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Tabular aids for computation of derived agrometeorological parameters on a weekly basis

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ABSTRACT

For Indian latitudes mean values of extra-terrestrial radiation and possible sunlight hours for the 52 standard weeks and hourly distribution percentage of extra-terrestrial radiation in the 12 calendar months are presented. Simple formulae for computing, from data of maximum and minimum temperatures, average day and night temperatures and hourly temperatures are presented.

Key Words : Extra-terrestrial radiation, Photoperiod, Diurnal temperatures

Analyses of data on a short-period basis are a must in Agrometeorology. The FAO has adopted the 10 day period (Dekad) as the ultimate time-unit for agrometeorological studies. The week has been taken as the time-unit in India for agrometeorological work. A lot of data is available on a weekly basis for the 52 standard weeks (Appendix I). In agrometeorological analyses recourse has often to be taken for the use of derived parameters, such as extra-terrestrial radiation, photoperiod, accumulated day and night degrees, photothermal units, heliothermal units and leaf-wetness duration, which are freqently computed.

Potential evapotranspiration (PET) is an important factor in the water needs of crops. In the computation of PET, the amount of solar radiation (Rs) received from the sun and sunlit sky, is an important factor that is recorded at a few stations only.Therefore, Rs is sought to be related to terrestrial radiation (Ra), maximum possible sunshine hours (N) and actual bright sunshine hours (n). For optimum use of solar radiation in various areas and seasons, information of Ra on an hourly basis is required.

Temperature can either obliterate (Went,1957) or modify (Huxley and Summerfield,1974) the influence of the nyctoperiod. Plants also exhibit thermo-periodicity i.e. show preferential response to daytime, night-time and mean temperatures. Temperatures during maturity of soybean, night-temperatures after flowering in wheat and rice and both day and night temperatures during ripening of maize are known to affect crop yield (Venkataraman and Krishnan, 1992).

Outbreak of diseases is influenced by leaf wetness duration (LWD). To compute LWD hourly values of temperature, especially during night-time is a must. In light of the above for many agrometeorological analyses data on avearge daytime, night-time and daily temperatures as well as hourly temperatures are required. Mostly data of only maximum and minimum temperatures are routinely available.Thus computing day, night and hourly temperatures from data of only maximum and minimum temperatures becomes important.

MATERIALS AND METHODS

The hourly temperatures follow two different cosine curves, viz., the ascending one T_A from sunrise of day at t_o hours to 1300 hours and the descending one T_B from 1300 hours to sunrise hour of next day (Robertson, 1983). The equations for T_A and T_B are given as:

$$T_A = Tm - \{ \frac{1}{2} R \, Cos\,(180 \frac{T_A - t_o}{13 - t_o})\} \quad (1)$$

$$T_B = Tm + \{ \frac{1}{2} R \, Cos\,(180 \frac{T_B - 13}{11 + t_o})\} \quad (2)$$

where, Tm is mean temperature.

From solution of the above equations and simplification the derived expressions, mean daytime temperature (T_D) and mean night-time temperature (T_N) are obtained.

$$T_D = Tm + \{ \frac{R}{4\pi} \frac{11 + t_o}{12 + t_o}\} \, Sin\alpha \quad (3)$$

$$T_N = Tm - \{ \frac{R}{4\pi} \frac{11 + t_o}{t_o}\} \, Sin\alpha \quad (4)$$

where $\alpha = \left(\frac{11 - t_o}{11 + t_o}\right) * 180$

and $\pi = 3.14159$

RESULTS AND DISCUSSION

Weekly sunlight hours

Data on sunlight hours (N), are available on a monthly and latitudanal basis, pertaining to the middle of each month (Allen *et al*,1998). Monthly N for latitudes 5, 10, 15, 20, 25 and 30° were carefully extrapolated to arrive at values pertaining to the middle of each of the standard weeks. The weekly values of N set out in Table 1, can directly be interpolated between latitudes.

Weekly extra-terrestrial radiation

Extra-terrestrial radiation (Ra) pertaining to the middle of each of the 12 calendar months have been presented by Venkataraman and Krishnamurthy(1965) for latitudes 5, 10, 15, 20, 25 and 30° N based on a solar constant value of 1.94 while the accepted (Allen *et al*,1998) is 1.96 cal $cm^{-2}min^{-1}$. The values were increased by 1% and the monthly Ra values of Venkataraman and Krishnamurthy(1965) were increased by 1% and carefully interpolated to arrive at weekly values pertaining to the middle of each of the standard weeks (Table 2).

Hourly extra-terrestrial radiation

The mean hourly extra-terrestrial radiation values pertaining to the middle of the hour form a sine curve with mirror-reflection halves centered around 12 hours local apparent time (LAT). Hourly values of Ra for the mid-point of each of the two identical LAT hours have been presented by Venkataraman and Krishnamurthy (1965) for the latitudes 5, 10, 15, 20, 25 and 30° for the 12 calendar months. These are now expressed as a percentage of the daily total Ra (Table 3). It is seen that irrespective of latitude and month the each of the LAT hours 8-9 and 15-16 receive 8% of the total daily Ra. It is also seen that the hourly distribution percentage for the same latitude and month varied for different hours and for the same hour and latitude it showed seasonal variation

Table 1 : Possible hours of sunlight.

Std. Week No.	Latitudes (°N)						Std. Week No.	Latitudes (°N)					
	5	10	15	20	25	30		5	10	15	20	25	30
1	11.8	11.5	11.3	10.9	10.7	10.3	27	12.3	12.7	12.9	13.3	13.6	13.9
2	11.8	11.6	11.4	11.0	10.8	10.4	28	12.3	12.6	12.9	13.2	13.5	13.8
3	11.9	11.6	11.4	11.1	10.9	10.5	29	12.3	12.5	12.9	13.1	13.5	13.8
4	11.9	11.7	11.5	11.2	10.9	10.6	30	12.3	12.5	12.8	13.1	13.4	13.6
5	11.9	11.7	11.5	11.3	11.0	10.7	31	12.3	12.5	12.7	13.0	13.3	13.5
6	11.9	11.7	11.5	11.4	11.1	10.9	32	12.3	12.5	12.7	12.9	13.1	13.3
7	11.9	11.8	11.6	11.5	11.3	11.1	33	12.3	12.4	12.6	12.8	13.0	13.2
8	11.9	11.9	11.7	11.6	11.5	11.3	34	12.3	12.3	12.5	12.7	12.9	13.0
9	11.9	11.9	11.8	11.7	11.7	11.5	35	12.2	12.3	12.4	12.5	12.7	12.8
10	11.9	11.9	11.9	11.9	11.9	11.7	36	12.2	12.2	12.3	12.4	12.5	12.6
11	12.0	12.0	12.0	12.0	12.0	12.0	37	12.1	12.1	12.2	12.3	12.5	12.5
12	12.0	12.1	12.1	12.1	12.2	12.2	38	12.1	12.1	12.1	12.2	12.2	12.2
13	12.1	12.1	12.2	12.3	12.3	12.4	39	12.1	11.9	12.0	12.1	12.0	12.0
14	12.1	12.2	12.3	12.4	12.5	12.6	40	12.1	11.9	11.9	11.9	11.8	11.8
15	12.2	12.2	12.4	12.5	12.6	12.8	41	12.0	11.8	11.9	11.8	11.7	11.6
16	12.2	12.3	12.5	12.7	12.8	13.0	42	12.0	11.8	11.8	11.7	11.5	11.4
17	12.3	12.5	12.7	12.8	12.9	13.2	43	11.9	11.7	11.7	11.6	11.4	11.1
18	12.3	12.5	12.7	12.9	13.1	13.4	44	11.9	11.7	11.6	11.5	11.3	11.1
19	12.3	12.6	12.8	13.0	13.2	13.5	45	11.9	11.7	11.5	11.3	11.1	10.9
20	12.3	12.6	12.8	13.1	13.3	13.6	46	11.9	11.6	11.4	11.2	10.9	10.6
21	12.3	12.7	12.9	13.1	13.4	13.7	47	11.9	11.5	11.3	11.1	10.7	10.4
22	12.3	12.7	12.9	13.2	13.5	13.8	48	11.9	11.5	11.3	11.1	10.7	10.4
23	12.3	12.7	12.9	13.3	13.7	14.0	49	11.9	11.5	11.3	11.0	10.6	10.2
24	12.4	12.7	13.0	13.3	13.7	14.0	50	11.8	11.5	11.2	10.9	10.6	10.2
25	12.4	12.7	13.0	13.3	13.7	14.0	51	11.8	11.5	11.2	10.9	10.6	10.2
26	12.3	12.7	12.9	13.3	13.6	13.9	52	11.8	11.5	11.3	10.9	10.7	10.3

Table 2 : Weekly extraterrestrial solar radiation (Cal cm^{-2} day^{-1})

Std. Week No.	Latitudes (°N)						Std. Week No.	Latitudes (°N)					
	5	10	15	20	25	30		5	10	15	20	25	30
1	813	757	693	629	565	505	27	867	891	919	950	973	990
2	818	764	699	636	573	516	28	874	892	922	951	975	991
3	825	775	711	649	588	534	29	877	893	921	946	968	980
4	835	788	729	669	609	559	30	877	895	918	937	953	960
5	845	801	747	689	631	583	31	877	895	915	929	941	942
6	857	817	769	713	657	613	32	877	986	912	921	928	923
7	870	834	790	737	683	642	33	877	897	909	913	915	905
8	879	847	809	762	713	673	34	881	895	901	900	895	881
9	887	861	827	787	743	703	35	884	892	894	887	875	857
10	896	874	845	813	773	733	36	887	890	887	876	858	836
11	905	887	863	838	804	764	37	890	888	881	865	841	815
12	904	891	873	854	825	791	38	888	880	868	846	817	785
13	903	895	884	870	847	817	39	884	869	852	824	790	753
14	902	899	895	887	870	845	40	880	859	836	803	764	721
15	901	903	906	904	893	873	41	875	850	819	782	738	689
16	896	904	912	915	909	895	42	869	838	802	759	711	658
17	889	903	915	921	920	912	43	860	825	785	738	687	632
18	881	901	917	927	931	929	44	851	813	769	717	663	606
19	873	900	919	933	941	947	45	841	797	778	691	633	573
20	865	898	921	938	950	961	46	830	782	787	665	602	541
21	860	895	919	940	954	967	47	823	771	745	651	587	524
22	855	892	917	942	958	973	48	816	761	702	637	572	507
23	849	889	915	945	963	979	49	808	749	688	628	555	487
24	844	885	913	947	967	986	50	800	736	674	606	309	467
25	851	887	915	948	969	987	51	805	743	681	613	547	479
26	859	889	917	949	971	989	52	809	749	687	621	556	492

Table 3 : Hourly percentage distribution of extra-terrestrial radiation. For latitudes 16 to 19° N data can be obtained by interpolation.

Local Apparent Time (hours)	April -August		Sept.& October		Nov. to January		Feb. & March	
	Latitudes (°N)		Latitudes (°N)		Latitudes (°N)		Latitudes (°N)	
	5-15	20-30	5-15	20-30	5-15	20-30	5-15	20-30
11-12 & 12-13	12.50	12.00	13.00	13.25	13.50	14.50	13.25	13.50
10-11 & 13-14	11.75	11.25	12.25	12.25	12.50	13.25	12.25	12.50
9-10 & 14-15	10.25	10.00	10.50	10.50	10.75	11.00	10.50	10.50
8-9 & 15-16	8.00	8.00	8.00	8.00	8.00	7.75	8.00	8.00
7-8 & 16-17	5.25	5.50	5.00	4.75	4.50	3.50	4.75	4.50
6-7 & 17-18	2.25	3.00	1.50	1.25	0.75	0.02	1.25	1.00

Table 4 : Simplified values of various terms used in Eqs. 3 and 4 different sunrise hours.

Sunrise hour (t_o)	α	$\sin\alpha$	$(11+t_o)/(12-t_o)$	$(11+t_o)/(t_o)$	¼ π
1	2	3	4	5	6
5	67.50	0.924	2.286	3.200	0.796
6	52.94	0.798	2.833	2.833	0.796
7	40.00	0.643	3.600	2.571	0.796.

while for the same hour and month, it was influenced only slightly at latitudes 5,10 and 15. At 30°N values were quite different from those at 20 and 25°N. For any given hour and latitude It was little influenced by the month within the seasons. For LAT hours 5-6 and 18-19 negligible amounts of Ra, mostly less than 5 cal $cm^{-2} day^{-1}$ is received from May to July at 20 to 30°N. Therefore, the above hours are not included in Table 3. Using Table 3 one can get hourly values of Ra with an accuracy of +3% for latitudes 5,10 and 15° N and + 5% for latitudes 20, 25 and 30° N. For latitude 16-19°N, these can be obtained through interpolation. Hourly values of Ra can be obtained with the help of Tables 2 and 3.

Day mean, night mean and hourly temperatures

Equations 3 and 4 above show that the factor influencing the computation of mean daytime and mean night-time temperatures from maximum and minimum values is the sunrise term (t_o). Therefore, for t_o values of 5, 6 and 7 the various terms were worked out (Table 4).

The products of columns 3, 4 and 6 columns 3, 5, 6 and give respectively the fractions of range (R) to be added to and minused from the mean temperature to get mean day and night temperatures. The results are summarised as follows.

Sunrise hour	Mean day temp	Mean night temp
5	Tm+0.17R	Tm-0.24R
6	Tm+0.18R	Tm-0.18R
7	Tm+0.185R	Tm-0.13R

Tm = (Max.+Min.)/2 and R= Max.-Min.

Mean night temperature is greatly influenced by the time of sunrise while mean day temperature is only slightly influenced by it. Also when sunrise hour is six hours, day and night mean temperatures would be the same.

Equations 1 and 2 show that the fraction of daily temperature range to be added to or minused from the mean temperature to obtain the hourly values would vary with the sunrise hour term t_o. Therefore, the fraction of R to be algebraically added to the mean temperarure to get the hourly values were worked out for each of the hours in the 24 hour period from sunrise of day to sunrise of next day for t_o values of 5, 6 and 7. (Table 5). It is seen that mean temperatures would be reached at t_o+4 and t_o+16 hours for t_o = 5, at t_o+3.5 and t_o+15.5 for t_o = 6 and at t_o+ 3 and t_o+15 for t_o = 7. Table 5 also reveals that in the epochs between the hours of mean temperatures and t_o and 1300 hours, the hourly values show equal positive and negative departures centered around the mean temperature hour.

These formulations would enable one to compute not only average day and night temperatures but also hourly temperatures from data of only maximum and minimum temperatures. Such exercises should facilitate computation of accumulated phyto or nycto temperatures above or below a basic values and lead to derivation of Pheno - meteorological relationships for estimating the duration of various crop stages.

Table 5 : Fraction of range to be algeberically added to mean to get hourly temperatures at different sunrise hours.

Hours	Sunrise hours (t_o)		
	5	6	7
t_o+1	-0.46	-0.45	-0.43
t_o+2	-0.35	-0.31	-0.25
t_o+3	-0.19	-0.11	0.00
t_o+4	0.00	+0.11	+0.25
t_o+5	+0.19	+0.31	+0.43
t_o+6	+0.35	+0.45	+0.50
t_o+7	+0.46	+0.50	+0.50
t_o+8	+0.50	+0.49	+0.47
t_o+9	+0.49	+0.47	+0.43
t_o+10	+0.46	+0.43	+0.38
t_o+11	+0.41	+0.37	+0.32
t_o+12	+0.35	+0.30	+0.25
t_o+13	+0.28	+0.22	+0.17
t_o+14	+0.19	+0.14	+0.09
t_o+15	+0.10	+0.05	0.00
t_o+16	0.00	-0.05	-0.09
t_o+17	-0.10	-0.14	-0.17
t_o+18	-0.19	-0.22	-0.25
t_o+19	-0.28	-0.30	-0.32
t_o+20	-0.35	-0.37	-0.38
t_o+21	-0.41	-0.43	-0.43
t_o+22	-0.46	-0.47	-0.47
t_o+23	-0.49	-0.49	-0.49
t_o+24	-0.50	-0.50	-0.50

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Appendix I : The" Standard Weeks "Calendar.

Week No.	Month	Dates	Week No.	Month	Dates
	January	1-7	27	July	2-8
2		8-14	28		9-15
3		15-21	29		16-22
4		22-28	30		23-29
5	Jan/Feb.	29-4	31	Jul/Aug	30-5
6	February	5-11	32	August	6-12
7		12-18	33		13-19
8		19-25	34		20-26
9	Feb/Mar	26-4*	35	Aug/Sept.	27-2
10	March	5-11	36	September	3-9
11		12-18	37		10-16
12		19-25	38		17-23
13	Mar/Apr	26-1	39		24-30
14	April	2-8	40	October	1-7
15		9-15	41		8-14
16		16-22	42		15-21
17		23-29	43		22-28
18	Apr/May	30-6	44	Oct/Nov	29-4
19	May	7-13	45	November	5-11
20		14-20	46		12-18
21		21-27	47		19-25
22	May/June	28-3	48	Nov/Dec	26-2
23	June	4-10	49	December	3-9
24		11-17	50		10-16
25		18-24	51		17-23
26	June/July	25-1	52		24-31#

* In Leap Year the week No.9 will be 26 February to 4 March i.e. 8 days.

Last week No. 52 will have 8 days, 24 to 31 December.