

# A Statistical Study of Micro-Climates

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## 1. Introduction.

With the starting of the Agricultural Meteorology Section at Poona in 1932, the study of variation of the micro-climate in different environments has been receiving considerable attention. This aspect of Agricultural Meteorology is being investigated in detail at the Central Agricultural Meteorological Observatory at Poona. The results of these investigations since 1932 have been discussed in a series of papers by Ramdas and co-workers<sup>1-11</sup>. A survey of the micro-climates of plant communities has been given in a recent paper which appeared in the *Indian Ecologist*<sup>10</sup>. A detailed discussion of the work done on 'micro-climatology' in India is being presented in another paper<sup>11</sup>.

It will be clear from the papers referred to above that a plant community profoundly modifies the micro-climate. This modification depends indeed on the density of the plant population, the stage of growth and the distribution of the foliage both in the vertical and horizontal directions. The question also arises whether the climate of a crop is related in a simple manner to that of an open space in the neighbourhood. In other words, can one assume that from a knowledge of the climate of the 'open', one can infer what would be the climate of a crop? In studying the effect of climate on crop growth and yield, is it essential to record in detail the micro-climate of the crop? Ramdas, Kalamkar and Gadre<sup>9</sup> have already shown that while conditions in different environments at the minimum temperature epoch are highly correlated, the correlation comes down very much in the day-time when turbulence sets in. In the present paper we shall pursue this aspect of the problem further by a statistical analysis of more recent data recorded at the Central Agricultural Meteorological Observatory in the open and inside a few crops.

## 2. Data used for the Analysis of Variance.

Table 1 gives full particulars regarding the crops in which the micro-climatic data discussed in this paper were recorded. The names of the environments and the periods considered are indicated below in Table 1 (a).

Table 1 (a)

Season	Name of environment	Period considered
S. W. Monsoon (rainy season)	'open' jowar suran sugarcane	17th to 31st August 1941
Winter (Dry cold season)	'open' jowar cotton sugarcane	8th to 22nd December 1936
Summer (hot season)	'open' cotton	17th to 31st March 1942

The analysis of variance of the dry bulb temperature and vapour pressure recorded with an Assmann Psychrometer at 9 levels above ground and at the epochs of minimum and maximum temperature was worked out for the season and environments referred to above.

Tables 2, 3 and 4 give the mean daily values of the dry bulb temperature in °C and the vapour pressure (mm. of Hg.) recorded in these three periods. The differences of temperature and of vapour pressure with height and environment are as described in earlier papers, viz., greater during the afternoon than in the morning, particularly in the dry season. The values in the tables speak for themselves and we now discuss the analysis of variance.

Tables, 5, 6 and 7 show the analysis of variance at the minimum temperature epoch. From the variance ratios given in these tables it will be clear that the variances due to 'date' and 'environment' are very high and the most significant.

Tables 8, 9 and 10 show the analysis of variance at the maximum temperature epoch; Here again the variance due to 'date' and 'environment' are very high and the most significant.

In all these tables it will also be observed that the variance due to 'height' is also quite high although smaller than the variances due to 'date' and 'environment'.

This means that, in general, when we deal with the 'micro-climate' the elements recorded may be expected to vary with environment, date and height, the variability decreasing in the order in which the above factors are mentioned. While this result will be evident from even a visual examination of the data, the tables of analysis of variance express these differences in a quantitative manner, bringing out the relative importance of the factors affecting the micro-climate.

### 3. Correlation Coefficients.

We may now consider the correlation coefficients of values of air temperature and vapour pressure, at each of the heights of observation in the 'open' with corresponding values in each of the crops under observation. These have been calculated separately for temperature and vapour pressure and for the minimum and maximum temperature epochs respectively. The environments and the periods of observation considered are indicated below.

Environments	Period
1. Open, jowar, sugarcane and suran	.. 1st to 31st August 1941
2. Open, jowar, cotton and sugarcane	.. 1st December 1936 to 3rd January 1937
3. Open and cotton	.. 17th March to 16th April 1942

Tables 11, 12 and 13 show the correlation of the 'open' with each of the crops, level by level and for the epochs of minimum and maximum temperature.

It will be seen that the correlation coefficients are all high during the minimum temperature epoch when the air layers are stratified. In the afternoon there is a general decrease in the correlation coefficients, due evidently to the differential effect of turbulence in the 'open' as compared to that inside the different crops. The decrease of correlation is much more pronounced in the case of air temperature than in the case of the vapour pressure. Also, in a dense irrigated crop like sugarcane, the temperature correlations become very low near the ground in the afternoon during clear weather but increase somewhat with height.

#### 4. Conclusion.

It will be observed from the data and results referred to above that the earlier conclusions of Ramdas, Kalamkar and Gadre are confirmed by the more recent data. It seems that if one wishes to study the effect of climate on crops, the micro-climatic observations must be recorded inside the crops concerned.

The authors wish to record their thanks to Dr. L. A. Ramdas for suggesting this investigation and giving the necessary facilities.

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TABLE I.

Particulars	1-8-1941 to 31-8-1941		1-12-1936 to 3-1-1937		17-3-1942 to 16-4-1942		
	Kharif Jowar	Suran	Sugarcane	Rabi Jowar	Cotton	Sugarcane	Cotton
Date of sowing	15-7-1941	15-5-1941	6-1-1941	21-9-1936	3-7-1936	17-1-1936	7-7-1941
Seed rate per acre	10 lbs.	10,000 corns	8,000 setts	20 lbs.	5 lbs.	8,000 setts	8 lbs.
Variety	Nilwa	Local	P. O. J. 2878	Maldandi	Broach	P. O. J. 2878	Waghead
Average distance between plants between rows.	18"	4 feet	5 feet	18"	3 feet	5 feet	3 feet
Average distance between plants within rows.	6"	3 feet	2"	3"	3 feet (2 plants in each spot)	2"	2 feet (2 plants in each spot.)
Date of earthing up	Nil	28-7-1941	22-7-1941	Nil	Nil	28-6-1936	Nil
Date of irrigation (during the period under study.)	Nil	27-7-1941 8-8-1941 17-8-1941 29-8-1941	27-7-1941 7-8-1941 17-8-1941 27-8-1941	Nil	Nil	28-11-1936 7-12-1936 19-12-1936 27-12-1936	Nil
Date of harvest	6-11-1941	3-2-1942	19-3-1942	25-1-1937	10-4-1937	17-2-1937	4-5-1942
Average height	3" (on 1-8-41) 2½" (on 6-9-41)	1½' (on 1-8-41) 2½' (on 6-9-41)	2½' (on 1-8-41) 3' (on 6-9-41)	6' (on 7-12-36) 7' (on 14-12-36) 7½' (on 28-12-36)	3' (on 7-12-36) 4' (on 14-12-36) 4' (on 28-12-36)	9' (on 7-12-36) 9' (on 14-12-36) 9' (on 28-12-36)	4 feet roughly

TABLE II

Mean Dry Bulb Temperature and Vapour Pressure during the period 17-8-1941 to 31-8-1941.

		Minimum Temperature Epoch							
Height	Dry Bulb Temperature				Vapour Pressure				
	Open	Kharif Jowar	Suran	Sugar-cane	Open	Kharif Jowar	Suran	Sugar-cane	
Surface level	..	22.4	22.4	22.3	22.1	17.2	17.2	17.3	17.5
1"	..	22.4	22.3	22.3	22.1	17.1	17.2	17.4	17.4
3"	..	22.3	22.3	22.2	22.0	17.0	17.2	17.4	17.4
6"	..	22.3	22.3	22.2	22.0	16.9	17.1	17.4	17.3
1 Foot	..	22.3	22.2	22.2	22.0	16.9	17.1	17.3	17.3
2 Feet	..	22.3	22.3	22.2	21.9	16.9	17.2	17.3	17.3
3 Feet	..	22.3	22.3	22.2	21.9	16.9	17.1	17.3	17.2
4 Feet	..	22.4	22.3	22.2	21.9	16.9	17.0	17.2	17.1
6 Feet	..	22.4	22.4	22.2	21.9	16.9	17.0	17.1	17.1

  

		Maximum Temperature Epoch							
Surface level	..	34.3	34.1	31.2	30.7	19.1	20.0	20.0	20.8
1"	..	32.8	32.2	31.0	29.5	18.4	19.2	19.4	20.2
3"	..	32.0	32.5	30.8	30.4	18.1	18.7	19.1	19.6
6"	..	32.0	32.0	30.7	30.3	18.0	18.3	19.0	19.3
1 Foot	..	31.2	31.4	30.5	30.1	17.6	18.2	18.7	18.8
2 Feet	..	30.7	31.0	30.2	29.8	17.6	18.2	18.5	18.6
3 Feet	..	30.2	30.5	29.8	29.8	17.5	18.0	18.0	18.6
4 Feet	..	29.9	30.3	29.6	29.6	17.3	17.9	17.8	18.5
6 Feet	..	29.5	29.9	29.3	29.5	17.2	17.6	17.8	18.4

TABLE III

Mean Dry Bulb Temperature and Vapour pressure during the period 8-12-1936 to 22-12-1936.

		Minimum Temperature Epoch							
		Dry bulb temperature				Vapour Pressure			
		Open	Rabi Jowar	Cotton	Sugar-cane	Open	Rabi Jowar	Cotton	Sugarcane
Surface level	..	9.1	10.0	9.1	10.5	7.2	8.0	6.9	8.8
1"	..	9.0	10.0	9.1	10.5	7.2	8.0	6.9	8.8
3"	..	8.9	9.8	9.2	10.4	7.2	8.0	6.9	8.7
6"	..	9.0	9.7	9.3	10.3	7.3	8.0	6.9	8.7
1 Foot	..	9.1	9.7	9.3	10.2	7.4	8.0	7.1	8.6
2 Feet	..	9.2	9.7	9.4	10.2	7.7	8.0	7.4	8.6
3 Feet	..	9.5	9.7	9.5	10.1	7.8	8.0	7.6	8.6
4 Feet	..	9.7	9.9	9.7	10.0	7.9	8.2	7.6	8.5
6 Feet	..	9.9	9.9	9.8	10.1	8.0	8.2	7.7	8.5



Maximum Temperature Epoch.								
Surface level..	33.8	31.1	32.4	25.3	9.3	10.2	9.8	18.8
1"	..	32.0	30.6	31.6	25.3	9.3	9.9	12.6
3"	..	31.2	30.5	31.2	25.5	9.0	9.7	12.6
6"	..	26.7	30.4	30.8	25.9	8.8	9.6	12.0
1 Foot	..	30.3	30.2	30.4	26.4	8.6	9.5	11.5
2 Feet	..	29.9	30.0	30.0	26.8	8.5	9.2	10.9
3 Feet	..	29.3	29.7	29.3	27.3	8.4	9.1	10.6
4 Feet	..	29.0	29.4	29.2	27.6	8.4	9.0	10.4
6 Feet	..	28.6	29.1	28.4	27.8	8.2	8.9	10.2

TABLE IV

Mean Dry Bulb Temperature and Vapour pressure during the period 17.3.1942 to 31.3.1942.

	Minimum Temperature Epoch				Maximum Temperature Epoch				
	Dry Bulb Temperature		Vapour Pressure		Dry Bulb Temperature		Vapour Pressure		
	Open	Cotton	Open	Cotton	Open	Cotton	Open	Cotton	
Surface	..	18.2	15.6	7.2	7.6	45.6	46.4	5.2	7.2
1"	..	18.1	15.2	7.1	7.4	44.9	45.3	4.8	6.4
3"	..	18.0	15.0	7.1	7.3	43.2	44.1	4.1	5.9
6"	..	18.0	14.7	7.2	7.3	41.9	43.3	3.9	5.3
1 Foot	..	18.0	14.7	7.3	7.4	41.1	42.4	3.7	4.9
2 Feet	..	18.1	14.6	7.4	7.6	40.5	41.7	3.6	4.7
3 Feet	..	18.2	14.5	7.4	7.7	39.9	41.1	3.4	4.3
4 Feet	..	18.4	14.9	7.7	7.8	39.4	40.5	3.5	4.0
6 Feet	..	18.6	15.8	7.8	7.8	39.1	39.8	3.5	3.9

TABLE V

## Analysis of Variance.

Dry Bulb Temperature and Vapour Pressure at different heights in the "open" and inside Khari Jowar, Suran and Sugarcane during the period 17-8-1941 to 31-8-1941 at the Minimum Temperature Epoch.

Due to	Degrees of freedom	Dry Bulb Temperature			Vapour Pressure		Value of "F" for			
		Sum of squares	Mean square	Variance ratio	Sum of squares	Mean square	Variance ratio	5% level of significance	1% level of significance	
Height	..	8	0.92	0.12	8.21**	4.84	0.61	13.86**	1.97	2.57
Date	..	14	910.22	65.02	4643.93**	235.33	16.81	382.05**	1.73	2.14
Environment	..	3	10.82	3.61	257.56**	11.18	3.73	84.77**	2.83	3.85
Height × Date	112	2.39	0.021	1.52**	1.04	0.01	0.23	1.29	1.45	
Height × Environment	24	0.67	0.027	1.92**	0.40	0.02	0.45	1.55	1.86	
Date × Environment	42	30.09	0.72	51.14**	27.73	0.66	15.00**	1.43	1.66	
Error	..	336	4.62	0.014		14.75	0.044			
Total	..	539	959.73			295.27				

\*\* Significant at 1% level.

TABLE VI

## Analysis of variance

*Dry Bulb Temperature and Vapour pressure at different heights in the "open" and inside Rabi Jowar, Cotton and Sugarcane during the period 8-12-1936 to 22-12-1936 at the Minimum Temperature Epoch.*

Due to	Degrees of freedom	Dry Bulb Temperature			Vapour Pressure			Value of "F" for	
		Sum of squares	Mean square	Variance ratio	Sum of squares	Mean square	Variance ratio	5% level of significance	1% level of significance
Height ..	8	8.46	1.06	29.41**	7.86	0.98	13.07**	1.97	2.57
Date ..	14	2086.84	49.06	4140.56**	818.06	58.43	779.17**	1.73	2.14
Environment..	3	82.95	27.65	768.05**	172.06	57.35	764.67**	2.63	3.85
Height x Date .	112	25.25	0.23	6.26**	11.09	0.10	1.33*	1.29	1.45
Height x Environment.	24	21.99	0.92	25.56**	12.44	0.52	6.93**	1.55	1.86
Date x Environment.	42	91.76	2.19	60.83**	40.95	0.98	13.07**	1.43	1.66
Error ..	336	12.00	0.036		25.26	0.075			
Total ..	539	2329.25			1087.72				

\*\* Significant at 1% level.

\* Significant at 5% level.

TABLE VII

## Analysis of Variance

*Dry Bulb Temperature and Vapour pressure at different heights in the "open" and inside cotton during the period 17-3-1942 to 31-3-1942 at the Minimum Temperature Epoch.*

Due to	Degrees of freedom	Dry Bulb Temperature			Vapour Pressure			Value of "F" for	
		Sum of squares	Mean square	Variance ratio	Sum of squares	Mean square	Variance ratio	5% level of significance	1% level of significance
Height ..	8	24.45	3.06	33.62**	11.45	1.43	12.77**	2.02	2.67
Date ..	14	1211.25	86.52	950.77**	1477.80	105.56	942.50**	1.78	2.24
Environment..	1	683.87	683.87	7515.05**	2.45	2.45	21.88**	3.93	6.87
Height x Date	112	18.11	0.16	1.78**	25.46	0.23	2.05**	1.38	1.57
Height x Environment.	8	8.40	1.05	11.54**	1.00	0.12	1.07	2.02	2.67
Date x Environment.	14	39.27	2.81	30.88**	35.18	2.51	22.41**	1.78	2.24
Error ..	112	10.16	0.091		12.56	0.112			
Total ..	269	1995.51			1565.90				

\*\* Significant at 1% level.

TABLE VIII

## Analysis of Variance

*Dry Bulb Temperature and Vapour Pressure at different heights in the "open" and inside Kharif Jowar, Suran and Sugarcane during the period 17-8-1941 to 31-8-1941 at the Maximum Temperature Epoch.*

Due to	Degrees of freedom	Dry Bulb Temperature			Vapour Pressure			Value of "F" for	
		Sum of squares	Mean square	Variance ratio	Sum of squares	Mean square	Variance ratio	5% level of significance	1% level of significance
Height ..	8	474.92	59.37	45.28**	253.90	31.74	144.25**	1.97	2.57
Date ..	14	2104.22	150.30	111.65**	759.57	54.23	246.64**	1.73	2.14
Environment .	3	228.11	76.04	58.05**	128.10	42.70	194.09**	2.63	3.85
Height x Date	112	171.33	1.53	1.17	69.67	0.62	2.82**	1.29	1.45
Height x Environment.	24	129.24	5.38	4.10**	11.83	0.49	2.23**	1.55	1.86
Date x Environment.	42	389.52	9.27	7.07**	205.18	4.89	22.25**	1.43	1.66
Error ..	336	410.37	1.311		73.79	0.220			
Total ..	539	3937.71			1502.04				

\*\* Significant at 1% level.

TABLE IX

## Analysis of Variance

*Dry Bulb Temperature and Vapour Pressure at different heights in the "open" and inside Rabi Jowar, Cotton and Sugarcane during the period 8-12-1936 to 22-12-1936 at the Maximum Temperature Epoch.*

Due to	Degrees of freedom	Dry Bulb Temperature			Vapour Pressure			Value of "F" for	
		Sum of squares	Mean square	Variance ratio	Sum of squares	Mean square	Variance ratio	5% level of significance	1% level of significance
Height ..	8	197.31	24.66	59.71**	208.08	26.01	88.47**	1.97	2.57
Date ..	14	687.37	49.09	118.86**	1420.74	101.48	345.17**	1.73	2.14
Environment..	3	1560.67	520.22	259.61**	741.03	247.01	840.17**	2.63	3.85
Height x Date	112	56.40	0.50	1.21	41.13	0.37	1.26	1.29	1.45
Height x Environment.	24	483.69	20.15	48.75**	72.98	3.04	10.34**	1.55	1.86
Date x Environment.	42	478.49	11.39	27.58**	140.98	3.36	11.43**	1.43	1.66
Error ..	336	138.63	0.413		93.70	0.294			
Total .....	539	3602.56			2723.64				

\*\* Significant at 1% level.



TABLE X

## Analysis of Variance

Dry Bulb Temperature and Vapour Pressure at different heights in the "open" and inside Cotton during the period 17-3-1942 to 31-3-1942 at the Maximum Temperature Epoch.

Due to	Degrees of freedom	Dry Bulb Temperature			Vapour Pressure			Value of "F" for	
		Sum of squares	Mean square	Variance ratio	Sum of squares	Mean square	Variance ratio	5% level of significance	1% level of significance
Height ..	8	1259.70	157.46	60.56**	187.91	23.48	71.36**	2.02	2.67
Date ..	14	557.30	39.81	15.30**	281.90	20.14	61.22**	1.78	2.24
Environment .	1	70.23	70.23	27.01**	100.71	100.71	306.11**	3.93	6.87
Height x Date	112	136.09	1.21	0.46	75.86	0.68	2.07**	1.38	1.57
Height x Environment.	8	5.82	0.73	0.28	15.89	1.99	6.05**	2.02	2.67
Date x Environment.	14	134.96	9.64	3.71**	47.76	3.41	10.36**	1.78	2.24
Error ..	112	291.73	2.604		36.83	0.329			
Total ..	269	2455.83			746.86				

\*\* Significant at 1% level.

TABLE XI

Correlation "r" during the period 1-8-1941 to 31-8-1941 between Air Temperature and Vapour Pressure respectively in the "open" with those recorded inside crops.

Height above ground level	Correlation of dry bulb temperature in the open with those inside			Correlation of Vapour pressure in the open with those inside				
	Jowar	Suran	Sugarcane	Jowar	Suran	Sugarcane		
	Minimum Temperature Epoch							
Surface ..	..	..	.95	.96	.90	.88	.85	.86
1" ..	..	..	.95	.95	.94	.91	.94	.90
3" ..	..	..	.94	.95	.94	.92	.92	.91
6" ..	..	..	.92	.94	.93	.91	.91	.90
1 Foot ..	..	..	.93	.94	.92	.89	.91	.87
2 Feet ..	..	..	.94	.94	.91	.91	.96	.89
3 Feet ..	..	..	.93	.90	.92	.92	.92	.89
4 Feet ..	..	..	.94	.93	.88	.90	.91	.88
6 Feet ..	..	..	.95	.95	.92	.91	.92	.88
	Maximum Temperature Epoch							
Surface ..	..	..	.83	.81	.67	.85	.63	.62
1" ..	..	..	.81	.82	.69	.77	.72	.51
3" ..	..	..	.82	.85	.72	.85	.83	.52
6" ..	..	..	.88	.86	.77	.81	.81	.54
1 Foot ..	..	..	.89	.88	.80	.79	.77	.60
2 Feet ..	..	..	.89	.86	.79	.82	.83	.69
3 Feet ..	..	..	.90	.86	.85	.89	.86	.70
4 Feet ..	..	..	.91	.85	.88	.88	.88	.71
6 Feet ..	..	..	.89	.87	.84	.86	.85	.77

For 5% level of significance  $r = .36$  and for 1% level of significance  $r = .46$

TABLE XII

Correlation " $r$ " during the period 1-12-1936 to 3-1-1937 (Except 23rd, 24th and 31st Dec.) between Air Temperature and Vapour Pressure respectively in the "open" with those recorded inside crops.

Height above ground level			Correlation of Dry Bulb Temperature in the open with those inside			Correlation of Vapour Pressure in the open with those inside		
			Jowar	Cotton	Sugarcane	Jowar	Cotton	Sugarcane
Minimum Temperature Epoch								
Surface	..	..	.97	.97	.97	.92	.91	.96
1"	..	..	.97	.97	.98	.97	.87	.97
3"	..	..	.99	.97	.93	.95	.93	.96
6"	..	..	.98	.97	.99	.97	.94	.97
1 Foot	..	..	.99	.97	.97	.93	.93	.95
2 Feet	..	..	.93	.97	.97	.97	.94	.95
3 Feet	..	..	.93	.95	.97	.97	.96	.96
4 Feet	..	..	.96	.93	.91	.98	.96	.97
6 Feet	..	..	.97	.93	.96	.97	.97	.96
Maximum Temperature Epoch								
Surface	..	..	.50	.70	.03	.90	.90	.83
1"	..	..	.40	.66	.10	.87	.91	.83
3"	..	..	.41	.62	.15	.85	.92	.83
6"	..	..	.53	.63	.20	.90	.94	.82
1 Foot	..	..	.56	.66	.20	.89	.93	.86
2 Feet	..	..	.54	.67	.22	.90	.93	.90
3 Feet	..	..	.56	.71	.37	.90	.93	.92
4 Feet	..	..	.52	.70	.41	.95	.92	.92
6 Feet	..	..	.53	.75	.57	.94	.91	.94

For 5% level of significance  $r = .36$  and for 1% level of significance  $r = .46$ .

TABLE XIII

Correlation " $r$ " during the period 17-3-1942 to 16-4-1942 between Air Temperature and Vapour Pressure respectively in the "open" with those recorded inside cotton crop.

Height above ground level			Minimum Temperature Epoch		Maximum Temperature Epoch	
			Dry bulb temperature	Vapour pressure	Dry bulb temperature	Vapour pressure
Surface	..	..	.93	.93	.70	.92
1"	..	..	.94	.98	.69	.92
3"	..	..	.95	.93	.63	.89
6"	..	..	.93	.98	.63	.92
1 Foot	..	..	.92	.93	.62	.93
2 Feet	..	..	.92	.93	.57	.89
3 Feet	..	..	.92	.99	.61	.95
4 Feet	..	..	.93	.93	.64	.96
6 Feet	..	..	.95	.98	.64	.95

For 5% level of significance  $r = .36$  and for 1% level of significance  $r = .46$ .