate of Sen slope) (mm per year)	B (Constant)
JAN	1980	2020	2.5	6.9	-1.19	0.000	0.00
FEB	1980	2020	0.9	4.3	0.21	0.000	0.00
MAR	1980	2020	8.5	19.5	0.86	0.000	0.00
APR	1980	2020	24.4	25.6	0.54	0.116	15.87
MAY	1980	2020	43.7	31.6	0.35	0.125	34.80
JUN	1980	2020	141.2	78.7	0.66	0.836	117.22
JUL	1980	2020	205.4	105.6	1.80+	2.545	146.80
AUG	1980	2020	170.5	103.7	1.77+	1.832	106.29
SEP	1980	2020	105.1	62.2	2.28*	1.954	55.97
OCT	1980	2020	105.1	85.0	1.94+	1.927	44.04
NOV	1980	2020	20.3	26.3	-0.56	0.000	6.3
DEC	1980	2020	4.4	10.3	-0.25	0.000	0

Note: * Confidence interval for level of significance is at 99 %

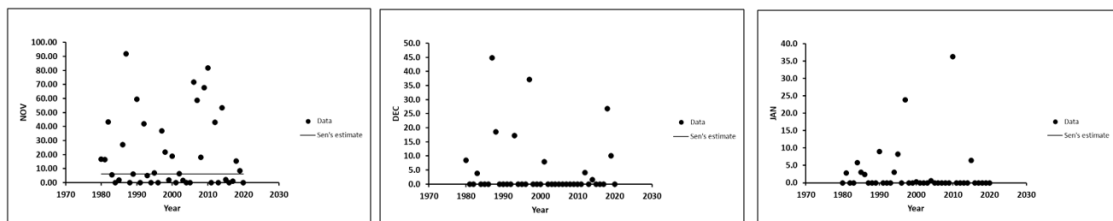


Fig 7: Rainfall (mm) trend of November, December, and January over 41 years at Bidi tobacco growing centre Nipani, Karnataka.

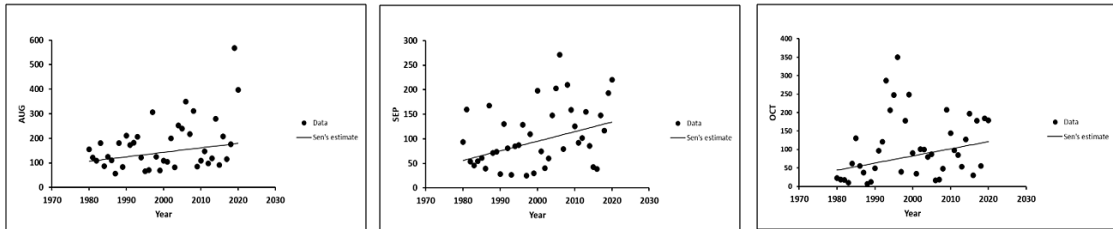


Fig 8: Rainfall (mm) trend of August, September, and October over 41 years at Bidi tobacco growing centre Nipani, Karnataka.

Rainfall Analysis of Bidi Growing Regions of Andhra Pradesh

The monthly distribution of rainfall in Bidi tobacco growing areas of Andhra Pradesh was observed and was depicted graphically (Fig.9) taking the

percentage of total monthly rainfall against the years from 1990 to 2020. The maximum rainfall was recorded in June, July, August, September and October whereas lowest rainfall was recorded in January, February, March and December.

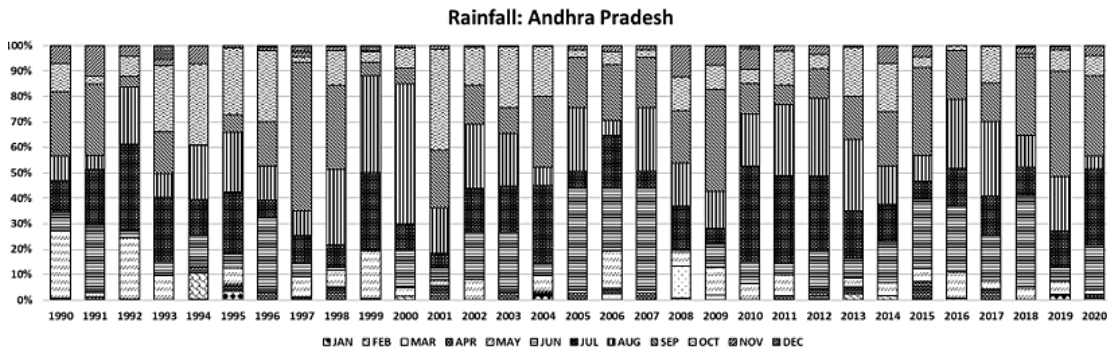


Fig. 9: Monthly distribution of rainfall in Bidi tobacco growing areas of Andhra Pradesh.

Table 3: Rainfall trend and Slope estimates of regular rainfall (1990-2020) at Bidi tobacco growing centre Nandyal, Andhra Pradesh

Time series	First year	Last Year	Mean (mm)	Standard Deviation (n-1)	Z value for Mann-Kendall Trend (S)	Q (Estimate of Sen slope) (mm per year)	B (Constant)
JAN	1990	2020	2.6	7.2	0.87	0.000	0.00
FEB	1990	2020	4.4	14.2	0.05	0.000	0.00
MAR	1990	2020	5.4	18.6	0.88	0.000	0.00
APR	1990	2020	15.9	18.6	-0.02	0.000	11.00
MAY	1990	2020	54.7	53.5	-1.29	-1.073	59.91
JUN	1990	2020	131.3	129.3	1.48	2.540	50.84
JUL	1990	2020	152.6	99.1	-0.10	-0.090	137.23
AUG	1990	2020	181.5	146.0	0.19	0.429	138.49
SEP	1990	2020	181.2	126.9	1.14	3.000	98.40
OCT	1990	2020	107.5	83.5	-1.33	-2.473	137.13
NOV	1990	2020	28.6	30.3	-0.76	-0.243	20.1
DEC	1990	2020	4.1	8.8	-0.41	0.000	0.8

Note: * Confidence interval for level of significance is at 99 %

The trend analysis of rainfall in *Bidi* tobacco growing Andhra Pradesh revealed that, the +ve trend was observed in January, February, March, June, August and September, whereas negative trends were recorded in *April, May, July, October, November and December*. The negative 'Z' values were very much high in October and November which coincided crop growth period. The negative trend in *July* will

coincide with *Bidi* tobacco nursery, however the magnitude was less. The positive trend in rainfall during June is high and the same can be utilized for nursery during July-August through proper moisture conservation measures. The negative trends in September and October, might significantly affect the crop growth as they coincided with crop growth (Table.03, Fig.10 and 11).

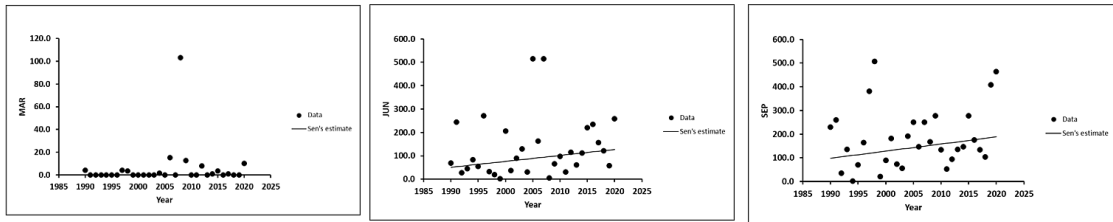


Fig 10: Rainfall (mm) trend of March, June, and September over 31 years at Bidi tobacco growing centre Nandyal, Andhra Pradesh.

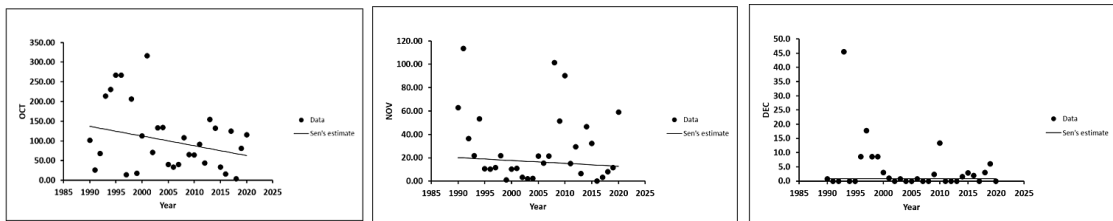


Fig 11: Rainfall (mm) trend of October, November, and December over 31years at Bidi tobacco growing centre Nandyal, Andhra Pradesh.

Effect of Rainfall Trends on *Bidi* Tobacco Nursery
 Nursery in *Bidi* tobacco is raised from July- August in Gujarat and Karnataka and July to September in Andhra Pradesh. A graph (Fig. 12, 13 and 14) was depicted by taking the average rainfall obtained during the nursery period of *Bidi* tobacco over the years (1990 to 2020). In Gujarat, a negative rainfall trend is noticed in July, whereas a positive rainfall trend is observed in August. Even though the extent of deviation is negligible in July, it suggests raising the nursery in the second fortnight of July. In Karnataka, the trend is positive in July and August. The extent of positive deviation is more in these months. They may fail of nurseries sometimes. Given this management interventions to mitigate the excess rainfall through protected nursery raising, provision to drain out excess moisture, raised seed beds, and mulches are to be followed invariably during nursery. In Andhra Pradesh, the trend is positive during August and September. However,

September month may witness excess rainfall as evidenced by a high 'S' value, which needs to be addressed through mitigation of excess moisture conditions.

Effect of Rainfall Trends on *Bidi* Tobacco Crop Growth

The active crop growth periods in *Bidi* tobacco are September-November in Gujarat and Karnataka and October to December in Andhra Pradesh. A graph (Fig. 15, 16 and 17) was depicted by taking the average rainfall obtained during the crop growth period of *Bidi* tobacco over the years (1990 to 2020). Among the three *Bidi* tobacco zones, the rainfall trend is positive during the crop growth period in Karnataka, it is inferred that, extent of deviation is extreme highly during August, September and October which results in crop failure occasionally. The soils being heavy, excess rainfall will cause inundation and affects root growth. Hence

contingency measures are to be prepared and kept ready for managing the excess water stress. In Gujarat, the active growth stage coincides with positive rainfall pattern except in October. However, the extent of deviation is negligible and is not going to affect crop growth. Among the three distinctive *Bidi* tobacco zones, *Bidi* tobacco in Andhra Pradesh experienced moisture stress during the crop growth

period. Hence moisture conservation/ drought mitigation strategies are to be followed to reduce the impact of the moisture stress. The extent of deviation is more during October and November, when the crop growth is between 40 to 70 days. Drought mitigation strategies viz., in-situ moisture conservation, mulching and, deep planting are to be followed for reducing the impact of stress.

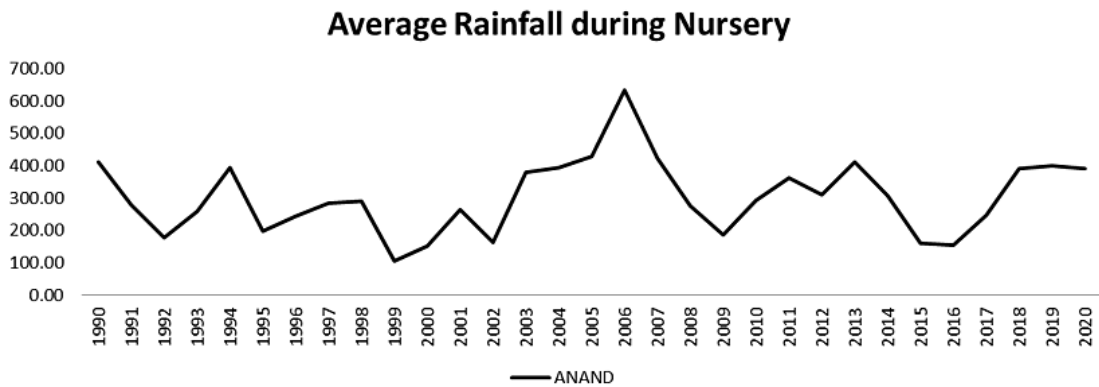


Fig. 12: Rainfall pattern during Bidi tobacco nursery in Gujarat (1990-2020)

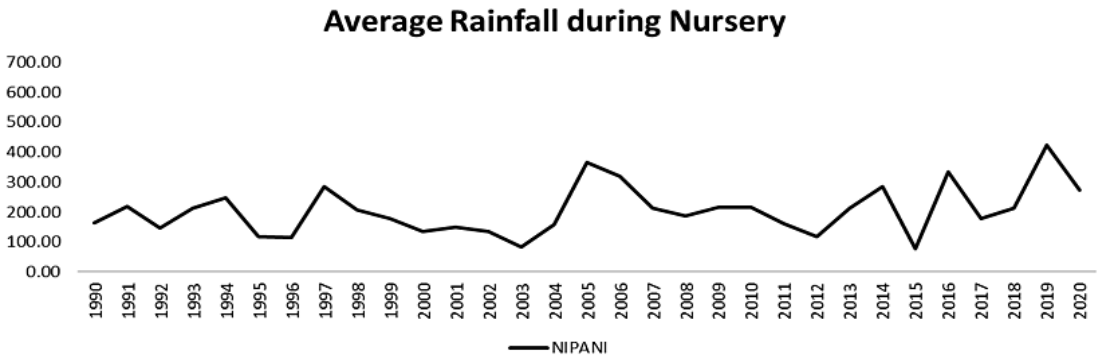


Fig. 13: Rainfall pattern during Bidi tobacco nursery in Karnataka (1990-2020)

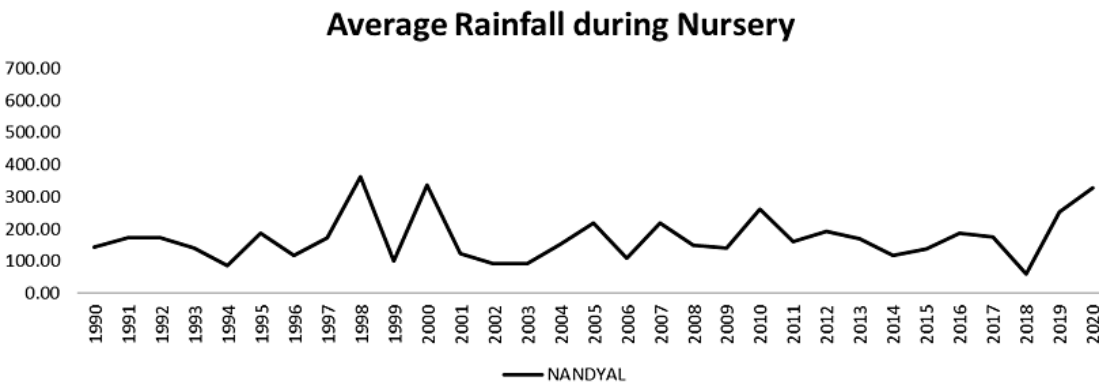


Fig. 14: Rainfall pattern during Bidi tobacco nursery in Andhra Pradesh (1990-2020)

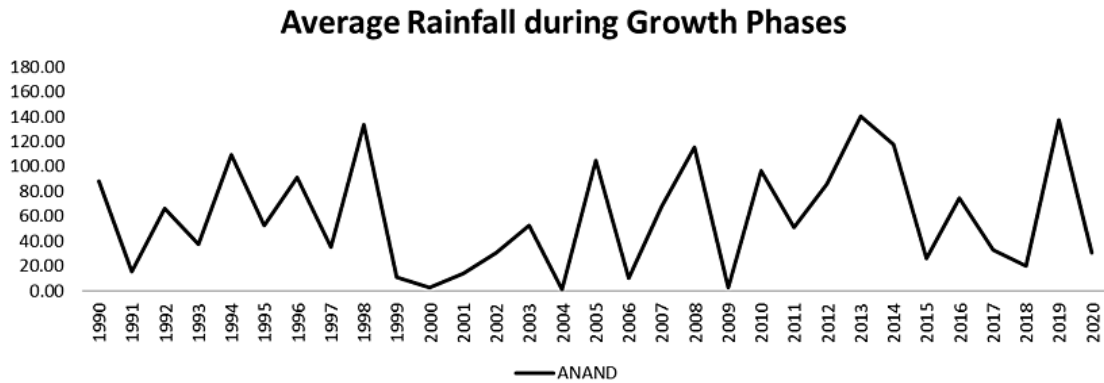


Fig. 15: Rainfall pattern of Bidi tobacco during crop growth at Gujarat

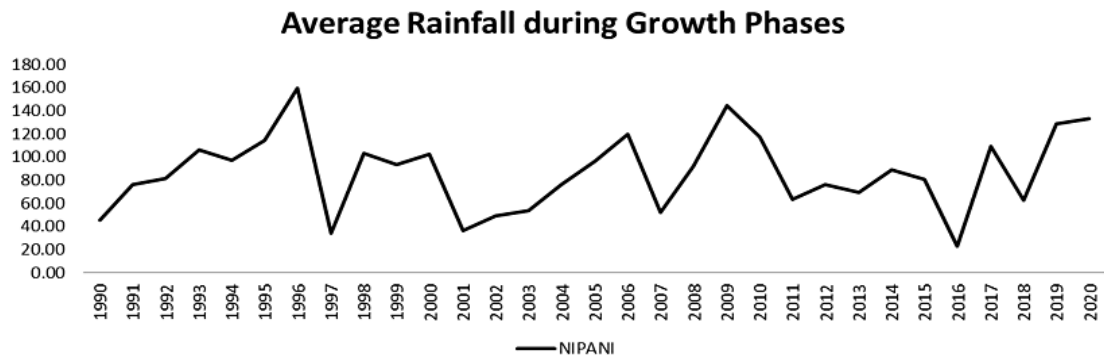


Fig. 16: Rainfall pattern of Bidi tobacco during crop growth at Karnataka

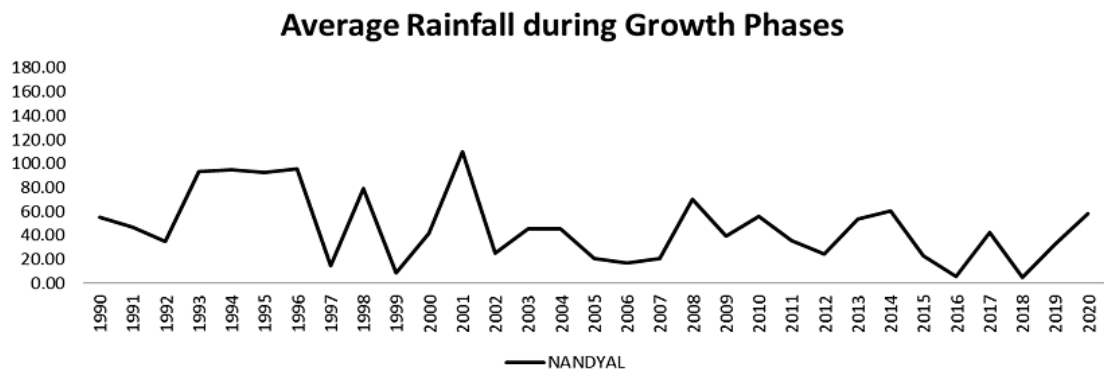


Fig. 17: Rainfall pattern of Bidi tobacco during crop growth at Andhra Pradesh

Conclusion

The study concludes that, among the three *Bidi* tobacco production zones, the rainfall trend in Gujarat is congenial to the *Bidi* crop. However, an excess rainfall trend in Karnataka, and a negative rainfall trend in Andhra Pradesh during nursery and main crop were detected.

The interventions i.e., improving field drainage for mitigating the effect of excess rainfall such as waterlogging leading to the prolonged saturated root zone and giving critical irrigation using stored rainwater in a farm pond to avoid moisture stress during the *Bidi* crop growth in Karnataka and Andhra

Pradesh respectively must be taken up by the *Bidi* growers to avoid the yield loss and poor leaf quality.

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Conflict of Interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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