MAUSAM, **65**, 2 (April 2014), 245-252

631.57 : 551.577.3 (540.25)

Impact of rainfall variability on fruit production in Jhalawar district of Rajasthan

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सार – इस अध्ययन का उद्देश्य राजस्थान के झालावाड़ जिले में वर्षा की परिवर्तनशीलता एवं इसकी प्रवृति का विश्लेषण करना तथा वर्षा की परिवर्तनशीलता के कारण फलों के उत्पादन को होने वाली हानि की जाँच करना है। फल की फसलों पर वर्षा की परिवर्तनशीलता की वजह से पड़ने वाले प्रभावों का व्यापक रूप से अध्ययन करने के लिए समयबद्ध श्रृंखलाओं का उपयोग किया गया है। यह पता चला है कि अन्त : वार्षिक और ऋतु निष्ठ विविधताएँ अध्ययन वाले क्षेत्र में फलों के उत्पादन में होने वाली घट बढ़ का प्रमुख कारण हैं। इस जिले में 218 मि.मी .के मानक विचलन और 24प्रतिशत के विचरण गुणांक के साथ 910 मि.मी .औसत वर्षा हुई। आँकड़ों (1973 – 2010) के विश्लेषण से यह पता चला है कि इस जिले में वार्षिक वर्षा की नकारात्मक प्रवृति (-0.23 से -17.41 मि.मी/.वर्ष) रही। संतरे के उत्पादन का मानसूनोत्तर वर्षा के साथ घनिष्ठ सहसंबंध देखा गया जबकि आम, अमरूद, नीबू, मौसंबी, पपीता, शरीफा और बेर के उत्पादन में इनका मानसून–पूर्व और दक्षिण पश्चिम मानसून ऋतु की वर्षा के साथ घनिष्ठ संबंध देखा गया है।

ABSTRACT. The objective of this study was to analyze the rainfall variability and trend, and examine vulnerability of fruits production to rainfall variability in Jhalawar district of Rajasthan. A time series data were used to carry out a comprehensive study of the effect of rainfall variability on fruit crops. It was observed that inter-annual and seasonal variabilities of rainfall were major cause of fluctuations in production of fruits in the study area. The district had 910 mm average rainfall with a standard deviation of 218 mm and coefficient of variation of 24 per cent. The annual rainfall as evident from analysis of data (1973-2010) showed negative trend (- 0.23 to - 17.41 mm/year) in the district. Productions of mandarin showed stronger correlations with the post-monsoon rainfall while those of mango, guava, lemon, mosambi, papaya, custard-apple and ber showed strong correlation with pre-monsoon and south-west monsoon rainfall.

Key words – Rainfall, Fruit production, Correlation and regression, Mann-Kendall test, Sen's slope.

1. Introduction

Fruit crops, may it be tropical or subtropical, are important components in overall ambit of agriculture. It is especially important for agriculturally dominant countries like India and China where 58.4% and 38.6% of the total population, respectively, is dependent on agriculture (Singh, 2012). Fruit crops being highly remunerative play important role in economy of growers. Mango, guava, lemon, mosambi and papaya constitute dominating stand in tropics and those custard-apple and ber in subtropics. In India, fruit crops cover 6.38 million hectares area and the production is 74.87 million tonnes which accounts for 29.25% of area and 31.13% of production of total horticultural crops. Rajasthan is the largest state of Indian Territory. Agriculture is followed over 165 lac hectares area in the state. However, only 51.1 thousand hectare area is under fruit crops with total production of 695.1 thousand tonnes and 13.6 t/ha productivity (Anon., 2012). Thus, the state contributes to 0.80% area and 0.01% production under national fruit production scenario. However, the production and productivity is no exemption from the impact of climate change. This is especially much more important in context to Rajasthan where horticulture relies heavily on rainfall. The state receives an annual normal rainfall of 530mm which seems sufficient for production, but their seasonal distribution influences a lot for successful production. The amount and temporal

Fig. 1. Location map of the study area

distribution of rainfall is generally the single most important determinant of inter-annual fluctuation in state as well as national crop production levels. A change in pattern of rainfall is being witnessed by many authors (Kumar *et al*., 2006; Pant and Hingane, 1988). Accordingly, different scientists have worked out the impact of climate change on production (Singh *et al*., 2009 for apple production, Haris *et al*., 2010 for rice production, etc).

Rainfall is one of the most important variables which affect the crop yield differently during various stages of its development. Indeed, statistical associations between rainfall and fruit production at sub-regional scales have not been studied in details. In present study the impact of rainfall variability on fruits production at annual and seasonal time scales for Jhalawar district of Rajasthan has been studied. The study would be useful in impact assessment of rainfall on various agri-horti ventures and on socio-economic technology at regional level.

2. Materials and methodology

The study pertains to Jhalawar district of Rajasthan, India. The district falls under humid south-eastern plain under Zone V of the Rajasthan with an area of about 6219 km^2 consisting of seven tehsils namely; Khanpur, Jhalarapatan, Aklera, Pachpahar, Pirawa, Manoharthana and Gangdhar (Fig. 1). It resembles English alphabet ‘S’ and lies between 23.45º and 24.52º N and between 75.27º and 76.56º E. Jhalawar district has the extensive fertile plain having rich black-cotton soil and is irrigated dominantly from Ahu and Kali Sindh rivers. Jhalawar district is known for the highest rainfall (910 mm) in Rajasthan. High rainfall along with rich soils provides adequate support to the agriculture in the district. The long-term mean annual rainfall of the district is 910 mm with a standard deviation of 218 mm and a coefficient of variation of 24%. The district experiences 38 mean number of rainy days with a standard deviation of 6 days and a coefficient of variation of 15.49%. The mean annual, monthly maximum and minimum relative humidity of the region are 69%, 88% (August) and 40% (April) respectively (Singh *et al*., 2012). Temperature varies according to altitude. The mean annual, monthly maximum and minimum temperatures in the district are 27.48 °C, 48.8 °C (May) and 5.5 °C (February), respectively.

The data used for the study were historical rainfall records and time series data on area coverage, production and yield of fruits. The rainfall data were collected from Water Resource Department, Government of Rajasthan, Sinchai Bhawan, Jaipur. Rainfall records were used for seven tehsils since 1973 to 2010. The horticultural statistics for the 2001-2010 decade were also collected from Directorate of Horticulture, Jhalawar.

Various methods of data analysis were employed in the study. Rainfall data were analyzed using Microsoft Office Excel 2007 and SPSS 16.0. Analysis of the rainfall data involved characterizing long-term mean values, and calculation of indices of variability and trends at monthly, seasonal and annual time scales. The coefficient of

TABLE 1

Annual and seasonal rainfall (mm), coefficient of variation and PCI during 1973-2010 in Jhalawar

Station	Annual		Winter		Pre- monsoon		SW Monsoon		Post- monsoon		PCI
	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	(%)
Khanpur	830.69	0.22	7.64	1.33	10.13	1.41	764.11	0.25	48.81	1.32	26
Jhalarapatan	915.83	0.34	11.06	1.77	13.74	1.13	838.82	0.35	52.21	1.40	26
Aklera	894.93	0.24	10.52	1.88	14.29	1.13	824.77	0.25	45.35	1.36	27
Pachpahar	868.14	0.29	7.65	1.57	13.10	1.38	784.58	0.30	62.81	1.23	25
Pirawa	1022.39	0.31	9.79	1.45	17.07	1.32	931.77	0.32	63.76	1.26	26
Manoharthana	988.55	0.31	12.15	2.08	15.46	1.32	905.31	0.32	55.63	1.68	26
Gangdhar	852.26	0.31	8.72	1.47	9.97	1.16	785.99	0.35	47.57	1.12	26

TABLE 2

Annual and seasonal rainfall trend during 1973-2010 in Jhalawar

Tehsil	Annual		Pre- monsoon		SW Monsoon		Post- monsoon		Winter	
	M-K test	Rainfall (mm/yr)	M-K test	Rainfall (mm/yr)	M-K test	Rainfall (mm/yr)	M-K test	Rainfall (mm/yr)	M-K test	Rainfall (mm/yr)
Khanpur	-0.075	-0.230	-0.569	0.000	0.075	0.150	-1.285	-0.303	0.000	0.000
Jhalarapatan	-1.132	-5.689	-0.790	0.038	-1.006	-4.907	-1.266	-0.445	0.117	0.000
Aklera	-2.213^{*}	-5.789	0.473	0.000	-1.748^{+}	-4.675	-2.111^{*}	-0.794	-0.812	0.000
Pachpahar	-1.509	-6.283	0.630	0.000	-1.559	-6.618	-1.842^{+}	-1.443	0.263	0.000
Pirawa	-3.709^{***}	-17.407	0.652	0.000	-3.118^{**}	-15.629	-2.713^{**}	-1.955	-0.138	0.000
Manoharthana	-2.225^{*}	-11.595	1.612	0.171	-2.125^{*}	-10.636	-1.325	-0.297	-0.263	0.000
Gangdhar	-1.559	-5.083	0.463	0.000	-1.220	-5.250	-1.545	-0.546	-0.135	0.000

$^{+}$Significant at 0.1 level, *Significant at 0.05 level, **Significant at 0.01 level, ***Significant at 0.001 level.

TABLE 3

Summary statistics of area (ha), production (q) and yield (q/ha) of fruits crops during 2001-2010 in Jhalawar

	Mandarin	Mango	Guava	Lemon	Mosambi	Papaya	Custard-apple	*Ber*
				Area				
Minimum	316322.7	14411.0	7893.6	2164.1	996.9	886.7	1006.0	1157.2
Maximum	2744807.0	45554.0	130910.0	21542.5	23744.0	15635.5	10060.0	13701.3
Mean	1114362.2	34617.5	29031.0	5901.0	4165.2	3956.5	2958.0	2891.5
CV (%)	71.5	25.9	127.4	100.7	168.5	124.4	122.9	135.0
				Production				
Minimum	4944.0	309.1	72.1	38.7	4.7	13.9	14.5	19.5
Maximum	8876.4	338.0	116.7	48.0	14.3	28.0	27.3	25.0
Mean	6995.5	322.4	95.0	42.2	9.6	19.9	25.4	22.4
CV (%)	20.8	3.0	19.3	6.5	28.8	24.9	15.3	8.5
				Yield				
Minimum	58.9	44.2	103.0	55.9	90.9	33.4	36.8	49.1
Maximum	345.1	145.4	1121.9	496.7	2442.8	1111.3	368.4	550.9
Mean	146.8	107.5	277.7	138.4	444.5	245.3	120.0	124.2
CV (%)	59.7	26.1	110.3	99.2	161.8	147.2	115.9	124.9

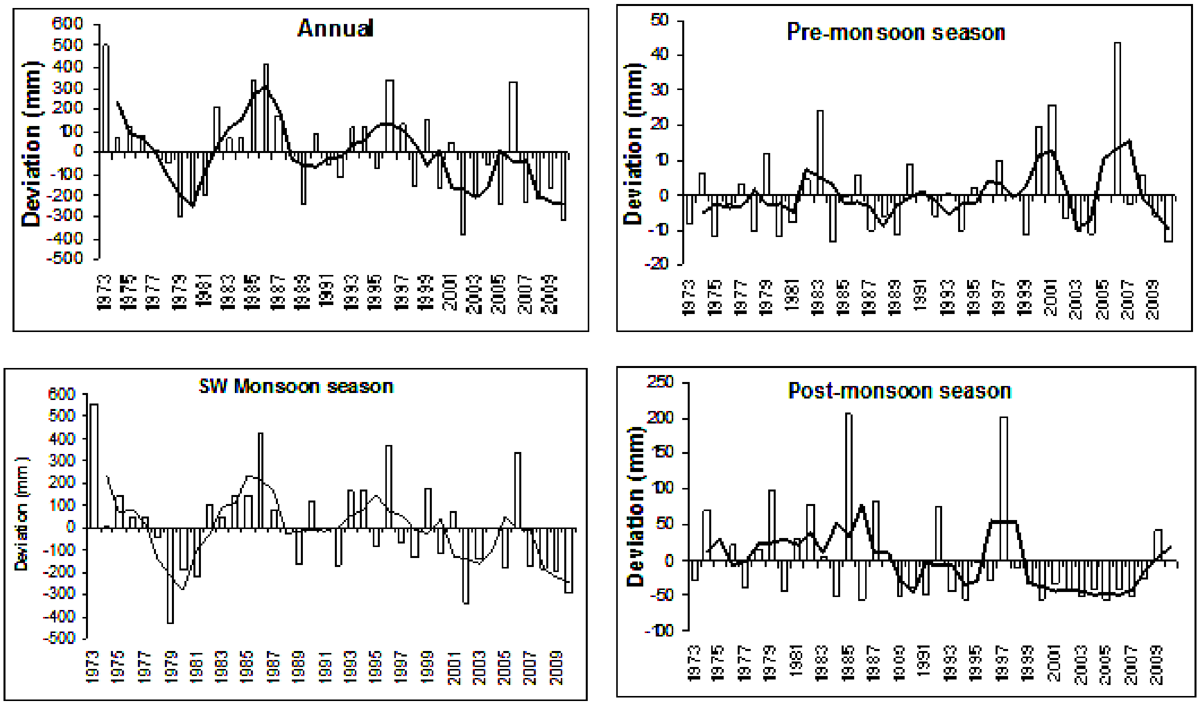

Fig. 2. Deviation of annual and seasonal rainfalls from long term averages (bold line 3-yrs moving average) in Jhalawar district

variation and the precipitation concentration index (PCI) were used as statistical descriptors of rainfall variability. The PCI values were calculated as per the method suggested by Oliver (1980) as under:

$$\mathrm{PCI} = 100 \times \frac{\sum_{i=1}^{12} P_i^2}{P^2} \quad (1)$$

where P_i is the rainfall amount of the *i*th month, and P = annual rainfall.

According to Oliver (1980), PCI values of less than 10 indicate uniform monthly distribution of rainfall, between 11 and 20 high concentration, and that of above 21 very high concentration. PCI is very useful to evaluate the degree of seasonal concentration of precipitation. The more concentrated is precipitation, the more difficult is water management, irrigation control, soil erosion prevention and the rainfed agriculture (Sahid and Khairulmaini, 2009).

The magnitude of the trend in the seasonal and annual series was determined using the Sen's estimator (Sen, 1968) and statistical significance of the trend in the time series was analysed using Mann-Kendall (MK) test (Mann, 1945; Kendall, 1975). Sen's slope method is a non-parametric approach frequently used for environmental data analysis because it is robust to missing data and outliers (Gilbert, 1987) and also gives a robust estimation of trend (Yue *et al*., 2002).

Standardized anomalies of rainfall were calculated and used to assess frequency and severity of droughts, as in Agnew and Chappel (1999):

$$A = \frac{(R_t - R_m)}{\sigma} \quad (2)$$

where, A = standardized rainfall anomaly, R_t= annual rainfall in year t; R_m= long-term mean annual rainfall, over a given period of observation; σ = standard deviation of rainfall over the period of observation. The drought severity classes are extreme drought ($A < -1.65$) at 95 percentile, severe drought ($-1.28 > A > -1.65$) at 90 percentile, moderate drought ($-0.84 > A > -1.28$) at 80 percentile, and no drought ($A > -0.84$) assuming that annual rainfall data are normally distributed.

The monthly rainfall series of all the tehsils were used to calculate an average rainfall for the district as per the formulae proposed by Nicholson (1985):

$$R_j = \frac{1}{I_j} \sum X_{ij} \quad (3)$$

TABLE 4

Correlation between fruit production and annual, seasonal and monthly rainfalls

Months	Mandarin	Mango	Guava	Lemon	Mosambi	Papaya	Custard-apple	*Ber*
January	-0.043	-0.880**	-0.345	-0.395	-0.338	-0.299	-0.432	-0.316
February	-0.477	0.261	-0.135	-0.230	-0.231	-0.349	-0.314	-0.254
March	-0.040	0.030	0.906**	0.862**	0.928**	0.768**	0.620	0.916**
April	0.683*	0.516	-0.184	0.178	-0.043	0.326	0.562	0.056
May	-0.358	0.331	0.494	0.422	0.351	0.214	0.206	0.340
June	0.072	0.684*	0.228	0.427	0.213	0.317	0.533	0.281
July	0.064	0.146	0.026	-0.013	0.006	-0.064	-0.104	-0.018
August	-0.488	-0.474	0.733*	0.620	0.629	0.458	0.352	0.644*
September	0.311	0.174	0.264	0.277	0.483	0.403	0.387	0.439
October	0.013	0.010	-0.07	-0.100	-0.093	-0.175	-0.213	-0.099
November	0.705*	-0.075	-0.317	-0.102	-0.175	0.210	0.098	-0.122
December	-0.203	-0.025	-0.189	-0.344	-0.123	-0.261	-0.200	-0.212
Winter	-0.507	-0.100	-0.282	-0.400	-0.378	-0.483	-0.502	-0.393
Pre-monsoon	-0.087	0.348	0.830**	0.844**	0.788**	0.690*	0.649*	0.797**
SW Monsoon	-0.284	-0.120	0.807**	0.737*	0.768**	0.576	0.506	0.770**
Post-monsoon	0.407	-0.036	-0.241	-0.146	-0.173	-0.019	-0.109	-0.151
Annual	-0.236	-0.092	0.807**	0.751*	0.773**	0.599	0.515	0.779**

* Significant at the 0.05 level, **Significant at the 0.01 level

where R_j is integrated rainfall for year j; X_{ij} is rainfall at station i for year j and I_j is the number of stations available for year j. Variability and trend in the rainfall were also examined using the same methods.

Correlation and regression analysis was used to examine relationships between monthly and seasonal rainfall and fruit production. The patterns of inter-annual rainfall variability and fluctuations in fruit production are also presented graphically to gain a better insight into rainfall-crop production relationships in the study area.

3. Results and discussion

The mean annual total rainfall in the district varies from slightly over 830 mm in Khanpur to more than 1020 mm in Pirawa (Table 1). Only one tehsil (Pirawa) had mean annual rainfall more than 1000 mm. Other six tehsils (Khanpur, Jhalarapatan, Aklera, Pachpahar, Manoharthana and Gangdhar) received less than 1000 mm of mean annual rainfall. Rainfall was found unimodal in most of the tehsils. Much of the rainfall was observed concentrated during the southwest (SW) monsoon season. The rainfall showed moderate inter-annual variability as expressed by the coefficients of variations (Table 1). Generally the winter (January–February), pre-monsoon (March–May) and post-monsoon (October–December) rainfalls were found much more variable than the SW Monsoon (June-September) rainfall. The contribution of SW Monsoon rainfall to the total annual rainfall was nearly 90% in all the tehsils in the district. Post-monsoon rainfall had about 5% to 7% contribution to the annual total in all the tehsils. The calculated PCI shows that rainfall in the district is generally having very high monthly concentration (PCI values more than 25%) in the study area. For the period 1973-2010, annual rainfall shows negative trend in all seven tehsils (Table 2). The significantly highest and lowest negative trends in annual rainfall were observed at Pirawa (17.41 mm/year) and Khanpur (0.23 mm/year) respectively. The deviations in the annual and seasonal rainfalls are shown in Fig. 2. The rainfall in the district is characterized by alternation of wet years and dry years in a periodic pattern. Of the 38 years of observations, 19 years (50%) recorded below the long-term average annual rainfall while 19 years above average. Most of the negative anomalies were observed

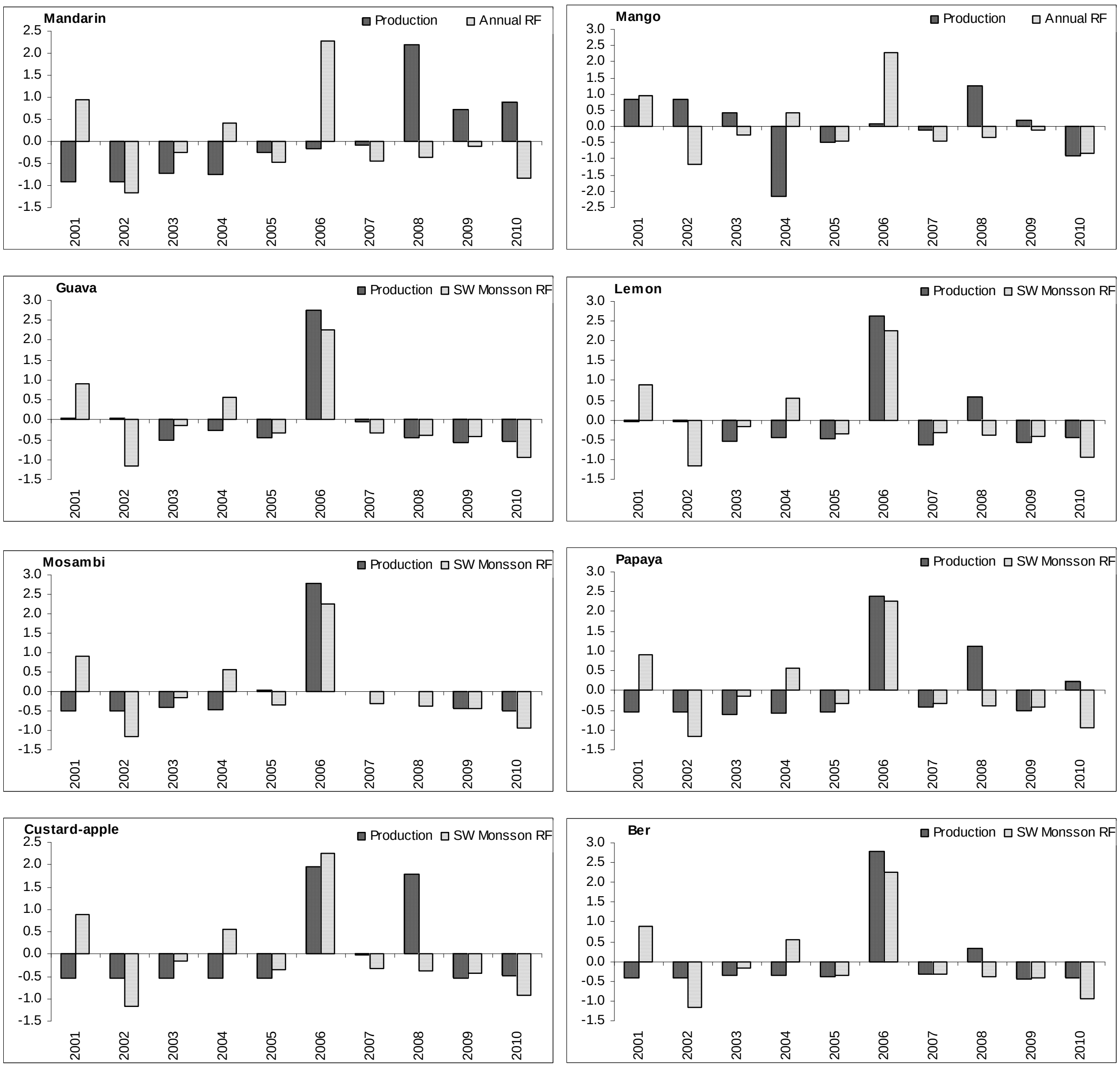

Fig. 3. Standard anomalies of fruits production and SW Monsoon and annual rainfall amounts in the Jhalawar district during 2001-2010

during 2000-10. Between 2002 and 2010, the annual rainfall has been below the long-term mean except the year 2006 when rainfall was above the mean. The lowest rainfall was recorded in 2002, showing the worst drought year. There were seven drought years during the period under study, *viz*; 1979, 1980, 1989, 2002, 2005, 2007 and 2010 accounting 18% of the total number of observations. In contrast, 1973, 1985, 1986, 1996 and 2006 were wet years, which represent 13 per cent of observations.

3.1. *Rainfall-production relationships*

The summary statistics on fruits production in the district for the period 2001-2010 has been presented in Table 3. Mandarin is the main fruit crop of the district in terms of area cultivated as well as total production obtained, followed by mango. In terms of yield, mosambi has the highest harvest. It exhibits the largest year-to-year variability in terms of area, production and yield as compared to the other fruit crops. This high inter-annual variability of yield appears to be due to inter-annual variability in rainfall.

Results of simple correlations among fruit production and monthly, seasonal and annual average rainfalls are presented in Table 4. The production of lemon, guava, mosambi and ber (jujube) showed significantly higher correlations with the pre-monsoon

TABLE 5

Multiple regression between fruit production and highly correlated monthly rainfalls

	Multiple regression model	F- test	R^2
1.	$Y_{\mathbf{Mandarin}} = 551247.6 + 90105.24X_4 + 29667.23\ X_{11}$	Significant	0.85
2.	$Y_{\mathbf{Mango}} = 38667.11 - 3242.43\ X_1 + 539.76\ X_4 - 1.24\ X_6$	Significant	0.88
3.	$Y_{\mathbf{Guava}} = 1304.23 + 2410.81\ X_3 + 63.02\ X_8$	Significant	0.91
4.	$Y_{\mathbf{Lemon}} = 2443.63 + 399.64\ X_3 + 5.10\ X_8$	Significant	0.78
5.	$Y_{\mathbf{Mosambi}} = 1199.12 + 568.53\ X_3 + 2.05\ X_8$	Significant	0.93
6.	$Y_{\mathbf{Papaya}} = 2337.48 + 330.18\ X_3$	Significant	0.59
7.	$Y_{\mathbf{C.apple}} = 1406.40 + 238.56\ X_3 + 629.37X_4 - 8.17X_6$	Significant	0.83
8.	$Y_{\mathbf{Ber}} = 527.15 + 280.43\ X_3 + 3.91X_8$	Significant	0.87

where X_1, X_3, X_4, X_6, X_8, and X_{11} are rainfall of January, March, April, June, August and November respectively.

and SW Monsoon rainfall while mandarin production showed a positive correlation with the post-monsoon rains. Lemon, guava and mosambi bears thrice in a year during February, July and October. Hence, in these crops pre-monsoon and SW Monsoon rainfall is highly contributory. In ber flowering through appears in September-October but the tree is pruned in May. After pruning rain (pre-monsoon) add in augmenting vegetative growth. The post-monsoon rain further favours its growth and the plant bears flower on new growth on conserved moisture with the cessation of post-monsoon rain. Thus, pre-monsoon and SW Monsoon showed high correlation with these fruit crops. In winter, it is natural phenomenon that the plant enters into dormancy. During winter whatever fruits remain on the tree, the plant nurtures them. However, the SW monsoon brings flush and vigour to the plant which is transformed ultimately to yield. In mandarin, new flush is related to emergence of flower bud which sets fruit and yield harvest. Hence, SW monsoon plays dominant role in fruit production. Annual rainfall had highly significant positive correlation with fruit production except mandarin and mango. At the monthly time scale, correlations between rainfalls of January-February and fruit production were found negative. In mango production, rainfall during February to June appeared to be particularly important. Fruits production showed high correlations with rainfall obtained during March except mandarin. In case of mandarin production, the rainfall received during April and November showed highly significant correlation. The production of guava and ber showed highly significant correlation with the rainfall received during March and August. Correlation between monthly rainfalls during March to September except July and the production of custard-apple appeared positively associated. The temporal distribution of rainfall at sub-monthly time scale had significant influence on production of fruit crops. Correlation coefficients among production and monthly and seasonal total rainfalls are, in other words, inadequate to capture the essence of impacts of rainfall variability on fruit production. In recognition to this, the general patterns of inter-annual rainfall variability and fluctuations in fruit production are presented graphically (Fig. 3) to gain a better insight into rainfall-production relationships in the district.

3.2. *Production-rainfall model*

The significant production of different fruits and dependence of these fruit crops on rainfall variability showed high correlation (Table 4). The rainfall of highly correlated months (> 0.500) was taken as an independent and production as dependent variables to develop multiple linear regression models (Table 5). In mango, rainfall during Jan-April-June had maximum variance of 88% (R^2 = 0.88) and it showed significant impact on mango production. Multiple regression model 2, strongly suggests that rainfall in the month of January and June had negative effect and that during April positive on the mango production. It may be explained in the light of the fact that during January flower primordial stage is over and there may be dilution of carbohydrate reserve leading to poor emergence of flower. However, with rainfall during June there may be excessive drop of even fully mature fruits of high weight and volume impacting total production drastically. It appears that rainfall during March and August accounts for 91% (R^2 = 0.91), 93% (R^2 = 0.93), 78% (R^2 = 0.78) and 87% (R^2 = 0.87) variation in productions of guava, mosambi, lemon and ber respectively (Table 5). The rainfall of April and November month impacted the mandarin production and accounts for 85% (R^2 = 0.85) variation, followed by papaya, in which the rainfall of March accounted 59%

(R^2 = 0.59) variation. Such type of influence of the rainfall during April and November on these crops might be due to its supportive role on growth. The production of custard-apple was found positively correlated with the rainfall of March and April and negatively on the rainfall of June which accounts for 85% (R^2 = 0.85) variation in production. In custard-apple March-April coincide with growth of fruit and the June with culmination of fruit growth. It is amplified from these studies that rainfall during some specific months had significant correlation with fruits production.

4. Conclusion

The findings of the study show that there are significant intra-regional differences in rainfall amount, variability and trend. Annual rainfall varied from about 830 mm in Khanpur to more than 1022 mm in the Pirawa tehsil of the district. The amount and variability of rainfall observed in Pirawa was higher than those of the Khanpur tehsil. Recovery of rainfall during the 1990s from the low values of the 1980s obscures decadal scale trends in annual and seasonal rainfall at some tehsils. Many tehsils show drier conditions in 2002 and 2010. Examination of trends in annual and seasonal rainfall generally shows absence of any systematic patterns of change across the district.

Inter-annual and seasonal variability of rainfall is a major cause of fluctuations in production of fruits in the district. Over the 2001-2010 decade, the influence of inter-annual variability in rainfall was reflected in the production of all the eight major fruits (mandarin, mango, guava, lemon, mosambi, papaya, custard-apple and ber) grown in the district. Productions of mandarin showed stronger correlations with the post-monsoon rainfall while those of mango, guava, lemon, mosambi, papaya, custard-apple and ber showed strong correlation with pre-monsoon and monsoon rainfall. With the variation in rainfall, the productions of the fruits showed statistically significant variations. It signifies that rainfall is the common yield-limiting factor in all the fruit crops. The fact that there are high correlations between fruit production and rainfall in the district indicates that farmers are vulnerable to food insecurity due to rainfall variability. Thus, there is a need for development of water resources including arrangement of rainwater harvesting at household level for high degree of ascertained fruit production.

Acknowledgements

The authors are grateful to the Department of Water Resource, Government of Rajasthan, Sinchai Bhawan, Jaipur and the Directorate of Horticulture, Jhalawar for making the data available for the study.

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