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THUNDERSTORM AND RAINFALL ACTIVITY OVER KHYBER PAKHTUNKHWA (KPK), PAKISTAN

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Fifty years (1961–2010) of thunderstorm (TS) and rainfall (RF) occurrence days for 11 available meteorological observatories of Khyber Pukhtunkhwa (KPK) spread over the province were used to obtain their monthly, overall seasonal and station wise seasonal percentages from all KPK totals. The monthly study has revealed two marked peaks of TS and RF while rainfall activity in end of winter and start of premonsoon is greater than in peak monsoonal months. Overall seasonal analyses of these two parameters suggest that rainfall yield associated with post-monsoon season, TS seems to be higher than the premonsoon season. Station wise seasonal analyses of winter indicate that all stations acquire much more RF accompanied with very little TS activity. The situation is altogether different during premonsoon and monsoon while in post-monsoon, the situation is rather complex. The present study will promote various components of TS and RF activity over KPK and will help the weather forecasters, aircraft pilots, agriculturists and planners in this respect.

Keywords: Thunderstorm, Rainfall, Annual, Seasonal

1. Introduction

More than 2000 thunderstorms (TS) take place every moment on the earth which is a major source of rainfall (RF) [1]. Accordingly about 45,000 TS occurs daily around the globe; 16 million TS per annum. Generally TS are spectacular and hazardous weather phenomena which mostly happen with RF [2]. Although it is estimated that TS produces beneficial rains with a few other positive effects but sometimes heavy rains create flash floods with associated cloud activity that may become a serious aviation hazard [3].

TS among RF may be accompanied with clusters of cumulonimbus clouds covering a wide area or it may be produced by a single cumulonimbus cloud and influence only a limited area [4]. By definition, it is not indispensable for RF to occur with TS but usually measurable precipitation happen with thunders [5]. Hence TS and related RF is of much significance and interest especially for premonsoon and monsoon seasons over plains of Pakistan. Although a couple of initial studies have been carried out in this respect [6,7] but these studies covered the period 1961-1990 and were confined to only TS activity. However, the present study comprises of an updated analysis of TS along RF activity.

The province Khyber Pukhtunkhwa (KPK) lies onwards to the plains of Punjab, Sind and beyond the Indus to South Asia. It is located in the north-west of the country. It borders Afghanistan to the north-west, Gilgit-Baltistan (GB) to the north-east, Kashmir to the east and Punjab to the south-east. The province covers the area of 74,521 km² [8] and lies in between the ranges of 69^o to 74^{o}E longitude and 31^o to 38^{o}W latitude (Figure 1).

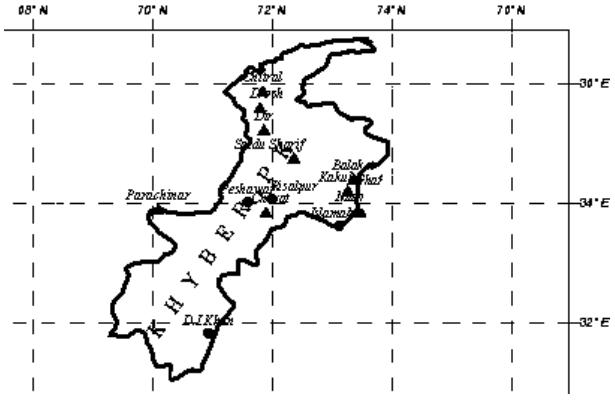

Figure 1. Meteorological Station network in Khyber Pukhtunkhwa.

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The climate of KPK varies immensely for a region of its size, most of the many climate types found in Pakistan as it varies in topography from dry rocky areas in the south to forests and green plains in the north. Geographically the province could be divided into two zones; the northern one extending from the ranges of the Hindu Kush to the borders of Peshawar basin, and the southern one extending from Peshawar to the Derajat basin. The northern zone is cold and snowy in winter with heavy rainfall and pleasant summer with the exception of Peshawar basin, which is hot in summer and cold in winter with moderate rainfall [9]. The southern zone is arid with hot summers and relatively cold winters and scanty rainfall. Despite these extremes in weather, agriculture remains important and viable in the area. RF varied so widely that some parts of KPK are typically dry, but on the other hand the province also contains the wettest parts of Pakistan in its eastern fringe.

The study of TS with RF occurrence may not only be accommodating planners in different fields to understand the climatology of these factors but also provide assistance to weather forecasters to predict these activities in studied areas of KPK. Although RF is considered as the most expected parameter to be occur with TS but hail, lightening and strong winds also have probability to be occur with. In this connection fortuity concerning aviation, crops, farming animals and birds may likely to pass off. Hence the consequences and upshots in this paper may also be helpful for farmers, agriculturists, disaster management authorities and for the aviation forecasters to predict the events occurring to avert any possibility of chance event in KPK.

2. Data and Methodology

TS and RF frequency data of 11 available meteorological observatories for 50 years (1961-2010) is used in this study from PMD archives. The TS data comprises of all types of thunderstorms including convective, orographic and seasonal. The study pore on daily basis data and hence not rivet on the precise time of occurrence, hence the criteria defined such that during 24 hours any number of occurrences is considered as one.

The quality, variation, spreadness and suitability of the data have been checked through different calculations of statistical parameters viz; variance, standard deviation minimums, maximums, range and interquartile ranges. After determination of the data appropriation for the study, monthly totals and monthly mean percentages of TS and RF occurrence has been computed. Moreover, seasonal percentage of occurrence of TS and RF are also calculated. For this purpose seasons are classified 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*. in 2005 [10]. Further analysis of seasonal percentages for each station is also carried out. The above described percentages are useful to understand the distribution of the above two parameters across the KPK.

3. Findings and Discussion

3.1. Annual TS & RF

To check the quality of data for further operations skewness values were computed. Both the parameters have very small skewness as indicated in Table 1, showing that the data is normally distributed. Further kurtosis which shows the degree to which a data set is peaked, appear with small negative values shows that both the distributions are little bit flatter than normal peak. Hence the data is found useful for further analysis. Then relationship between TS and RF is viewed through correlation. The correlation coefficient (CC) for above two quantities is 0.571. Although this value displays that the quantities are sufficiently correlated but not representing very strong correlation. It might be due to the ending winter and starting premonsoon RF activity which acquire higher peaks than monsoon accompanied with relatively less values of TS.

To evaluate the spreadness and central tendency, the data is 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 1.72 (for TS) and 5.39 (for RF). Similarly third quartile (Q3) presents the said condition for 75% with the values 13.42 and 11.52 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 i.e. IQR for TS (11.70) is almost double than RF (6.13).

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	39.27	6.27	0.58	17.08	16.50	1.72	13.42	11.70	0.01	-1.67
RF	9.88	3.14	3.61	12.91	9.30	5.39	11.52	6.13	0.06	-1.46

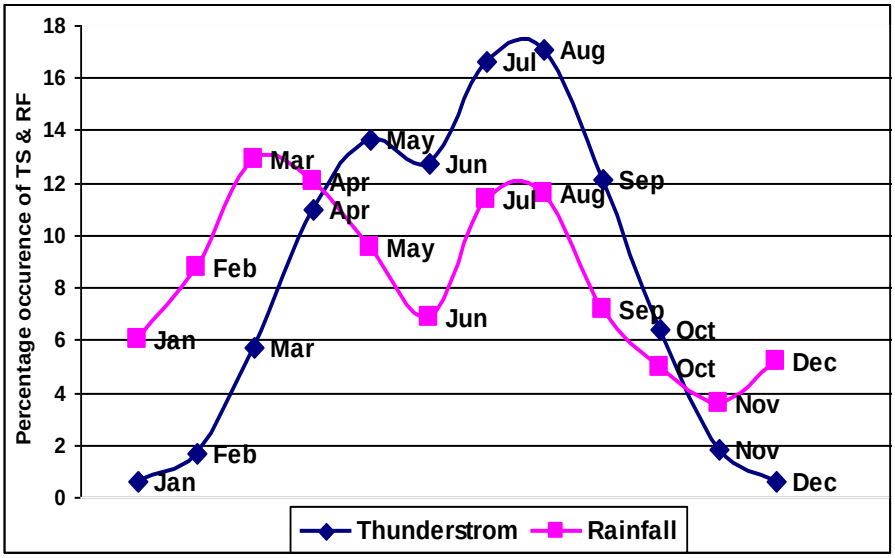

Figure 2. Annual percentages of TS and RF during 1961-2010 over KPK.

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

After going through the data quality and suitability, total mean monthly annual percentage frequency of TS and RF is computed. Two peaks appears expressing maximum TS activity in premonsoon in May (13.65%) and second one occur in monsoon i.e. August (17.08%) as shown in Figure 2. In contrast least activity comes out for winter months, December and January (~0.58%). The minimum activity may be due to the fact that this period is dominated by westerlies in KPK [11]. The pattern shows that TS activity starts rising from January and reaches to its utmost in May. Then it declined in June (12.72%) but soon rises in monsoon and again reaches it second peak (greater than first) in August. Then consistently the activity goes down till December. All the related percentages are illustrated in Figure 3.

From mid premonsoon to almost mid post-monsoon (i.e. from May to October) RF activity is less than TS and vice versa for remaining months (Figure 2). It explores the maximum TS activity in these months, hence TS in KPK are found highly associated with the monsoon season. Like TS it also has two maxims. RF activity start rising after November (3.61%) and continuously follow the same trend through December (5.18%) and reaches to its maximum value of 12.91% in March. It then starts decline and reaches to its second lowest value in June (6.88%). It then shoot up again and reaches to its second peak in August (11.58%) with very close value in July (11.36%). Finally occurrence of RF starts decreasing and reaches to its minimum value in November. All the percentages of RF are shown in Figure 4.

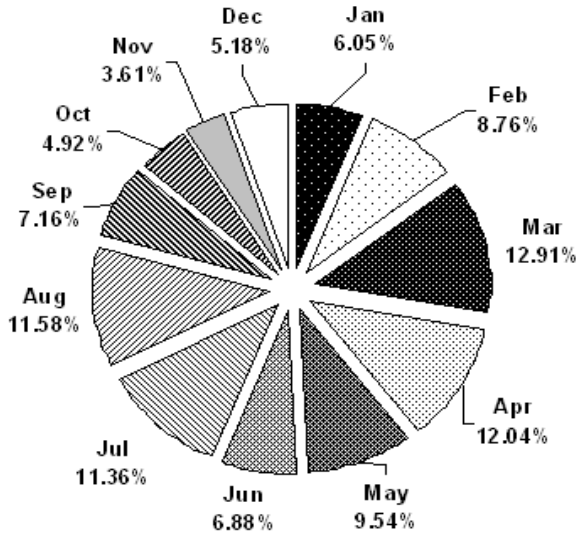

Figure 3. Annual %age of TS over KPK (1961-2010).

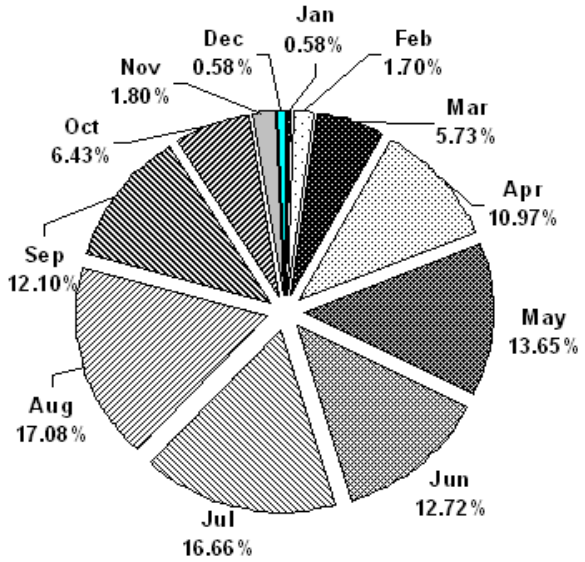

Figure 4. Annual %age of RF over KPK (1961- 2010).

3.2. Seasonal TS & RF (overall)

It appears that the percentage of occurrence of TS activity 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 24.3% higher and 15.7% lesser than the TS in winter and monsoon respectively (Figure 5). The percentage of occurrence of RF in premonsoon, monsoon, post-monsoon, and winter seasons is 28.5, 30.1, 8.5 and 32.9% respectively, whereas the corresponding TS percentage is 37.3, 45.8, 8.2 and 8.9% respectively. From these percentages it appears that maximum TS activity observed in the monsoon season (i.e. 45.8%) while RF maximum appears in winter (32.9%).

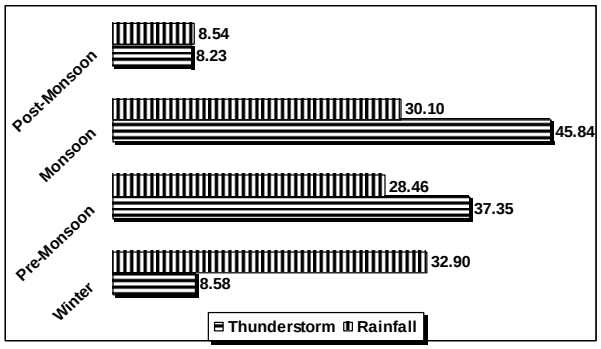

Figure 5. Seasonal percentage occurrence of TS & RF over KPK (1961-2010).

Computed seasonal Correlation Coefficients (CC) for all seasons comes out as 0.45. Concerning winter and premonsoon seasons, the correlation found is very strong (0.93) and highly negative (-0.63) respectively. It is to be noted that correlation is maximum (i.e. 1) for monsoon and post-monsoon seasons. The observed higher value of CC may be an outcome of the maximum TS and RF activity during and after the monsoon season. The negative value of CC for premonsoon is also to be noted as it is shoeing the contrast situation than winter.

These studies suggested that premonsoon and monsoon are associated with merging of thunderstorm activity. Further, it is also seen that in the premonsoon season the percentage of occurrence of TS is 37.3% and that of RF is 28.5%. These higher and lower values of TS and RF for this season can be explained as the RF associated with certain TS is mainly due to convection. Hence the RF yield confined to certain TS depends upon the availability of moisture and in some cases RF yield may not be available due to lack of moisture [12].

During the post-monsoon season, the percentage of occurrence of TS and RF activity is observed to be nearly the same (i.e. 8.4 and 8.5%, respectively). Percentage comparison of TS and RF between premonsoon and post-monsoon seasons (i.e. 29.1 and 19.9%) suggests that TS in post-monsoon seasons produces more rainfall. Possibly the more RF activity is mainly due to the western disturbances [13].

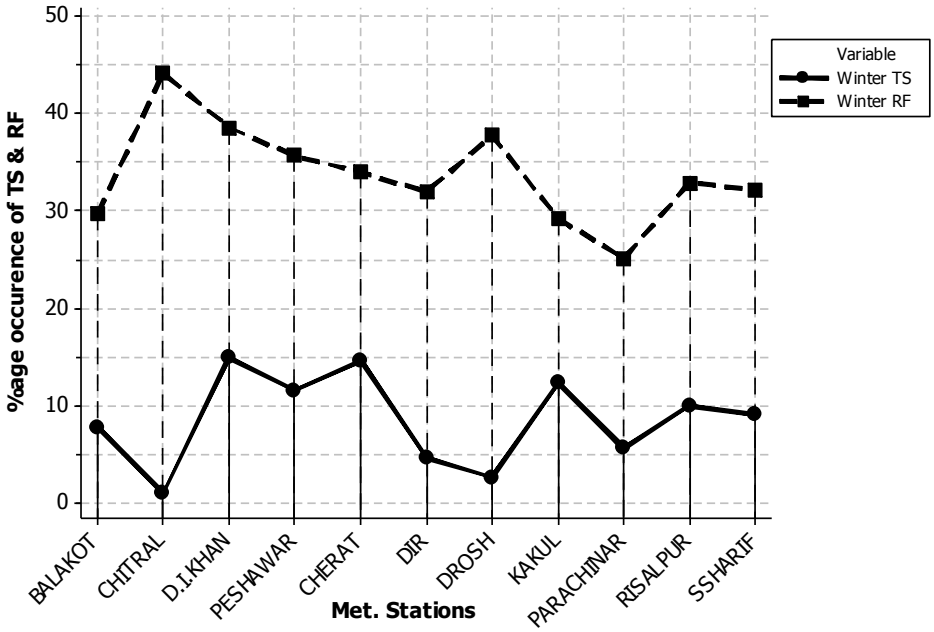

Figure 6. Station wise percentage occurrence of TS & RF in winter over KPK.

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	21.98	4.69	1.06 (Chitral)	15.00 (D.I. Khan)	13.94	4.68	12.37	7.69
Winter RF	26.90	5.19	25.10 (Parachinar)	44.15 (Chitral)	19.05	29.69	37.74	8.05
Pre-mon. TS	22.29	4.72	31.32 (Cherat)	47.54 (Chitral)	16.22	34.19	40.64	6.46
Pre-mon. RF	8.93	2.99	24.52 (Cherat)	33.00 (Drosh)	8.48	26.27	31.07	4.80
Monsoon TS	6.77	2.60	42.10 (D.I. Khan)	51.01 (Risalpur)	8.91	43.31	47.20	3.89
Monsoon RF	60.75	7.79	12.66 (Chitral)	37.22 (Kakul)	24.56	26.25	34.81	8.56
Post-mon. TS	1.88	1.37	4.91 (D.I. Khan)	9.721 (Chitral)	4.81	7.59	9.14	1.55
Post-mon. RF	4.20	2.05	5.43 (D.I. Khan)	12.11 (Parachinar)	6.68	7.049	9.49	2.44

3.3. Seasonal TS & RF (station wise)

Overall TS activity in winter is not only less than any other season but it is also less than RF for any reporting meteorological station (Figure 6). Chitral showing the extreme opposite recorded situation where RF activity is more than 41 times higher than TS. It appears with highest RF (44.15%) and lowest TS (1.06%) throughout the winter. The second opposite situation observed in Drosh where RF occurrence (37.73%) is found more than 14 times higher than second last TS activity (2.67%). The minimal rainfall occurs at Parachinar (25.10%) with the corresponding TS (5.65%). Maximum TS occur at D.I. Khan (14.99%) with RF (38.57%) while it is very close to Cherat which acquires 14.65% TS activity with RF (33.95%). Percentage range of TS is 1.3 times lesser than RF (Table 2).

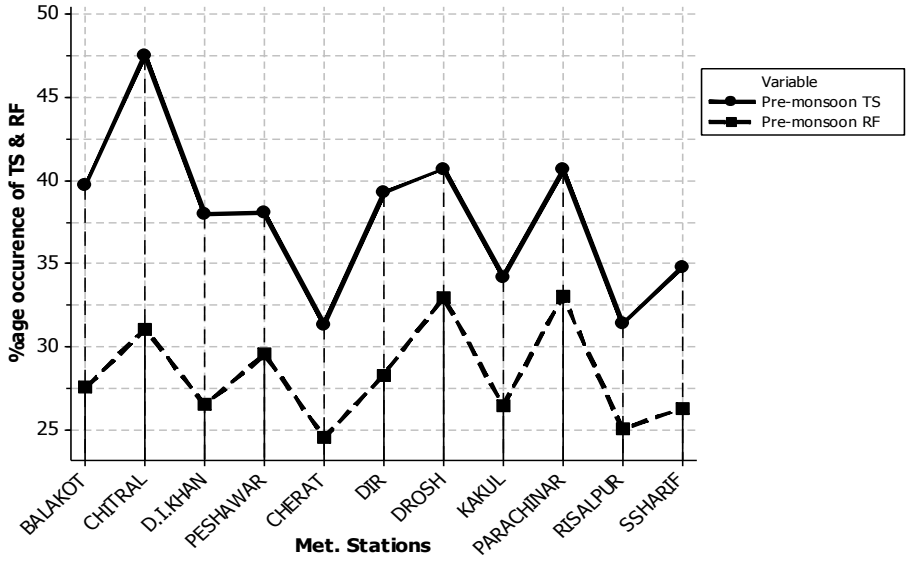

Figure 7. Station wise percentage occurrence of TS & RF in premonsoon over KPK.

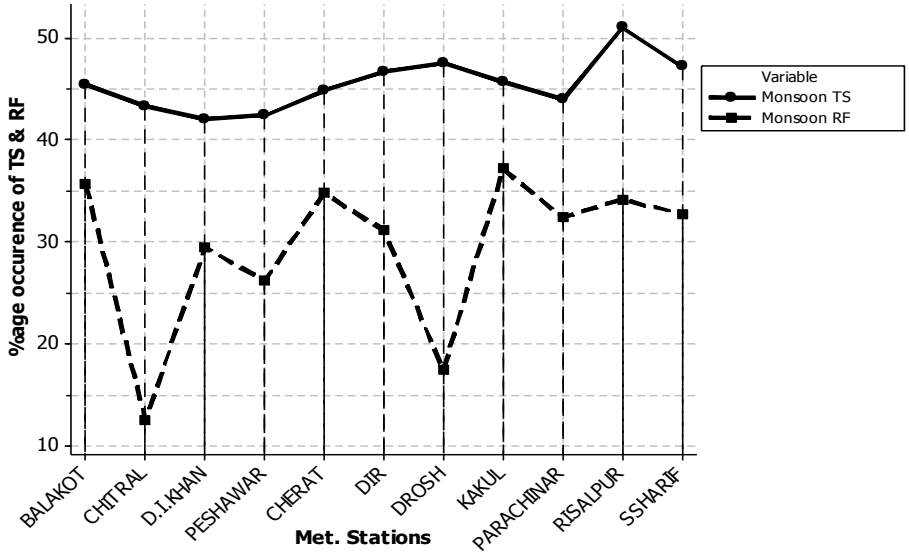

Figure 8. Station wise percentage occurrence of TS & RF in monsoon over KPK.

In comparison to winter, throughout TS activity is found greater than RF in premonsoon season for every recorded station. Further higher TS activities are almost followed by highest RF activities (Figure 7). Chitral got highest occurrence of TS (47.54%) with 31.07% RF while Drosh appear with second (32.94%) highest RF along 40.69% TS activity. Fewest TS and RF occurred in Cherat with 31.32% and 24.52% respectively. For this season, percentage range of TS is almost double than RF.

The condition of monsoon season is demonstrated in Figure 8. Overall both TS and RF activity is more than premonsoon season. TS activity has been spread uniformly over all stations with the outcome values between 42 to 52%. The situation regarding RF is in contrast and vary roughly in between 12 to 38% Risalpur acquire maximum TS activity (51.01%) with 34.18% RF while highest RF appears in Kakul (37.22%) with 45.74% TS. 12.66% RF is noted for Chitral as minimum rainfall (12.66%) station with relatively very high thunder activity (43.30%). It is noticeable that TS range (8.48) is almost one third of RF range (24.56).

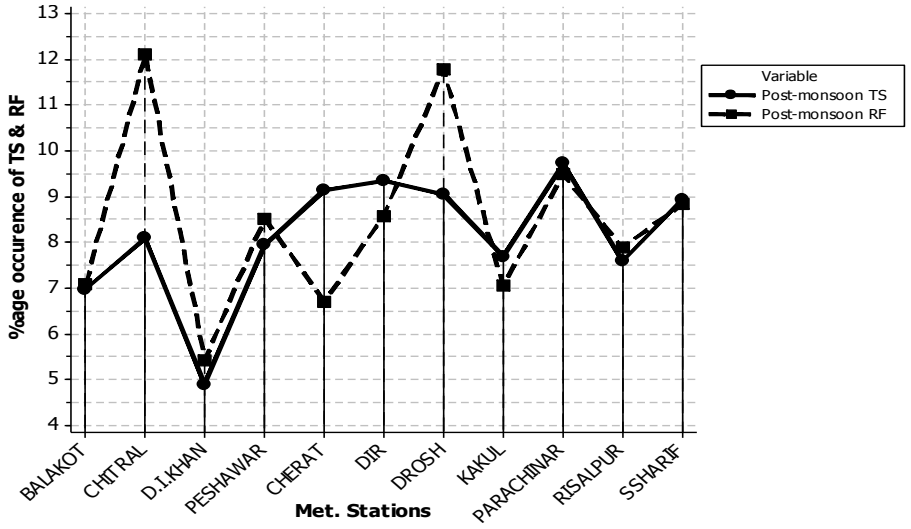

Figure 9: Station wise percentage occurrence of TS & RF in post-monsoon over KPK.

The condition of post-monsoon season is rather complex. (Figure 8). Out of eleven, there are six stations where the RF activity is greater than TS while the situation is vice versa for remaining four stations. Highest RF is recorded for Chitral 12.11% with 8.09% TS. Minimum RF appear for D.I. Khan 5.43% with 4.09% TS. It is also interesting that TS and RF ranges for this season are much closer (4.81 and 6.68) than any other season. Some useful values regarding station wise seasonal analysis are tabulated in Table 2.

4. Conclusion

After quality and suitability checkout, fifty years (1961-2010) data of TS and RF for 11 observatories of KPK analyzed on monthly, overall seasonal and station wise seasonal basis. Following are conclusive outcomes of this study.

i. RF activity in winter is greater than in monsoon while the highest TS activity occur in monsoon.

ii. 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 premonsoon season.

iii. In winter all meteorological observatories/ station acquire considerably larger amount of RF than TS. Contrast situation is observed in premonsoon while more contrast in Monsoon. The situation of post-monsoon is hybrid.

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