A NOTE ON THE INFLUENCE OF LUNAR PHASE ON THE RAINFALL IN THE MONTH OF JULY IN CALCUTTA, 1878-1924.

By P. C. MAHALANOBIS.

Introduction.

In Bengal it is popularly believed that rainfall increases on certain particular *tithis* (lunar days) such as the eleventh, the new moon (*amāvasyā*) or the full moon (*purnimā*). In 1925 when I was in charge of the Calcutta Meteorological office I made a preliminary study of the variation of rainfall during the first thirty days of July and found that the rainfall in the *Krsna* (dark) phase was significantly greater. I had however postponed publication of the results as I was hoping to be able to make a more complete investigation. As the opportunity for such fuller investigation did not occur for a long time, I sent a short note to Physics and Mathematics Section of the Indian Science Congress in 1936. At that time the note was based on the 47 years 1878-1924. In the course of the discussion in the Science Congress it was suggested that the metonic cycle might be a relevant factor. The analysis has been now conducted for two metonic cycles covered by the period, and all the results are published in the hope that the question would be investigated more fully by others.

Nature of the Material.

With the help of old Bengali almanacs the actual periods or *tithis* (lunar days) for the first thirty days of July for each year were charted. The actual rainfall during each lunar period was then obtained from the continuous record of rainfall at the Alipore Observatory.[1]

As the duration in hours of the different lunar days was different, the actual rainfall during any particular lunar period was divided by actual duration, so that the intensity of rainfall in inches per hour was obtained in each case. This formed the primary material for the present note. The mean intensities of rainfall on different lunar days in the two phases are shown in Table 1.

Table 1. Intensity of Rainfall on Different Lunar Days in Calcutta, July 1878—1924.

Lunar Day (*Tithi*)		Bright Phase (*Sukla*)		Dark Phase (*Krsna*)		Combined	
		Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Pratipad	(1)	0·3215	0·8727	0·4602	0·7850	0·7817	0·6145
Dvitiya	(2)	0·2277	0·4760	0·8768	0·6559	0·6045	0·5781
Tritiya	(3)	0·3094	0·5111	0·8400	0·4612	0·6494	0·4868
Chaturthi	(4)	0·8996	0·9355	0·4123	0·5676	0·8119	0·7787
Panchami	(5)	0·1849	0·2759	0·4959	1·1065	0·6808	0·8064
Sasthi	(6)	0·4506	0·0162	0·8404	0·4409	0·7910	0·7190
Saptami	(7)	0·4798	0·7527	0·4870	0·7500	0·9168	0·7513
Astami	(8)	0·2006	0·3262	0·4588	0·8266	0·6544	0·6284
Navami	(9)	0·8589	0·8885	0·6245	0·9421	0·9834	0·9132
Dasami	(10)	0·2847	0·4820	0·5681	1·2188	0·8528	0·9110
Ekadasi	(11)	0·3970	0·8754	0·4668	0·9629	0·8638	0·9202
Dvadasi	(12)	0·4315	0·6863	0·6109	0·9665	1·0424	0·8382
Trayodasi	(13)	0·3482	0·4431	0·4864	0·6997	0·8296	0·5856
Chaturdasi	(14)	0·8177	0·4098	0·8559	0·5707	0·6786	0·4968
Purnima or Amavasya	(15)	0·8726	0·5024	0·8589	0·4645	0·7815	0·4838

[1] The Alipore Observatory (Calcutta) is a first class observatory and in 1925 was the headquarters of the Instrument Section of the Indian Meteorological Department. The records at the Alipore Observatory are believed to be quite reliable.

Calculations were made separately for each phase as well as for both phases taken together. It will be noticed that differences between lunar days or between years were quite insignificant, but the difference between the two lunar phases was very definitely significant.

The analysis of variance for each phase and for the whole period is given in Table 2.

TABLE 2. ANALYSIS OF VARIANCE : RAINFALL IN JULY, 1878-1924.

Factor of Variation	Degrees of Freedom	Sum of Squares	Mean Square	Ratio of Variance Observed	Ratio of Variance Expected 1%
	Both Phases.				
Year	46	0·0434	0·00094	0·96	1·41
Lunar Phase	1	0·0084	0·00840	8·57	6·62
Lunar days (*Tithis*)	14	0·0123	0·00088	0·90	2·07
Lunar days (*Tithis*) × Phases	14	0·0094	0·00067	0·68	2·07
Residual	1334	1·3092	0·00098		
Total	1409	1·3827			
	Bright Phase (*Sukla*)				
Year	46	0 0423	0·00092		
Lunar days (*Tithis*)	14	0·0095	0·00068	0·21	1·46
Residual	644	0·4911	0·00076	0·89	2·11
Total	704	0·5429			
	Dark Phase (*Krsna*)				
Year	46	0·0617	0·00134	1·11	1·46
Lunar days (*Tithis*)	14	0·0122	0·00087	0·07	2·11
Residual	644	0·7531	0·01170		
Total	704	0·8270			

The differences between years or lunar days again come out quite insignificant in both cases. We conclude therefore that the rainfall on different lunar days (or in different years) in July in Calcutta during the period 1878-1924 were on an average nearly the same. The influence of lunar day on rainfall, if any, is too small to be detected on the basis of the present material.

The actual mean rainfalls in the two phases in each year are shown in Table 3.

TABLE 3. TOTAL MONTHLY RAINFALL IN THE TWO LUNAR PHASES IN INCHES IN CALCUTTA IN JULY, 1878-1924.

Years	Bright Phase (*Sukla*)	Dark Phase (*Krsna*)	Years	Bright Phase (*Sukla*)	Dark Phase (*Krsna*)	Years	Bright Phase (*Sukla*)	Dark Phase (*Krsna*)
1878	2·07	7·51	1894	5·41	4·57	1910	4·49	5·90
79	2·38	8·82	1895	2·54	1·68	11	2·18	2·96
1880	4·26	9·05	96	7·21	8·75	12	7·56	3·53
81	6·64	4·77	97	4·66	7·18	13	2·83	11·74
82	4·86	6·48	98	4·40	7·89	14	5·76	7·87
83	6·40	10·69	99	10·96	9·29	1915	4·18	6·18
84	5·47	5·86	1900	4·98	4·05	16	1·95	5·79
1885	3·56	3·86	01	4·14	7·98	17	6 98	5·14
86	7·19	7·15	02	3·10	10·59	18	4·08	3·39
87	3·67	14·18	03	2·09	3·97	19	4·23	6·77
88	3·04	7·72	04	5·42	11·69	1920	10·90	3·10
89	7·00	4·92	1905	3·28	19·22	21	3·27	6·12
1890	4·55	5·52	06	9·02	8·79	22	11·27	3·32
91	1·36	6·94	07	3·38	4·64	23	5·46	10·91
92	4·81	6·75	08	10·68	13·17	24	4·74	5·35
93	7·68	8·52	1909	3·75	4·77			

In 32 years out of 47, the actual rainfall was greater in the *Kṛṣṇa* (dark) phase. We have already seen from the analysis of variance given in Table 2 that this difference is statistically significant.

The average rainfall in the *Kṛṣṇa* (dark) phase was 6.81 inches against 5.08 inches in the *Sukla* (bright) phase with a difference of 1.73 inches. As I had worked with the intensity of rainfall (and not the total rainfall) on different lunar days the observed difference cannot be ascribed to differences in the duration of the lunar days in the two phases.

We may next consider another possible source of error. There is an appreciable seasonal fluctuation in the distribution of monsoon rainfall in Calcutta. If either of the phases occurred more frequently, during the limited experience of 47 years, in the earlier or later part of July, the observed difference might conceivably be ascribed to the seasonal fluctuation of the rainfall. The frequency with which each lunar day in either phase occurred on each solar date of July was therefore tabulated and is shown below in Table 4 ; the χ^2 statistic was used to test whether there was any significant differentiation between the two phases. Using the average of the frequencies in both the phases as the expected value, the observed value of χ^2 was 3.572, which with 29 degrees of freedom, gives a probability of nearly 1.00 for the deviations equal to or greater than the observed deviation. The test shows that there was no significant differentiation.

TABLE 4. FREQUENCY DISTRIBUTION OF EACH LUNAR DAY IN THE TWO PHASES.

Date	Bright Phase (*Sukla*)	Dark Phase (*Krsna*)	Total	Expected	Deviation	Date	Bright Phase (*Sukla*)	Dark Phase (*Krsna*)	Total	Expected	Deviation
1	21	17	38	19·0	2·0	16	22	25	47	23·5	1·5
2	23	22	45	22·5	0·5	17	23	23	46	23·0	0·0
3	24	27	51	25·5	1·5	18	26	22	48	24·0	2·0
4	24	22	46	23·0	1·0	19	23	24	47	23·5	0·5
5	24	27	51	25·5	1·5	20	26	23	49	24·5	1·5
6	22	23	45	22·5	0·5	21	23	24	47	23·5	0·5
7	24	24	48	24·0	0·0	22	23	23	46	23·0	0·0
8	24	23	47	23·5	0·5	23	23	24	47	23·5	0·5
9	31	27	58	29·0	2·0	24	22	27	49	24·5	2·5
10	25	22	47	23·5	1·5	25	23	24	47	23·5	0·0
11	22	25	47	23·5	1·5	26	22	22	44	22·0	0·5
12	23	24	47	23·5	0·5	27	25	22	47	23·5	1·5
13	24	24	48	24·0	0·0	28	26	23	49	24·5	1·5
14	26	25	51	25·5	0·5	29	23	25	48	24·0	1·0
15	23	26	49	24·5	1·5	30	15	15	30	15·0	0·0

$\chi^2 = 3{\cdot}572$; $n' = 30$; $P \longrightarrow 1{\cdot}00$.

EFFECT OF METONIC CYCLE.

The next point to be considered was the metonic cycle. The analysis was repeated for two complete metonic cycles 1878-1895 and 1896-1913, and the results are given below.

The actual mean values and standard deviations of rainfall on each lunar day in the two lunar phases in the two metonic cycles 1878-1895 and 1896-1913 are shown in Tables 5 and 6.

TABLE 5. MEAN INTENSITY OF RAINFALL IN INCHES

Lunar day (*Tithi*)		1878—1895 (I)			1896—1913 (II)			1878—1913 (I) & (II)		
		Dark Phase (*Krsna*)	Bright Phase (*Sukla*)	Combined	Dark Phase (*Krsna*)	Bright Phase (*Sukla*)	Combined	Dark Phase (*Krsna*)	Bright Phase (*Sukla*)	Combined
Pratipad	(1)	·0105	·0220	·0163	·0253	·0137	·0195	·0179	·0179	·0179
Dvitiya	(2)	·0170	·0088	·0129	·0220	·0060	·0140	·0195	·0074	·0135
Tritiya	(3)	0135	·0107	·0121	·0155	·0118	·0137	·0145	·0112	·0129
Chaturthi	(4)	·0183	·0178	·0181	·0233	·0095	·0164	·0208	·0157	·0172
Panchami	(5)	·0296	·0131	·0214	·0098	·0064	·0081	·0197	·0098	·0147
Sasthi	(6)	·0185	·0073	·0129	·0140	·0278	·0209	·0163	·0175	·0169
Saptami	(7)	·0157	·0242	·0199	·0085	·0192	·0138	·0121	·0217	·0169
Astami	(8)	·0186	·0110	·0148	·0261	·0060	0160	·0224	·0085	·0154
Navami	(9)	·0262	·0096	·0179	·0254	·0265	·0259	·0258	·0180	·0219
Dasami	(10)	·0114	·0090	·0102	·0331	·0144	·0263	·0248	·0117	·0182
Ekadasi	(11)	·0141	·0115	·0128	·0273	·0144	·0208	·0207	·0129	·0168
Dvadasi	(12)	·0353	·0178	·0266	·0136	·0214	·0175	·0244	·0196	·0220
Trayodasi	(13)	·0292	·0091	·0192	·0306	·0151	·0228	·0299	·0121	·0210
Chaturdasi	(14)	·0305	·0098	·0202	·0151	·0119	·0135	·0228	·0109	·0168
Purnima or Amavasya	(15)	·0195	·0114	·0154	·0141	·0177	·0159	·0168	·0145	·0156
Average		·0205 ± ·00187	·0129 ± ·00117	·0165 ± ·00110	·0206 ± ·00213	·0148 ± ·00169	·0177 ± ·00137	·0206 ± ·00139	·0138 ± ·00101	·0172 ± ·00085

TABLE 6. STANDARD DEVIATIONS.

Lunar days (*Tithis*)		1878—1895 (I)			1896—1913 (II)			1878-1913 (I & II)		
		Dark Phase (*Krsna*)	Bright Phase (*Sukla*)	Combined	Dark Phase (*Krsna*)	Bright Phase (*Sukla*)	Combined	Dark Phase (*Krsna*)	Bright Phase (*Sukla*)	Combined
Pratipad	(1)	·0105	·0214	·0168	·0308	·0181	·0253	·0230	·0198	·0214
Dvitiya	(2)	·0247	·0108	·0191	·0349	·0073	·0252	·0302	·0092	·0224
Tritiya	(3)	·0155	·0123	·0140	·0213	·0179	·0197	·0186	·0154	·0171
Chaturthi	(4)	·0237	·0183	·0212	·0269	·0092	·0201	·0254	·0145	·0207
Panchami	(5)	·0184	·0211	·0177	·0082	·0090	·0086	·0111	·0163	·0139
Sasthi	(6)	·0226	·0128	·0182	·0162	·0540	·0399	·0197	·0392	·0310
Saptami	(7)	·0169	·0418	·0316	·0120	·0289	·0221	·0146	·0357	·0273
Astami	(8)	·0302	·0153	·0239	·0364	·0122	·0272	·0334	·0138	·0256
Navami	(9)	·0296	·0082	·0217	·0466	·0565	·0518	·0390	·0404	·0397
Dasami	(10)	·0145	·0076	·0116	·0666	·0227	·0497	·0482	·0169	·0361
Ekadasi	(11)	·0199	·0163	·0182	·0580	·0205	·0435	·0434	·0185	·0333
Dvadasi	(12)	·0418	·0297	·0363	·0172	·0323	·0259	·0320	·0310	·0315
Trayodasi	(13)	·0460	·0140	·0340	·0360	·0203	·0292	·0413	·0174	·0317
Chaturdasi	(14)	·0626	·0135	·0453	·0317	·0141	·0256	·0496	·0138	·0364
Purnima or Amavasya	(15)	·0234	·0140	·0193	·0180	·0226	·0204	·0209	·0188	·0199
Average		·0308 ± ·00188	·0192 ± ·00083	·0256 ± ·00088	·0350 ± ·00151	·0278 ± ·00120	·0319 ± ·00097	·0324 ± ·00098	·0285 ± 00071	·0281 ± ·00060

Table 7 shows the analysis of variance for the two metonic cycles separately and the two cycles taken together.

TABLE 7. ANALYSIS OF VARIANCE : TWO METONIC CYCLES.

Factor of Variation	Degrees of Freedom	Sum of Squares	Mean Square	Ratio of Variance	
				Observed	Expected 1%
1878—1913					
Between Lunar days (*Tithis*)	14	·007660	·000547	—	—
Between Years	35	·036644	·001047	1·33	1·67
Between Phases	1	·012201	·012201	15·44	6·63
Between Metonic Cycles	1	·000248	·000248	—	—
Lunar days (*Tithis*) × Phases	14	·014564	·001040	1·32	2·09
Residual	1014	·852504	·000790		
Total	1079	·923821			
1878—1895					
Between Lunar days (*Tithis*)	14	·009495	·000678	1·04	2·11
Between Years	17	·013408	·000789	1·21	1·99
Between Phases	1	·007894	·007894	12·07	6·64
Lunar days (*Tithis*) × Phases	14	·012200	·000871	1·33	2·11
Residual	493	·322581	·000654		
Total	539	·365578			
1896—1913					
Between Lunar days (*Tithis*)	14	·012789	·000910	—	
Between Years	17	·022979	·001352	1·33	1·99
Between Phases	1	·004538	·004538	4·47	6·64
Lunar days (*Tithis*) × Phases	14	·016823	·001202	1·18	2·11
Residual	493	·500917	·001016		
Total	539	·557996			

The difference between the two lunar phases is very definitely significant, while differences between *tithis* (lunar days), between years, or between the two metonic cycles, and the interaction between lunar phase and lunar day are all statistically negligible.

In both the cycles we find again that differences between lunar days and years, or the interactions between lunar days and phases are inappreciable, while the difference in rainfall in the two lunar phases is definitely significant.

The comparison of lunar days and of years is shown in greater detail for each of the two phases in the two metonic cycles in Table 8.

TABLE 8. ANALYSIS OF VARIANCE.

Factor of Variation	Degrees of Freedom	Sum of Squares	Mean Square	Ratio of Variance Observed	Ratio of Variance Expected 1%
Bright Phase (*Sukla*) 1878–1895					
Between Lunar days (*Tithis*)	14	·006687	·000478	1·29	2·15
Between Years	17	·010278	·000605	1·64	2·03
Residual	238	·087826	·000369		
Total	269	·104791			
Dark Phase (*Krsna*) 1878–1895					
Between Lunar days (*Tithis*)	14	·014999	·001071	1·13	2·15
Between Years	17	·011948	·000703		2·03
Residual	238	·225946	·000949		
Total	269	·252893			
Bright Phase (*Sukla*) 1896–1913					
Between Lunar days (*Tithis*)	14	·011697	·000805	1·08	2·15
Between Years	17	·015201	·000894	1·15	2·03
Residual	238	·183913	·000773		
Total	269	·210811			
Dark Phase (*Krsna*) 1896–1913					
Between Lunar days (*Tithis*)	14	·017855	·001275	1·04	2·15
Between Years	17	·033287	·001958	1·59	2·03
Residual	238	·291505	·001225		
Total	269	·342647			

Differences between lunar days and between years are entirely insignificant in every case.

CONCLUSION.

A statistical analysis of the rainfall in the month of July in Calcutta during the 47 years 1878-1924 did not show any appreciable differences between the intensity of rainfall on different lunar days. Differences in rainfall between years or between two metonic cycles were also insignificant.

The rainfall in the *Krsna* (dark) phase was however significantly greater than the rainfall in the *Sukla* (bright) phase in both the metonic cycles and also for the whole period of 47 years. It is not possible to say whether this is a freak result without similar analysis of the rainfall for other months in Calcutta or other places. In view of the statistically significant results reported in the present note this question deserves further consideration.

Statistical Laboratory, Calcutta.
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