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# OCCURRENCE OF THUNDERSTORM AND RAINFALL OVER PUNJAB, PAKISTAN (1961-2010)

N. SADIQ

Institute of Space and Planetary Astrophysics, University of Karachi, Karachi, Pakistan

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Occurrence of Thunderstorms (TS) and Rainfalls (RF) are contemplated via monthly, station wise seasonal and overall seasonal percentage analyses for all over the Punjab. Fifty years (1961-2010) data of the mentioned parameters for thirteen meteorological stations, uniformly distributed over the province, were utilized in this study. Monthly study has revealed the highest activity of TS and RF in the two months of monsoon (July and August) while rainfall occurrence acquired second highest frequency in the end of winter (March). Overall seasonal analysis shows markedly high activity of TS and RF in premonsoon and monsoon season while in winter RF frequency is almost twofold than TF. Further, rainfall yield in post-monsoon and winter season is comparable but TS activity is highly variable. Station wise seasonal analysis of winter explore that all stations acquire much more RF accompanied with little TS activity. The situation is altogether different for premonsoon and monsoon, while for post-monsoon it is composite. The results of this paper will help to provide updated cogitative assistance not only to the people concerned with the science, art or business of cultivating the soil but also to the community concerned with weather, aviation and planning.

**Keywords**: Pakistan, Punjab, Thunderstorm frequency, Rainfall frequency, Percentage analysis

## 1. Introduction

Typical frequency of thunderstorms per hour is more than 1900 over earth. Studies of worldwide distribution of thunderstorm (TS) show that they are more frequent in tropics while highest frequency per year is observed in the northern hemisphere between 20-30$^{o}$ N. In the southern hemisphere these are frequent in equatorial regions and extends upto 20$^{o}$ S [1]. Severe thunderstorms comprise three-quarter inch hail and/or wind gusts of 50 knots. The storm is considered to be ended in 15 minutes after the last thunderclap heard. It is important to note that definition of TS does not include events of rainfall (RF); but measurable precipitation is commonly observed with TS. Hence these are considered as the major source of rain.

Downbursts are the common hazard associated with thunderstorms. These are localized downdrafts at the base of cumulonimbus (CB) clod that strike the ground and spread out horizontally. When the extent of the downburst is less than 4 kilometers, it is called microburst. Short lived heavy rain with gusts cause much damage at the surface and is a major hazard to aircraft. In fact, some of the worst commercial aircraft disasters have been related to landing in downbursts conditions.

The above mentioned parameters are important in respect of Pakistan in monsoon and premonsoon particularly and in winter and post-monsoon generally. In contrast to few outdated thunderstorm studies [2,3], present analyses comprise the update investigation of TS along RF activity over the province of Punjab. This work is the continuation of an initial study that has been carried out for the Khyber Pukhtunkhwa province [4].

The land of five rivers, Punjab is in the south of Khyber Pukhtunkhwa province and the federal capital Islamabad. It borders India to southeast, Sindh to the southwest and Azad Kashmir to northeast, while Balochistan and Federally Administered Tribal Areas (FATA) are located in the west. Excluding some hilly areas in the northwest and extreme southwest, the province is predominantly on plain level. There is also a deserted Cholistan belt in the southeastern part and a plateau adjacent to the mountains known as Potohar plateau. The province covers an area of 205,344 sq km [5] and lies almost in between the ranges of 69º to 76º and 29º to 34º longitudes and latitudes, respectively (Figure 1).

* Corresponding author : nsadiq@uok.edu.pk

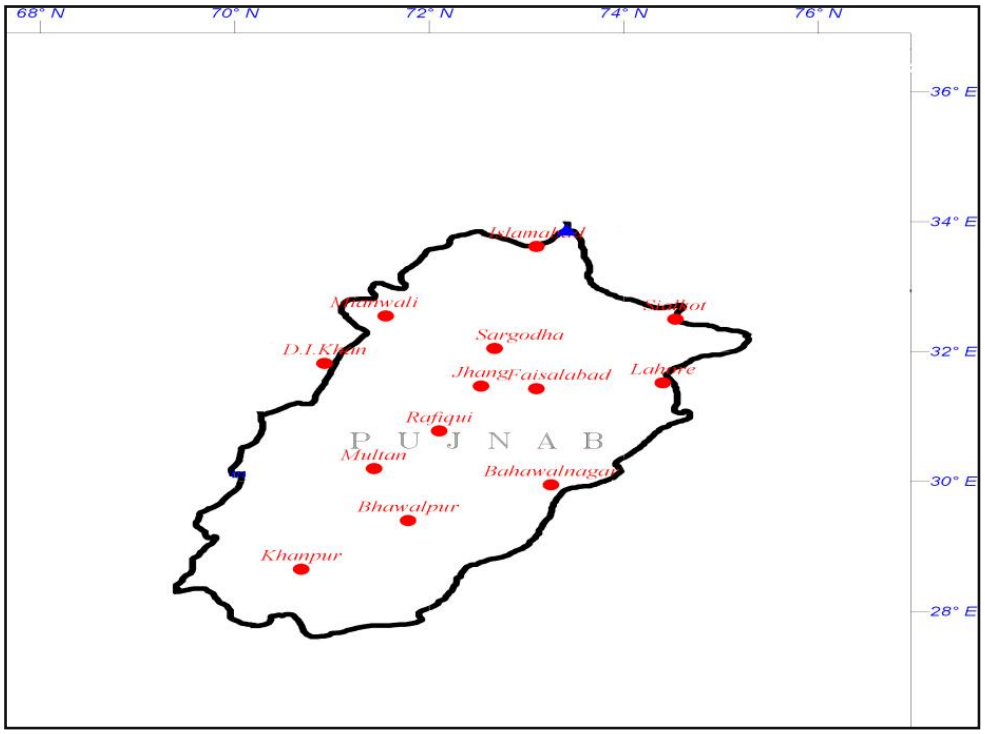


Figure 1. Meteorological Station network in Punjab

Most of the areas of this fertile province experience the climate of warm winters often accompanied with precipitation. Summer heat sets in after spring time until mid-April which leads the initial beginning of temperatures by mid-February. Onset of southwest monsoon is expected hopefully to reach in the end of May. In the month of August the atmospheric oppressive heat is accentuated by the rainy season but the severe part of the summer is over [6]. Cooler weather does not invade till late October. RF in the province is varied so highly and widely in all seasons, with much potential that loss of life and property is always vulnerable to this parameter.

The present study of TS and RF frequencies will be helpful to agriculturists weather forecasters and planners in the related fields of Punjab. Even though TS is the most common parameter to occur with RF but gusty winds, lightning and Pellets of frozen rain also have chance to be occur with. Hence, in this hazardous fortuity, civil and defense aviation, seasonal and annual crops, farming birds and animals may likely to be fall in an inappropriate character or identity. Therefore, outcomes and ensues of this study will also be provide assistance to disaster management cell and forecasters of the aviation to predict the close probability of such events in Punjab.

## 2. Data and Methodology

The data used in this study comprises TS and RF frequencies over thirteen meteorological observatories of Punjab for the last 50 years (1961-2010). The TS data comprises of all types of seasonal, orographic and convective thunderstorms. As the temporal resolution of data is 24 hours and hence not rivet on the exact time of occurrence, therefore according to defined criteria during any considered day any number of occurrences is considered as one.

Different calculations of statistical parameters viz: variance, standard deviation minimum, maximum, range and interquartile range are calculated to check the quality, variation, spreadness and suitability of data. As the employed statistical parameters suggest that data is appropriate for the study, therefore monthly totals, monthly mean and seasonal percentages of occurrence has been computed. For the analyses, seasons are cogitated as premonsoon (April to June); monsoon (July to September); post-monsoon (October and November) and winter (December to March) as suggested by Hussain et al. [7]. Moreover, analysis of seasonal percentages for each station is also carried out.

Table 1. Some characterized statistical and analytical values for TS and RF.

| Parameter | Variance | St. Dev. | Min | Max | Range | Q1 | Q3 | IQR | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|---|---|---|
| TS | 37.92 | 6.16 | 1.30 | 18.70 | 17.40 | 1.99 | 12.58 | 10.59 | 0.38 | -1.10 |
| RF | 19.28 | 4.39 | 2.45 | 16.61 | 14.16 | 4.29 | 10.22 | 5.93 | 0.62 | -0.04 |

## 3. Findings and Discussion

### *3.1 Annual TS and RF*

As a first step, before the analyses, the data quality is checked through the skewness. Both the parameters have very small skewness (i.e. less than one) as in Table 1, indicating that considered data is almost normally distributed. Further, kurtosis which shows the degree to which a data set is peaked, appear as slightly negligible negative value for RF and slightly greater than one for TS shows that distribution is little bit flatter than normal peak. Therefore, the data is found to be used for further analysis. The correlation coefficients (CC) are calculated to view the relationship between TS and RF. For the above two quantities the value of comes out as 0.905 with zero P-value, indicating that the quantities have very strong correlations in the Province. The situation is different from Khyber Pukhtunkhwa where only sufficient correlation (0.571) is found with P-value 0.052 [4]. The deviation of RF values from the standard is about half than the TS, which shows that nature of TS activity is more scattered than RF.

For estimation and nature determination of the spreadness and central tendency, the data is further divided into quartiles i.e. data is divided into four equal parts. First quartile (Q1) presents 25% of the data are less than or equal to 1.99 (for TS) and 4.29 (for RF). Similarly third quartile (Q3) presents the mentioned state of the data for 75% with the outcome values 12.58 and 10.22 for TS and RF, respectively. The interquartile range (IQR) is the distance between the first and third quartiles (Q3-Q1); thus it spans the middle 50% of the data. It certified the variation almost according to standard deviation and in the present study, IQR for TS (10.59) is almost double than RF (5.93).

The values of standard deviation, range and IQR indicates that understanding and prediction of TS activity require more precision than RF, as the TS activity is more varied than RF. Some important statistical parametric values including variance, standard deviation, minimum, maximum range and interquartile range are tabulated in Table 1. Q2 simply presents the median which has no such significance in this case, hence not included in the Table.

Total mean monthly annual percentage frequencies of TS and RF shows that peak thunderstorm activity (above 17%) appears in the months of Monsoon (July and August) in contrast to the end of post-monsoon (November) and start of the winter season (i.e. from December to January) when least (less than 2%) activity is found. Such a minimal activity may be due to the fact that this period is dominated by westerlies in Punjab region [8]. Monthly time series pattern of TS activity shows gradual rise from May to June and rapid mounting from June to July, then gradually decrease up to September after which the sudden fall is observed (Figure 2).

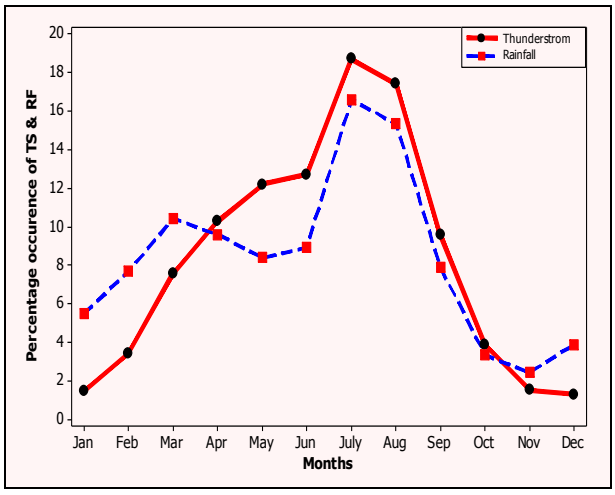


Figure 2. Annual percentages of TS and RF during 1961-2010 over Punjab.

During pre-monsoon, monsoon and at the beginning of pre-monsoon (i.e. from April to October) RF activity is less than TS while the situation is vice versa for the remaining months. It explores the maximum TS activity in these months, hence Thunderstorms in Punjab are found highly associated with the premonsoon and monsoon seasons. Unlike TS it has two peaks; RF activity starts rising after November (2.45% to 3.89% in December) and continuously follows the same trend through January (5.49) and February (7.67%) and reaches to its maximum value of 10.42% in March. It then starts decline and reaches to its second lowest value in May (8.39%). It then shoots up again and reaches to its second peak in July (16.61%) with close value in August (15.34%). Finally occurrence of RF starts decreasing and reaches to it minimum value in November. The percentage distributions of the both parameters are shown in Figures 3 and 4.

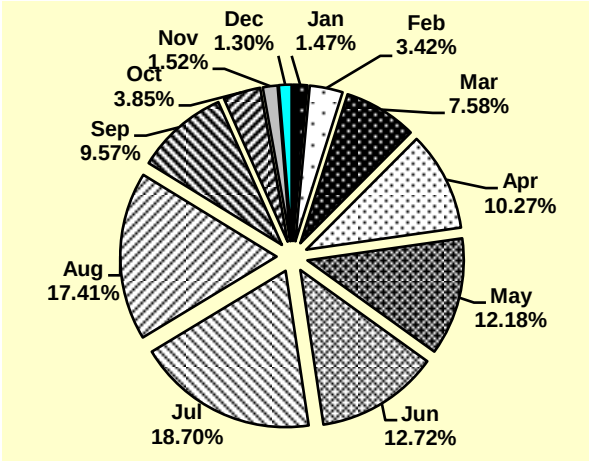


Figure 3. Annual %age of TS over Punjab 1961-2010).

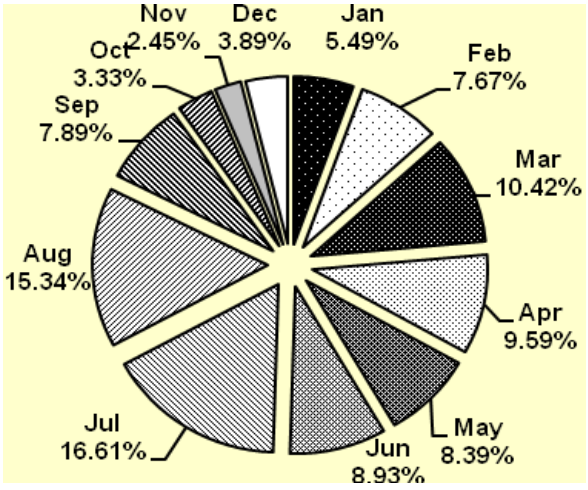


Figure 4. Annual %age of RF over Punjab (1961-2010).

### *3.2. Seasonal TS and RF (overall)*

The percentage of TS frequency appears to be higher than that of RF activity in the premonsoon and monsoon seasons whereas it is nearly equal in post monsoon seasons. RF activity is almost 13.7% higher and 5.85% lesser than the TS in winter and monsoon respectively (Figure 5). The percentage occurrence of RF in premonsoon, monsoon, post-monsoon, and winter seasons are 26.9, 39.84, 5.78 and 27.47% respectively, whereas the corresponding TS percentages are 35.17, 45.69, 5.37 and 13.77% respectively. From these percentages it appears that maximum TS activity observed in the monsoon season (45.7%) while RF maximum appears in monsoon (39.84%). The result is different from Khyber Pukhtunkhwa where maximum TS activity is found in monsoon but maximum rainfall activity is found in winter season [4].

Correlation Coefficients (CC) are also computed for all the seasons. Oftenness of RF and TS is sufficiently correlated in winter (0.56) and monsoon (0.51). Pre-monsoon shows the higher degree of sufficiently correlation with the value of 0.67 while strong correlation comes out for post-monsoon (0.87) season. Obviously, no specific trend in correlations was found.

Pre-monsoon and monsoon seasons appear as merging with the activity of TS. Further, it is also seen that in the pre-monsoon season the percentage of occurrence of TS is 35.17% and that of RF is 26.91%. The higher values of TS in this season as compared to RF may be explained in terms of RF association with certain TS, which is mainly due to the convection phenomena. Because the RF yield confined to given TS depends upon the moisture availability. In a few cases RF yield may not be available due to lack of moisture availability.

TS and RF percentage frequencies for monsoon season are observed to be nearly the same (i.e. 5.37 and 5.78%, respectively) while the percentage comparison of both parameters for pre-monsoon and post-monsoon seasons (i.e. 29.8 and 19.9%) suggests more RF in post-monsoon seasons due to RF. Possibly the more RF activity is mainly due to the western disturbances [9].

### *3.3. Seasonal TS and RF (station-wise)*

During the winter season TS activity is uniformly distributed over the province as all the meteorological observatories reported the activity

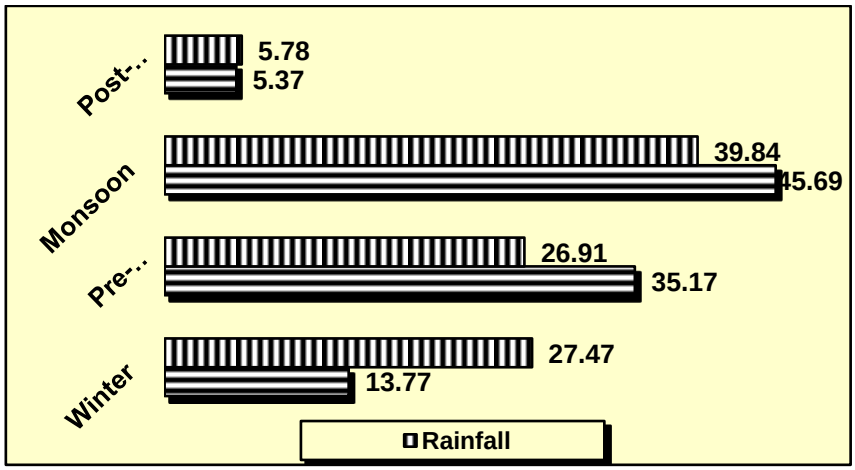


Figure 5. Seasonal percentage occurrence of TS and RF over Punjab (1961-2010).

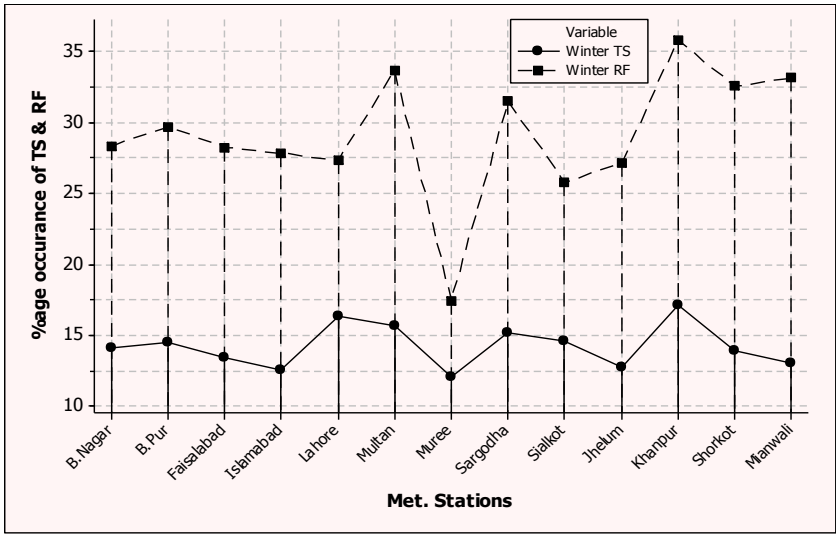


Figure 6. Percentage occurrence of TS and RF in winter over Punjab.

within the variation range of 5% only. This activity is not only less than pre-monsoon and monsoon seasons but throughout the season it is also less than rainfall activity for any reporting meteorological station (Figure 6). The range of rainfall occurrence is almost 3.7 times than the TS. Their least activities are observed in Murree where the frequency of both parameters in the city is very close such that occurrence of RF is just 5.37% greater. In contrast, most frequent occurrences are found in Khanpur where RF is more than twice active. Overall variation in rainfall is more than threefold as compared to thunder that describes the highly variant nature of rainfall frequency. Second and third highest TS activities are observed at Lahore (16.34%) and Multan (15.66%) with the corresponding RFs 27.30% and 33.68%, respectively.

In comparison to winter, TS activity is found greater than RF in pre-monsoon season for every recorded station. Further, higher TS activities are almost followed by highest RF activities (Figure 7). Multan got highest occurrence of TS (40.42%) with 29.49% RF while Bahawalpur appear with second (40.20%) highest RF along 26.52% TS activity. Noticeable lowest degree frequencies of the TS and RF in this season are occurred at Islamabad (31.38% with corresponding rainfall 25.68%) and Khanpur (23.71% with corresponding thunderstorm as 33.16%), respectively. For this season, percentage range of TS is about 33% more than RF.

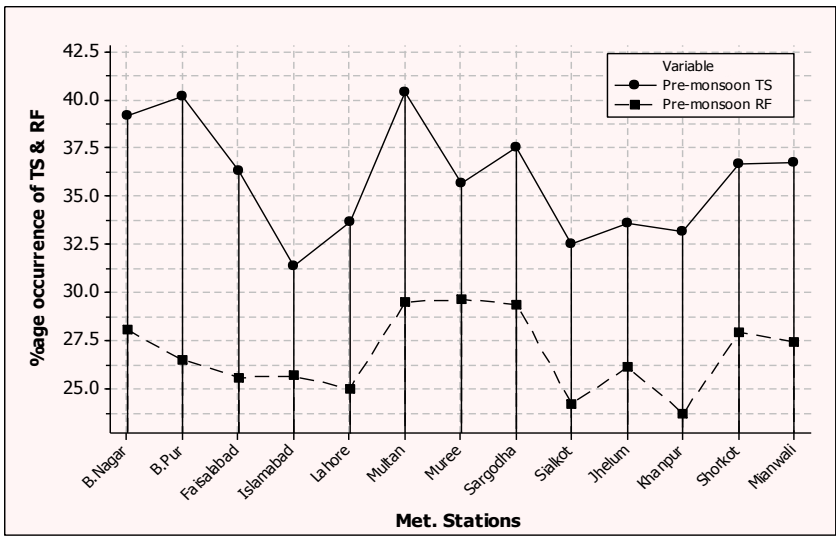


Figure 7. Percentage occurrence of TS and RF in premonsoon over Punjab.

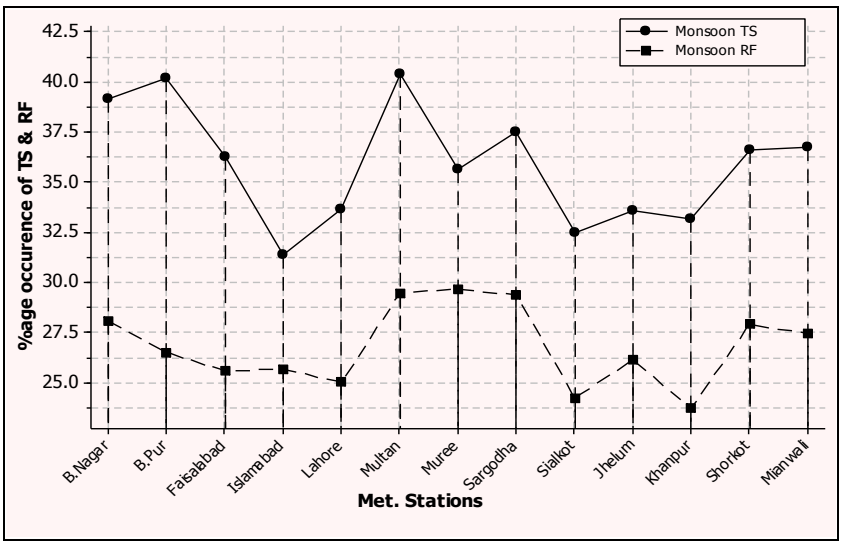


Figure 8. Percentage occurrence of TS and RF in monsoon over Punjab.

Figure 8 is the manifestation of monsoonal situation. Overall activities of both the variables are more than pre-monosoon seasons. Oftenness of thunderstorms are uniformly spread over all the reported stations with the outcome range of 9% (i.e. between 40.36% and 49.45), while range of rainfalls' is slightly stretched (13.74%) than former parameter (between 31.87% and 45.61). Islamabad acquires maximum TS activity (49.45%) with 39.57% RF while highest RF appears in Murree (45.61%) with 44.70% TS.

Among all the seasons, TS and RF are least active in post-monsoon seasons with very small (1.15%) range difference. It is evident from Figure 9 that highest frequencies of both the parameters are almost same (7.53% for TS and 7.28% for RF) for the same station (i.e. Murree). Minimum TS (3.31% for Khanpur) and RF (4.22% for Faisalabad) values are also closer to each other. The condition of this season is rather relatively complex; for Lahore and Murree RF occurrence is lesser (i.e. 5.10% and 7.28%) than TS (5.52% and 7.53%) while for rest of the stations TS activities are higher than RF. Some useful values regarding station-wise seasonal analysis are summarizes in Table 2.

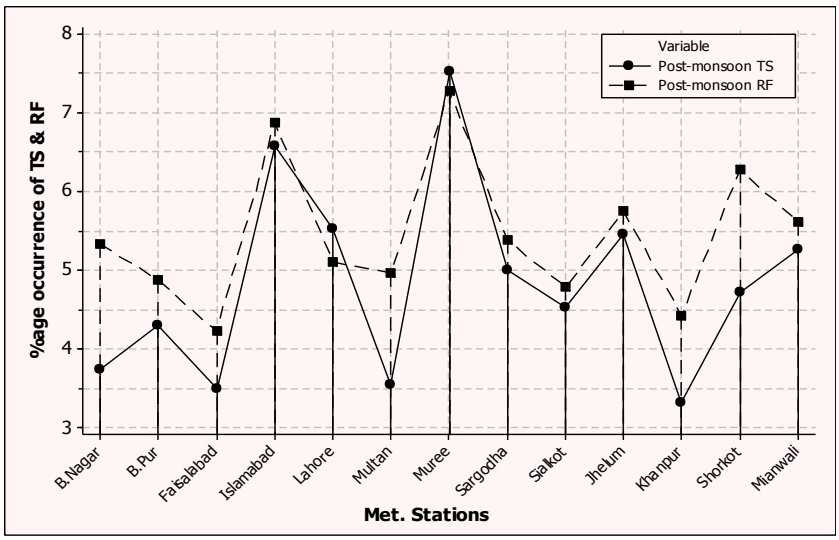


Figure 9. Percentage occurrence of TS and RF in post-monsoon over Punjab.

Table 2. Analytical percentage values for TS and RF frequencies.

| Parameter | Variance | St. Dev | Min. (Met. St.) | Max (Met. St.) | Range | Q1 | Q3 | IQR |
|---|---|---|---|---|---|---|---|---|
| Winter TS | 2.297 | 1.51 | 12.08 (Murree) | 17.08 (Khanpur) | 4.99 | 12.86 | 15.43 | 2.56 |
| Winter RF | 21.48 | 4.64 | 17.45 (Murree) | 35.86 (Khanpur) | 18.41 | 27.23 | 32.86 | 5.63 |
| Premon TS | 8.64 | 2.94 | 31.38 (Islamabad) | 40.42 (Multan) | 9.04 | 33.38 | 38.36 | 4.98 |
| Premon RF | 3.99 | 2.00 | 23.71 (Khanpur) | 29.66 (Murree) | 5.94 | 25.31 | 28.74 | 3.43 |
| Monsoon TS | 7.97 | 2.82 | 40.36 (Multan) | 49.45 (Islamabad) | 9.08 | 42.60 | 47.49 | 4.88 |
| Monsoon RF | 20.80 | 4.56 | 31.87 (Multan) | 45.61 (Murree) | 13.74 | 33.75 | 42.25 | 8.51 |
| Postmon TS | 1.56 | 1.25 | 3.31 (Khanpur) | 7.53 (Murree) | 4.21 | 3.64 | 5.49 | 1.84 |
| Postmon RF | 0.82 | 0.91 | 4.22 (Faisalabad) | 7.28 (Murree) | 3.06 | 4.83 | 6.01 | 1.18 |

## 4. Conclusion

Undermentioned are the conclusive outcomes of the analyses.

i. TS activity remains higher than RF during premonsoon, monsoon and upto start of post monsoon (i.e. April to October) and vice versa for rest of the year.

ii. Highest TS and RF activity is observed in monsoon while RF occurrence also have a second highest frequency at the end of winter

iii. TS activity in pre-monsoon and monsoon season is greater than RF while RF activity in winter is greater than premonsoon. Two peaks of RF are noticed.

iv. Seasonal percentage of occurrence of TS and RF shows that (a) in the monsoon season

both parameters show higher percentage of occurrence (b) rainfall activity associated with TS in the post–monsoon season is higher than that of the pre-monsoon season.

v. In winter, all the meteorological observatories/stations acquire considerably larger amount of RF than TS, except Murree. Overall percentages in pre-monsoon and monsoon seasons are higher than other seasons. The situation is different in pre-monsoon while in monsoon the situation is altogether different. Both the parameters are least frequent and acquire very close values in the post-monsoon season.

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