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Sudden changes in crop environment, as influenced by total solar eclipse

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सार — फसल से संबंद्ध वातावरण में खग्रास ग्रहण के कारण आने वाले आकस्मिक परिवर्तनों का अध्ययन करने के लिए, अक्तूबर 1995 के दौरान, केनिंग, पश्चिम बंगाल की प्रधान वाष्पन - उत्सर्जन वेधशाला में भारत मौसम विज्ञान विभाग के पुणे स्थित कृषि मौसम विज्ञान प्रभाग द्वारा एक प्रयोग किया गया। इस अध्ययन से ग्रहण के दिन 0900 बजे (भा.मा.स.) विभिन्न ऊँचाइयों, पर फसल वितान तापमान और वेधशाला तापमान दोनों ही में लगभग 2.0° C की अचानक कमी का पता चला है। फसल वितान और वेधशाला दोनों ही में ग्रहण के दिन 0900 बजे (भा.मा.स.) सापेक्ष आर्द्रता (प्रतिशत) में भी अचानक वृद्धि हुई। ग्रहण के दिन 10 से 20 से.मी. तक जमीन के नीचे की मिट्टी में तापमान एकाएक गिरा और इससे मिट्टी के तापमान का पुनः स्थापन विलम्ब से हुआ। निम्नतम तापमान 21.2°C था। ग्रहण से पहले और बाद के दिनों की तुलना में ग्रहण के दिन धूप वाले समय में 0.8 घंटे की कमी आई। ग्रहण के दौरान 0900 से 0930 बजे (भा.मा.स.) के बीच पवन की गति लगभग स्थिर थी। ग्रहण के दिन रिकार्ड कियागया सकल दैनिक ई.टी. न्यूनतम था। ग्रहण के दिन 0830 बजे (भा.मा.स.) (0.2 एम.एम.) रिकार्ड किया गया वाष्पन-उत्सर्जन अन्य दिनों की तुलना में आधे से भी कम था और यह 11.30 बजे (भा.मा.स.) (0.3 एम.एम.) भी लगभग इतना ही पाया गया।

ABSTRACT. The Division of Agricultural Meteorology, at Pune of IMD conducted an experiment at Principal Evapotranspiration Observatory, Canning, W.B., during October, 1995 to study the sudden changes in crop environment. The present study revealed that both the crop canopy temperature and observatory temperature at different heights recorded sharp fall of around 2.0°C at 0900 hr (IST) on the eclipse day. The relative humidity (%) increased sharply at 0900 hr (IST) on the eclipse day within crop canopy as well as within observatory. The soil temperature dropped suddenly at 10 and 20 cm depths of the subsoil and delayed reversal of the soil temperature gradient occurred on the eclipse day; the grass minimum temperature was 21.2°C. Bright sunshine hours reduced by 0.8 on the eclipse day as compared to the preceding and succeeding days. The wind during the eclipse period was almost calm between 0900 - 0930 hr(IST). The daily total ET recorded on the eclipse day was the minimum. The rate of evapotranspiration was less than half as compared to the other days, as recorded at 0830 hr(IST) (0.2 mm) on the eclipse day, which was closely followed by that observed at 1130 hr(IST) (0.3 mm).

Key words — Total solar eclipse, Crop canopy, Soil temperature gradient, Grass minimum temperature, Subsoil, ET (Evapotranspiration).

1. Introduction

On 24 October, 1995, the moon's shadow blackened out the rising sun for few seconds along a 14000 km path from central Iran to south China sea including the Indian subcontinent, covering a 46 km strip from Bikaner in Rajasthan to Diamond Harbour in W.B. The eclipse of 24 October, 1995 started in India, at around 0723 hr(IST) and ended at around 1019 hr(IST) with the duration of total eclipse varied between 48 seconds in Rajasthan to 82 seconds in W.B.

The total eclipse was of great importance to agrometeorologists because it was equivalent to a very short phase of night time conditions during the day. Radiation activated physiological, biochemical processes in plants were expected to show sudden response. Light, its duration, intensity, quality, nature of receipt and distribution has obvious impact on meteorological / micrometeorological parameters which directly or indirectly influences many phases of plant growth and development, temporarily. Changes in atmospheric parameters as influenced by total eclipse were expected to have some effect on crop behaviour on the eclipse day as compared to the preceding and succeeding days.

The changed environmental elements as a result of total solar eclipse and their temporary effects on crop growth were complex because in field, the crops were always subjected to a constant interaction with various combinations of elements. It was observed that in general, at extremely low radiation intensity the photosynthetic efficiency reduced. The crop productivity decreased at low temperatures.

TABLE 1 (a - h)

Agrometeorological observations during the total solar eclipse of 24 October, 1995

Date 1995	Hours (IST) of observations																
	0530	0630	0730	0800	0830	0900	0930	1000	1030	1130	1230	1330	1430	1530	1630	1730	mean
(a) Mean crop canopy temperature (°C)																	
23 Oct	25.0	26.8	26.8	-	30.3	-	30.6	-	29.8	31.7	31.5	29.6	31.0	29.2	26.1	26.4	28.8
24 Oct	23.5	25.0	25.7	26.3	26.4	25.6	27.8	27.4	29.0	28.4	30.5	28.5	29.2	28.2	24.7	25.0	27.0
25 Oct	20.5	21.6	22.4	-	22.5	-	24.9	-	26.4	30.0	29.7	29.8	28.1	27.0	25.0	25.8	25.7
(b) Mean crop canopy relative humidity (%)																	
23 Oct	98.7	96.0	98.0	-	81.3	-	74.7	-	87.7	74.3	79.0	84.0	78.7	72.3	91.0	90.7	85.1
24 Oct	93.0	91.7	89.3	86.7	82.3	97.0	91.7	93.0	76.7	80.7	77.0	77.7	72.3	67.3	88.3	93.3	84.9
25 Oct	84.3	96.0	93.3	-	92.3	-	80.7	-	82.7	70.7	70.0	65.7	73.0	78.0	86.7	75.3	80.7
(c) Mean vapour pressure (mm of water)																	
23 Oct	23.5	25.4	26.0	-	26.4	-	24.6	-	27.6	26.1	27.3	26.1	26.5	22.0	23.1	23.4	25.2
24 Oct	20.2	21.9	22.2	22.3	21.3	24.0	25.6	25.5	22.9	23.4	25.2	22.7	22.1	19.4	20.6	21.1	22.6
25 Oct	15.3	18.5	19.0	-	19.0	-	19.0	-	21.4	22.4	22.0	20.7	20.8	21.0	20.6	18.8	19.9
(d) Air temperature (°C) observed at 2.0 m height within observatory																	
22 Oct	25.5	26.5	26.4	-	27.4	-	29.0	-	30.2	29.0	30.1	30.4	29.5	29.5	27.5	28.0	28.4
23 Oct	25.4	26.0	27.4	-	28.6	-	29.5	-	31.5	30.5	31.5	32.0	30.0	31.0	27.2	25.5	28.9
24 Oct	24.6	24.0	26.0	26.5	26.5	24.8	26.7	26.5	30.2	29.7	27.6	27.5	31.3	29.7	26.0	25.8	27.1
25 Oct	21.5	21.9	24.5	-	24.5	-	25.0	-	25.4	29.0	29.2	29.0	29.8	28.8	28.4	25.9	26.4
26 Oct	20.0	21.2	22.8	-	24.8	-	24.5	-	24.7	28.3	30.9	31.1	30.0	30.4	28.0	25.7	26.3
(e) Air temperature (°C) observed at 3.0 m height within observatory																	
22 Oct	25.0	26.2	26.0	-	27.0	-	29.0	-	30.0	28.5	30.0	30.1	29.4	29.4	27.0	27.8	28.1
23 Oct	25.2	26.0	27.2	-	28.3	-	29.3	-	30.8	30.3	31.1	31.5	29.5	30.5	26.7	25.4	28.6
24 Oct	24.3	23.8	25.8	26.3	26.2	24.5	26.6	26.3	29.0	29.0	27.6	27.0	30.9	29.4	25.5	25.6	26.7
25 Oct	21.0	21.8	24.1	-	24.0	-	24.5	-	25.0	28.5	29.1	28.5	29.6	28.5	28.0	25.7	26.0
26 Oct	19.8	20.8	22.0	-	24.5	-	24.5	-	24.6	27.6	30.0	29.5	28.0	28.2	27.9	25.5	25.6
(f) Relative humidity (%) observed at 2.0 m height within observatory																	
22 Oct	96	91	97	-	92	-	86	-	79	76	72	74	76	74	89	93	84
23 Oct	98	93	87	-	81	-	79	-	74	67	62	68	77	64	84	94	79
24 Oct	80	92	91	86	83	97	80	83	60	62	81	72	52	59	83	81	78
25 Oct	80	76	60	-	69	-	70	-	76	57	56	66	53	58	61	71	66
26 Oct	95	94	89	-	78	-	82	-	88	61	51	51	50	53	59	73	71
(g) Relative humidity (%) observed at 3.0 m height within observatory																	
22 Oct	98	91	96	-	89	-	83	-	79	78	72	66	75	73	92	90	83
23 Oct	98	93	87	-	79	-	76	-	73	67	61	71	79	64	86	92	79
24 Oct	82	93	90	83	80	97	80	83	63	65	80	71	51	59	85	81	78
25 Oct	82	73	62	-	67	-	69	-	74	57	54	66	51	58	59	68	65
26 Oct	95	93	92	-	81	-	81	-	87	59	53	59	59	62	58	74	73
(h) Mean soil temperature (°C) profile upto 20 cm depth																	
22 Oct	27.2	27.3	26.7	-	27.4	-	28.3	-	28.7	29.2	29.7	30.0	30.0	30.0	29.8	29.5	28.8
23 Oct	27.4	27.6	27.1	-	27.2	-	27.3	-	28.4	29.0	29.7	29.7	29.8	29.7	29.5	28.6	28.5
24 Oct	25.7	25.8	26.0	26.1	26.3	26.4	26.2	26.6	27.0	27.8	28.4	28.7	28.9	28.9	28.8	28.2	27.2
25 Oct	24.4	24.5	25.2	-	24.8	-	25.8	-	26.2	27.0	27.6	28.1	28.3	28.4	28.0	28.3	26.7
26 Oct	24.2	24.3	24.4	-	25.0	-	25.4	-	26.7	27.1	27.7	28.2	28.4	28.5	28.2	28.1	26.6

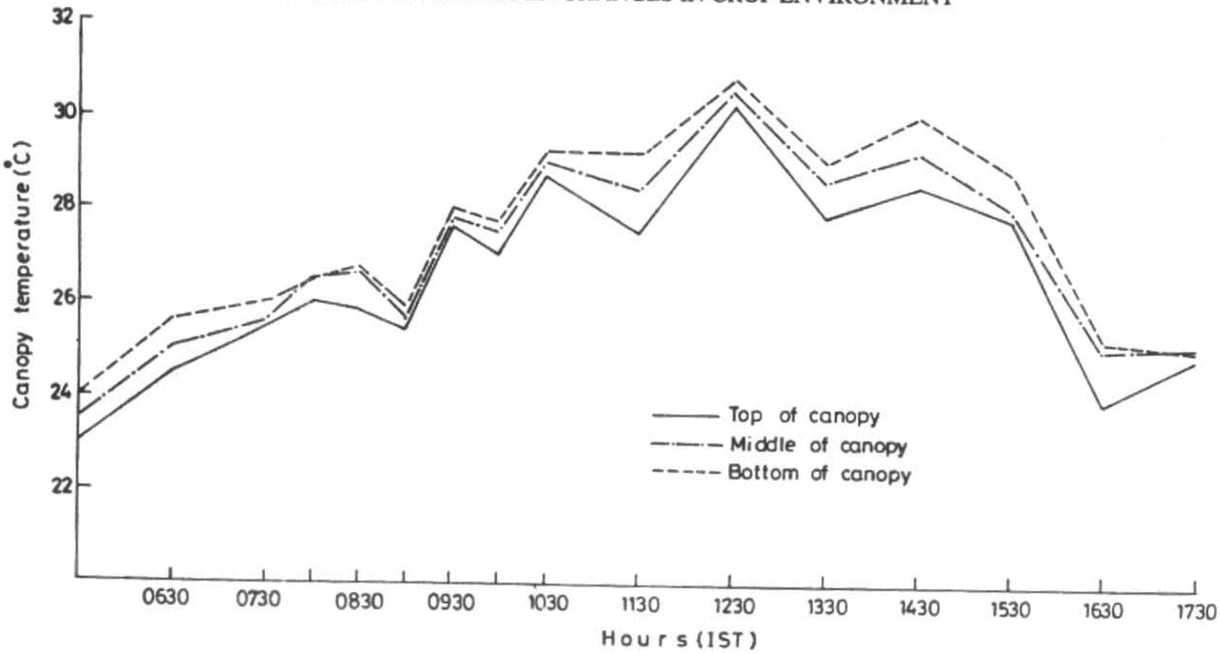

Fig.1. Rice crop canopy temperature at various levels on the solar eclipse day

The crop respiration rates also varied according to light intensity. Reduction in hours of bright sunshine as influenced by total solar eclipse could reduce productivity during the period.

The Division of Agricultural Meteorology, at Pune, of IMD undertook a study of various parameters within crop environment during the total solar eclipse period. Within the path of total eclipse, the most suitable site available is at Principal Evapotranspiration Observatory, Canning, W.B., which is adjacent to the experimental rice fields of Central Soil Salinity Research Institute. The different parameters studied were crop canopy temperature (°C), its relative humidity (%), vapour pressure (mm), observatory vertical temperature (°C) and relative humidity (%) profiles, soil temperature (°C) profiles, grass minimum temperature (°C), daily maximum and minimum temperatures (°C), bright hours of sunshine, wind speed (knots) and direction, and evapotranspiration (mm). Intensive observations were carried out with the objective of pin pointing the impact of total solar eclipse on the crop environment.

2. Methodology

2.1. *Crop canopy temperature at different heights*

Assmann psychrometer dry bulb thermometer was used for measuring rice crop canopy temperature (°C) at three different heights within canopy *viz.* bottom level (within 0-5 cm from ground level), middle (within 30-35 cm from ground level) and top (within 60-65 cm from ground level). After winding the psychrometer, sufficient time was allowed to make the dry bulb reading steady and then the temperature was recorded. The observations were recorded at hourly interval from 23 - 25 October, 1995 between 0530 to 1730 hr(IST), except on 24 October, 1995 on which the observations were taken at half - hourly interval between 0730 to 1030 hr(IST) (Fig.1). The computed mean of the canopy temperature is presented in Table 1(a).

2.2. *Crop canopy relative humidity and vapour pressure (of water) at different heights*

Assmann psychrometer dry bulb and wet bulb temperatures were recorded within the rice crop canopy, from which relative humidity (R.H. %) and vapour pressure (V.P. in mm) were computed by use of standard tables. The R.H. values were computed from 23 - 25 October, 1995 at hourly interval between 0530 to 1730 hr(IST), except between 0730 to 1030 hr(IST), observations were computed at half-hourly interval (Fig.2). The mean R.H. (%) and V.P. (mm) are determined and presented in Table 1 (b) and (c), respectively.

2.3. *Observatory vertical temperature profiles*

The vertical temperature profiles were recorded by Assmann psychrometer dry bulb thermometer at different heights *viz.* 1.0, 2.0 and 3.0 meters. After winding the psychrometer, sufficient time was given to make the dry bulb reading steady and then it was recorded. The observations were recorded at hourly interval from 22 - 26 October, 1995 between 0530 to 1730 hr(IST), except on the eclipse day between 0730 to 1030 hr(IST), the observations were recorded at half-hourly interval. The temperature observed at 1.0 m is presented in Fig.3 and that observed at 2.0 and 3.0 m heights are presented in Table 1 (d & e).

2.4. *Observatory vertical relative humidity profiles*

The R.H. (%) profiles at different heights *viz.* 1.0, 2.0 and 3.0 meters were computed (through standard tables) by use of Assmann psychrometer dry bulb and wet bulb tem-

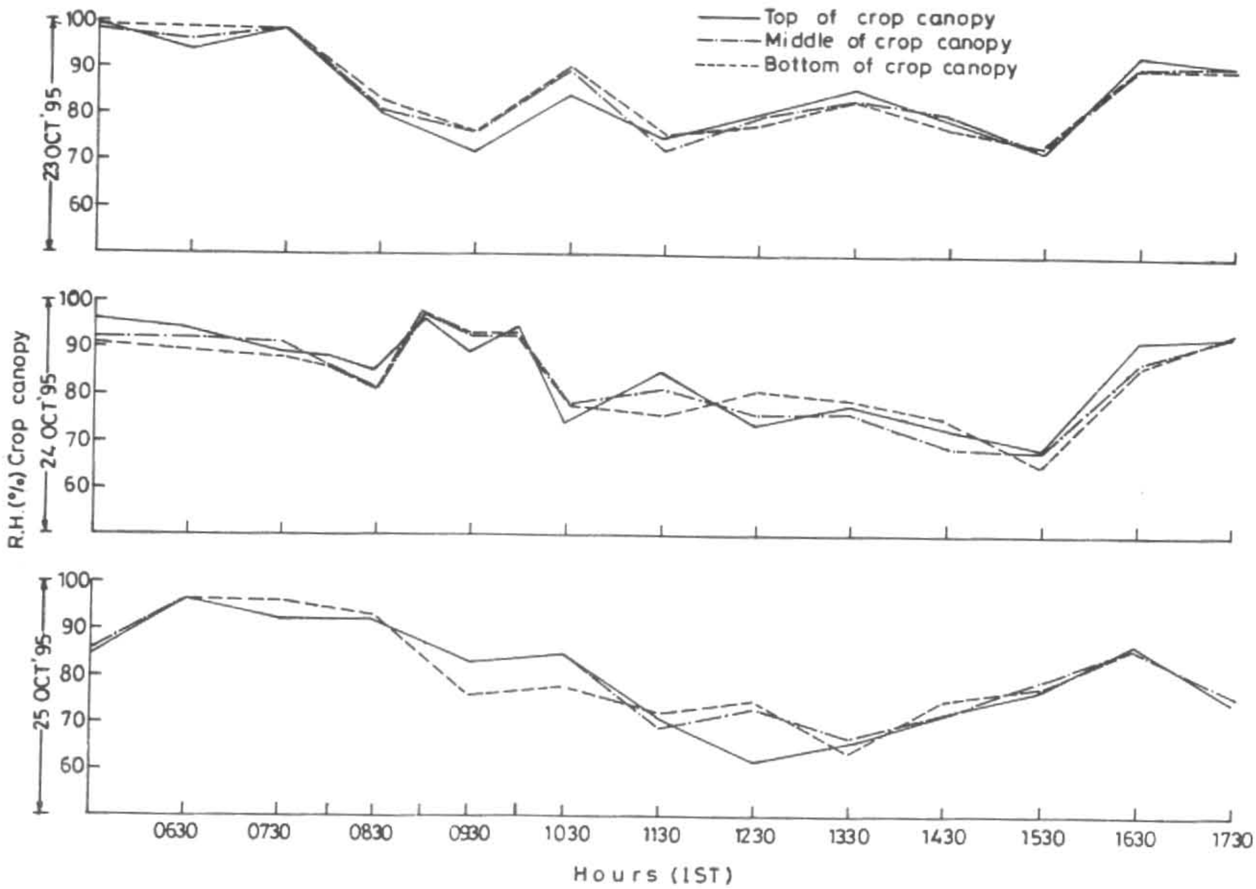

Fig.2. Rice crop canopy relative humidity as observed on the eclipse day and in the preceding and succeeding days

perature readings. The observations were taken from 22 - 26 October, 1995 at hourly interval between 0530 to 1730 hr(IST), except on 24 October, 1995 between 0730 to 1030 hr(IST), the values were computed at half- hourly interval. Observatory vertical R.H. (%) profile at 1.0 m height is presented in Fig.4 and that observed at 2.0 and 3.0 m heights are presented in Table 1(f&g).

2.5. *Soil temperature profiles*

The soil temperature profiles at 5.0, 10.0 and 20.0 cm depths were measured by mercury-in-glass soil thermometers. The thermometers were provided with an inclination of 120° with the ground. The soil temperatures were recorded from 22 - 26 October, 1995 at hourly interval between 0530 to 1730 hr(IST), except on the eclipse day between 0730 to 1030 hr (IST), the observations were taken at half-hourly interval (Fig.5). The mean of the soil temperature observed at different depths is presented in Table 1(h).

2.6. *Grass minimum temperature*

The grass minimum thermometer recorded the grass minimum temperature (°C). The sheathed minimum thermometer was exposed on a plot covered with short grass of 2.5 to 5.0 cm size within observatory. The instrument was read in the morning and reset in the evening. The reading was taken once daily from 23 - 26 October, 1995 and is presented in Table 2(a),

2.7. *The maximum and minimum temperatures*

The Stevenson's screen maximum and minimum thermometers were used for measurement of the maximum and minimum temperature during 22 - 26 October, 1995. The frequency of both the observations were once daily and are presented in Table 2(b).

2.8. *Bright sunshine hours*

Sunshine recorder was used for measurement of bright sunshine hours. The instrument was placed in such a way that the light from the sun as it passed through the glass sphere was concentrated to a point on the card and burnt it right through. The observations were recorded (in the form of burn) on short curved winter card and after computation, daily hours of bright sunshine were recorded from 22 - 26 October, 1995 and are presented in Table 2(c), Fig.6.

2.9. *Wind speed and wind direction*

Portable cup-counter anemometer and portable wind-vane (in Japanese portable kit) were used for measuring wind speed (in meter/second) and wind direction, respectively. The wind speed was converted into knots by multi-

TABLE 2

Grass minimum temperature, the maximum and minimum temperatures and bright sunshine hours as observed on the eclipse day and in the preceding and succeeding days

(a) Grass minimum temperature (°C)		(b) The Maximum and minimum temperatures (°C)			(c) Bright sunshine hours	
Date (1995)	Temperature (°C)	Date (1995)	Maximum	Minimum	Date (1995)	Hours
23 Oct	22.7	22 Oct	31.8	24.1	22 Oct	6.7
24 Oct	21.2	23 Oct	32.6	24.1	23 Oct	10.5
25 Oct	16.9	24 Oct	31.2	21.9	24 Oct	9.7
26 Oct	14.9	25 Oct	31.0	18.6	25 Oct	10.5
		26 Oct	31.5	19.0	26 Oct	10.5

plying wind speed in meter/second with 1.94. Considering the height of different crops wind profiles were measured at 1.0 m and 2.0 m heights Figs.7(a&b). Observations were recorded from 23 - 25 October, 1995 at hourly interval between 0530 to 1730 hr(IST), except on 24 October between 0730 to 1030 hr(IST), the observations were recorded at half-hourly interval.

2.10. *Evapotranspiration*

Volumetric lysimeter was used for measurement of evapotranspiration (mm). The crop plants were grown in the soil tank, sunk in the middle of the field. The float mechanism controlled the flow of water from the reservoir in such a way as to keep the water table in the tank to a desired depth. The observations were recorded from 0530 to 1730 hr(IST), at 3-hourly interval from 22 - 26 October, 1995 (Fig.8). However, the rice crop within the lysimeter tank was at harvesting stage.

3. Results and discussion

The morning sky on 24 October, 1995 witnessed the total solar eclipse. A sudden but significant, temporary change in agrometeorological parameters occurred during the eclipse period. The data are presented either in tabular forms or in the form of figures with the "cause and effect" relations.

3.1. *Crop canopy temperature at different heights*

The observations were recorded at bottom, middle and top of the canopy from 23-25 October, 1995 and observations on the eclipse day are presented in Fig.1. The bottom level of the canopy was always slightly warmer than the higher canopy levels.

On 23 October, 1995 (*i.e.* in the preceding to the solar eclipse day), the morning and afternoon temperatures were low and between 0830 to 1530 hr(IST) the temperature was greater than or equal to 29.0°C, On the eclipse day, the pattern of the preceding day temperature was almost maintained except during the eclipse period (Fig.1). A sharp drop in temperature was observed at 0900 hr (IST) (*i.e.* just after the totality phase). The temperature in the early morning and evening hours were a bit lower as compared to the preceding day and between 1030 to 1430 hr(IST) the temperature was around 29.0°C. In the succeeding day, the morning temperature was low as compared to the preceding two days, otherwise it followed the usual trend as observed on 23 October, 1995. The temperature was around 29.0°C between 1130 to 1330 hr(IST).

The mean canopy temperature as observed through Table 1(a) showed that on the eclipse day, the canopy temperature was low as compared to the preceding day. The mean canopy temperature on 24 October, 1995 showed marked fall of around 1.5 to 2.0°C at 0900 hr(IST) as compared to the temperature recorded at 0830 and 0930 hr(IST).

The temperature drop, on the eclipse day, during the eclipse period within crop canopy followed the same trend as observed within the observatory. The canopy temperature increased slightly from bottom to top, because of heat release by evaporation (of stagnant water within rice field) and transpiration (through foliages) which remained confined within the crop canopy and the top of the canopy represented the transitional layer (as interface between canopy and its upper atmosphere) where the temperature was slightly lower. The temperature drop showed a time lag of around 12 minutes from the period of total eclipse. During the period of total eclipse, sun was completely covered by the moon's shadow and thus, automatically the temperature was gradually reduced.

3.2. *Crop canopy relative humidity and vapour pressure at different heights*

The daily R.H. (%) as computed between 23 - 25 October, 1995 are presented in Fig.2. The usual trend was that during morning and evening hours the values were high and during the middle of the day, values were low (as observed on 23 and 25 October, 1995). Within the canopy the variation was not so prominent. But on the eclipse day during eclipse period, the values increased sharply (between 0830 to 1030 hr(IST) and afterwards it followed the usual trend. The mean R.H. (%) as observed within the crop canopy (Table 1b) showed that on the eclipse day at 0900 hr(IST) the value was 97% (a rise of around 15% as compared to that observed at 0830 hr(IST).

The mean vapour pressure (V.P. in mm) computed within crop canopy (Table 1c) showed that in the morning and evening hours, the values were comparatively low which increased as the day approached noon time observation. On the eclipse day, the V.P. increased sharply between 0830 to 1030 hr(IST).

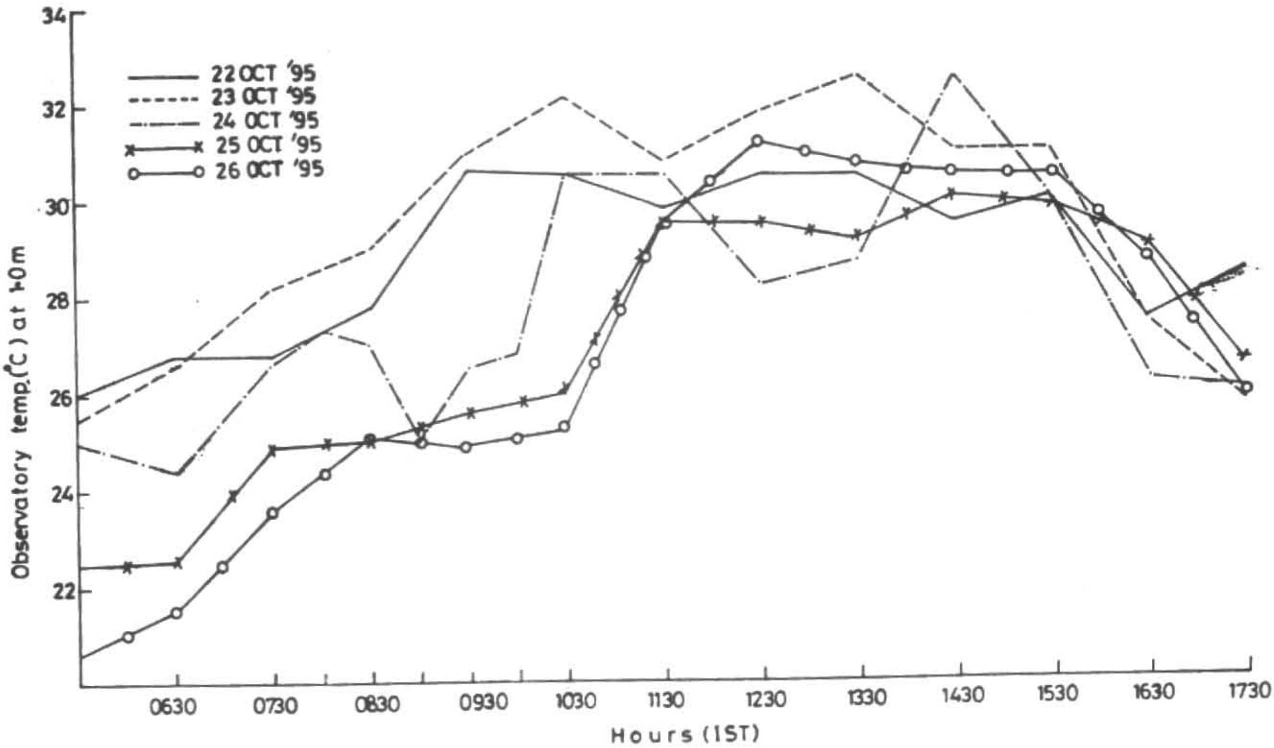

Fig.3. Observatory air temperature at 1.0 m height on the solar eclipse day and in the preceding and succeeding two days

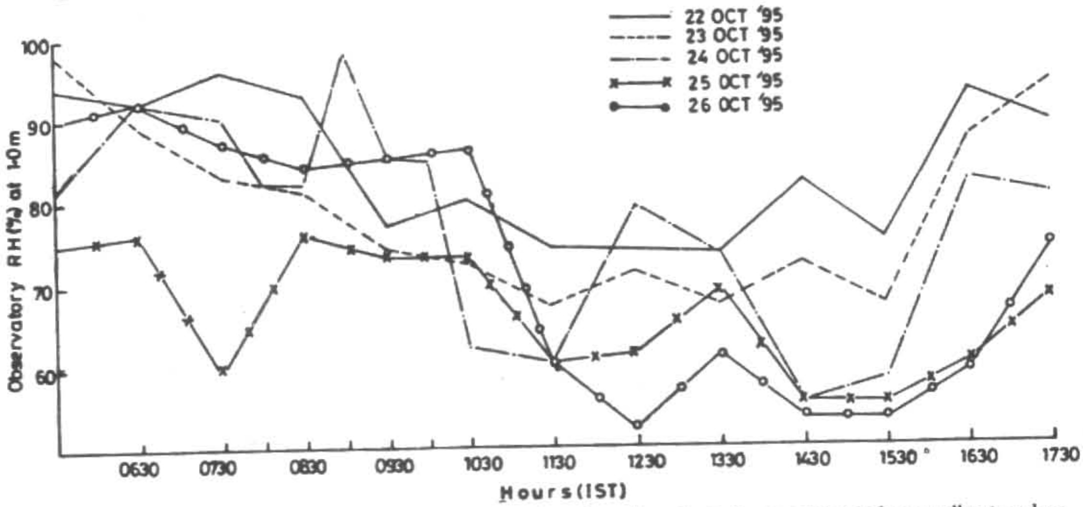

Fig.4. Observatory relative humidity at 1.0 m height, on the solar eclipse day in the preceding and succeeding two days

On the eclipse day, during eclipse period, both the R.H. (%) and V.P. (mm) increased sharply with the sharp drop in temperature during that period.

3.3. *Observatory vertical temperature profiles*

The usual trend of air temperature within observatory was, low temperature during early morning and evening hours and high temperature between 1130 to 1530 hr(IST). On 24 October 1995, at 1.0 m layer, the temperature reduced sharply, the maximum drop of around 2.0°C was observed at 0900 hr(IST) and afterwards it followed the usual trend (Fig.3). The observatory air temperature decreased slightly with height, otherwise the trend was almost similar at 2.0 and 3.0 m layers (Table 1 d&e) as compared to that observed at 1.0 m layer. The temperature recorded at 0900 hr(IST) at different layers were 25.0°C (at 1.0 m), 24.8°C (at 2.0 m) and 24.5°C (at 3.0 m). The mean air temperature on the eclipse day was low as compared to the preceding two days. However, in the succeeding two days the temperatures were lower as compared to that observed on 24 October 1995.

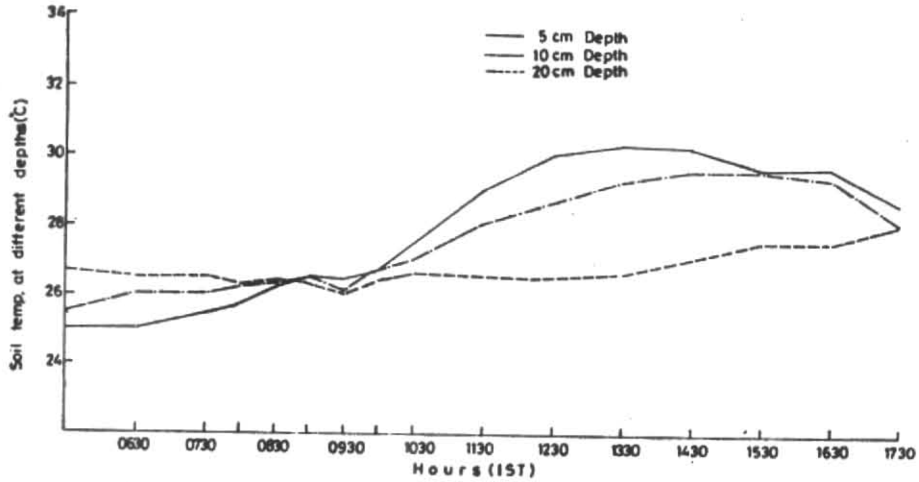

Fig.5. Soil temperature at different depths as observed on 24 October, 1995 (the solar eclipse day)

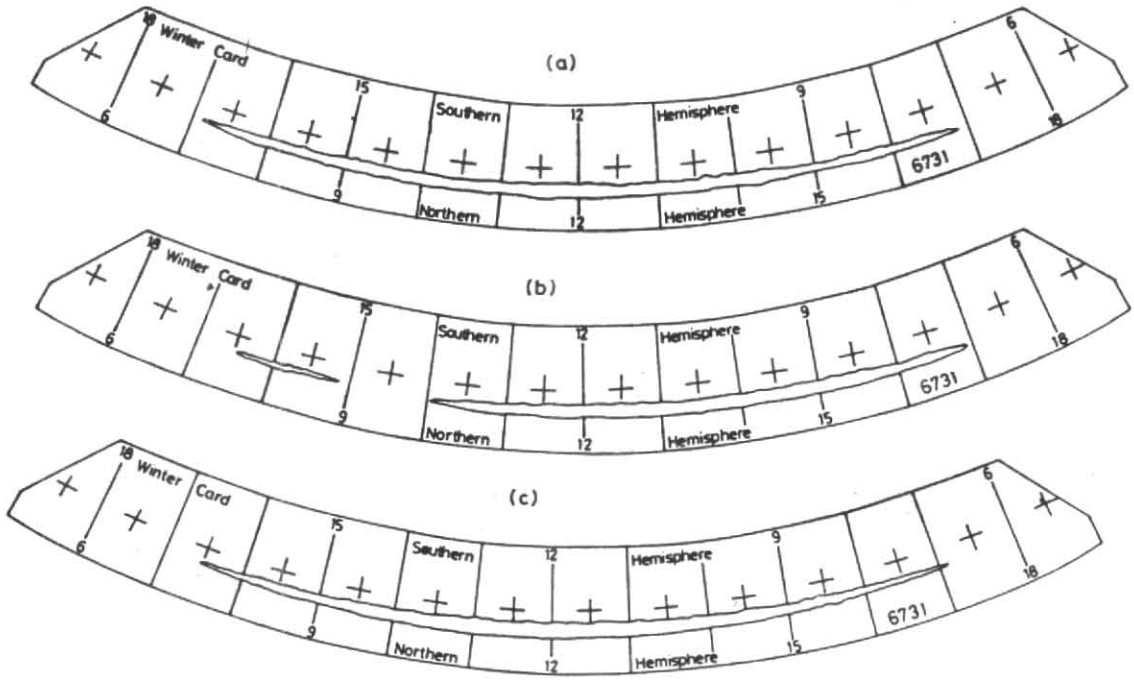

Fig.6. Hours of bright sunshine as recorded by sunshine recorder (A-23 October, 1995, B-24 October, 1995, C-25 October, 1995

The air temperature within observatory reduced after 0800 hr(IST) just after the commencement of solar eclipse. With the increase in proportion of sun covered by the moon's shadow, the percentage cut of the solar energy reaching earth also increased with a few minutes lag. The phenomenon of total solar eclipse occurred at 0848 hr (IST) and the maximum fall occurred at 0900 hr(IST) (for all the layers). The fall in temperature in the succeeding two days were neither because of total solar eclipse nor because of early winter; it was due to other phenomenon as reported by India Meteorological Department (IMD) Alipore, West Bengal.

3.4. *Observatory vertical relative humidity profiles*

The observatory R.H. (%) was high in the early morning and in evening hours and in the mid-day, values were low for all the five day studied from 22 - 26 October, 1995. On the eclipse day at 1.0 m layer, during the eclipse period, the values showed sharp rise from 0830 to 0900 hr(IST) (the increase was around 16%) and afterwards, the values followed the usual trend (Fig.4). The observatory R.H.(%) maintained the same trend at 2.0 and 3.0 m heights (Table 1 f&g), to that observed at 1.0 m height. The sharp rise of around 14% was observed at 0900 hr(IST) in 2.0 m layer, as compared to 0830 hr(IST) observation, while during the

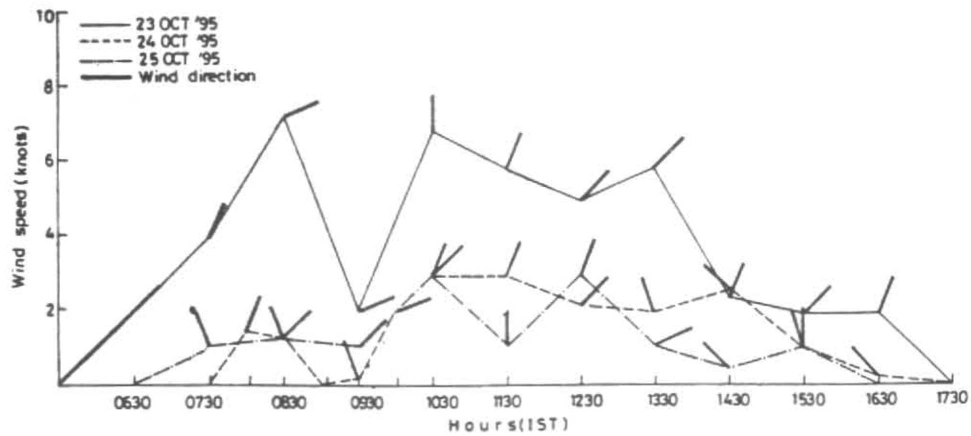

Fig.7(a). The wind profile (its speed and direction) at 1.0 m height on the eclipse day and in the preceding and succeeding days

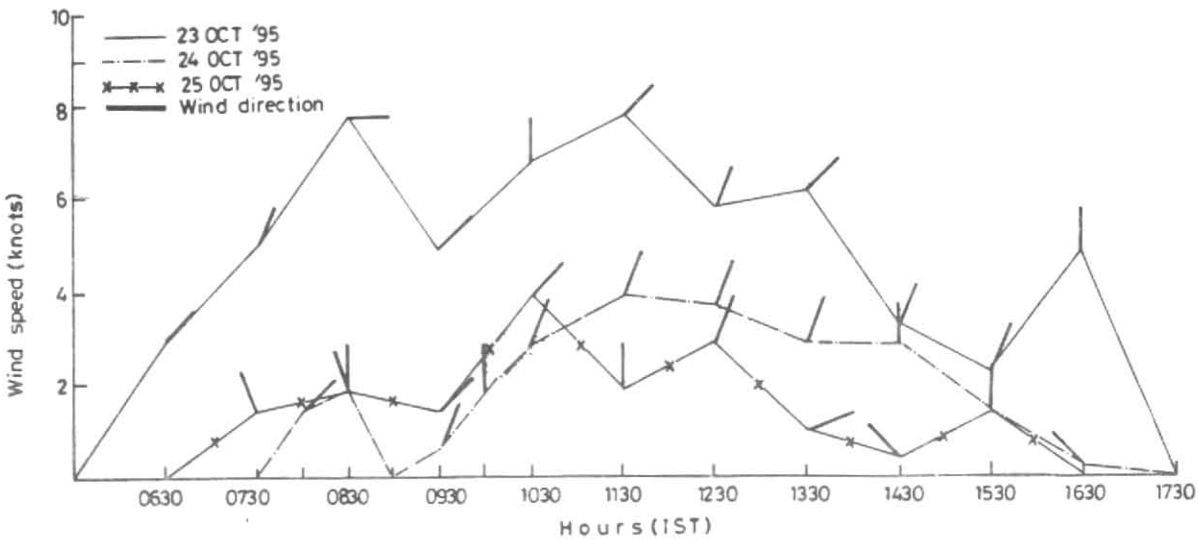

Fig.7(b). The wind profile (its speed and direction) at 2.0 m height on the eclipse day and in the preceding and succeeding days

same time on the eclipse day at 3.0 m layer, the rise was 17% as compared to the value observed at 0830 hr(IST).

The reason for sharp rise in R.H. (%) within observatory was the same to that observed within crop canopy. With the sharp drop in temperature during the eclipse period, the R.H. (%) increased sharply.

3.5. *Soil temperature profiles*

The soil temperatures (°C) was observed at 5.0, 10.0 and 20.0 cm, showed that the mean soil temperature of different layers, was higher in the preceding two days as compared to the eclipse day, while the succeeding two days recorded lower average soil temperature (Table 1h). The usual trend was, initially, in the morning hours, soil temperature was low, with the warning of the earth (during day time) gradually the temperature within the subsoil increased and attained the peak between 1430 to 1530 hr(IST) and afterwards it decreased.

On 22 and 23 October 1995, in the early morning at 0530 and 0630 hr(IST) soil temperature was higher at 20.0 cm depth as compared to the 5.0 or 10.0 cm depth soil layer and the reversal of temperature gradient occurred after 0730 hr(IST) from which time, the top soil became warmer till 1730 hr(IST) observation. On 25 and 26 October, 1995, the reversal of soil temperature gradient occurred between 0730 to 0830 hr(IST). However, on the eclipse day, the soil temperature at 20.0 cm soil depth was higher as compared to 5.0 or 10.0 cm depth soil layer upto 0830 hr(IST) and between 0900 to 1000 hr(IST) the variation in soil temperature among different layers were negligible (Fig.5). Therefore, the true reversal of soil temperature gradient occurred after 1000 hr(IST). Afterwards, till the evening (1730 hr IST)observations, 5.0 cm depth soil layer maintained the higher temperature, followed by 10.0 cm depth soil layer in comparison with the 20.0 cm depth soil layer. On the eclipse day, a sudden temperature drop was observed at 0930 hr

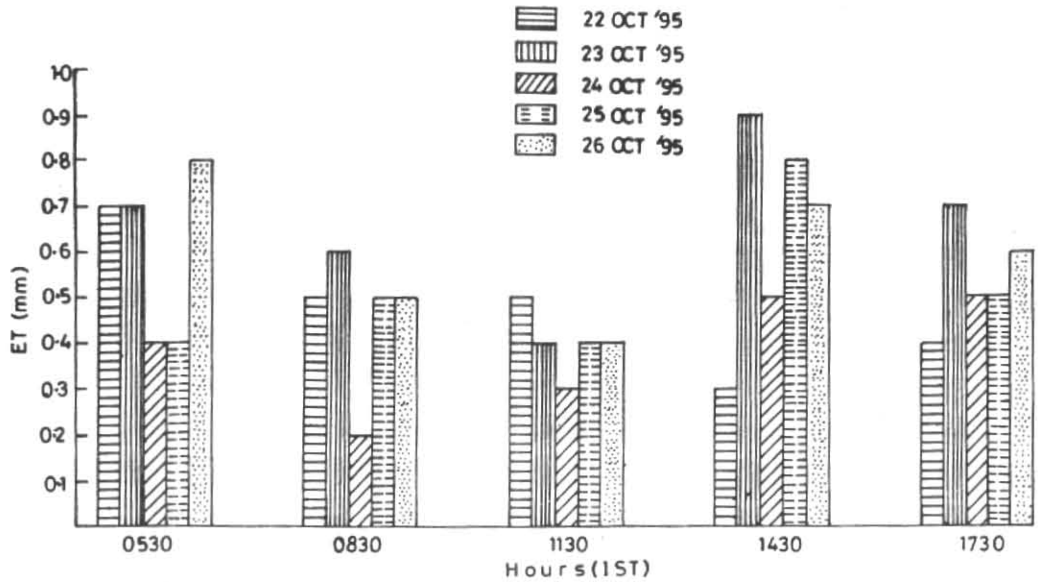

Fig.8. Evapotranspiration at 3-hourly interval on the eclipse day and in the preceding and succeeding days

(IST). The soil temperature drop was around 0.4 to 0.5°C which was prominent at 10.0 and 20.0 cm soil depths.

The solar energy reached the earth's surface which flowed downward from the surface layer to the deeper subsoil during day time. The reverse was the case during night time when heat energy flowed from deeper subsoil to the surface layers which continued even in the early morning. Thus, when the earth's surface was sufficiently heated, the reversal of soil temperature gradient occurred, as observed during the experimental period. But, on the eclipse day, the process of reversal of temperature was delayed because in the morning hours, source of energy was cut-off for sometime. The drop in soil temperature was observed at 0930 hr(IST) though the event occurred at 0848 hr(IST). This time lag was because the heat energy flowed from surface layer to the deeper subsoil which took some time.

3.6. *Grass minimum temperature*

The grass minimum temperature (°C) which gave the idea about the occurrence of ground frost, were recorded during the experimental period (Table 2). The temperature recorded on the eclipse day was 21.2°C, which was lower than the preceding days grass minimum temperature. In the succeeding days the values were further lower as compared to that observed on the eclipse day (apparently there was no effect on grass minimum temperature).

3.7. *The maximum and minimum temperatures*

The daily maximum and minimum temperatures (°C) as observed during the experimental period are presented in Table 2(b). The maximum temperature recorded during the period showed only slight variation among the days, while the minimum temperature varied significantly. The minimum temperatures recorded in the preceding two days were higher as compared to that observed on the eclipse day and the succeeding two days recorded further lowering in minimum temperature. The maximum and the minimum temperatures recorded on the eclipse day were 31.2°C and 21.9°C, respectively. Thus, the solar eclipse resulted in greater fluctuation in daily temperature pattern.

3.8. *Bright sunshine hours*

The hours of bright sunshine were recorded (in the form of burn) on the sunshine card and are presented in Fig.6, Table 2(c). On 22 October, 1995, because of the dense cloud cover, the bright sunshine hours were less, while on 23, 25 and 26 October, 1995, the hours of bright sunshine were the same (10.5 hr). However, on the eclipse day the hours of bright sunshine was less (only 9.7 hr).

During the eclipse period because of total eclipse, the concentration of light energy was insufficient to cause burn over the card which reduced the hours of bight sunshine by 0.8 hr (equivalent to 48 minutes).

3.9. *Profiles of wind speed and wind direction*

The wind profile observed at 1.0 m height was lower as compared to that observed at 2.0 m height [Fig.7(a&b)]. The wind was calm upto 0730 hr(IST) and also at 1730 hr(IST) on the eclipse day. The wind speed reduced after 0830 hr(IST) on the eclipse day and between 0900 and 0930 hr(IST) the wind speed was approximately zero and from 1000 hr(IST) wind started blowing with increasing speed. The pattern was almost similar for both 1.0 and 2.0 m air layers.

The northerly wind component was prevalent at both 1.0 and 2.0 m air layers. The wind direction on the eclipse day at different hours of observations were NNE (at 1.0m), NE (at 2.0 m); NNW (at 1.0 and 2.0 m); calm (at 1.0 and 2.0 m); NNW (at 1.0 m), NNE (at 2.0 m); ENE (at 1.0 m), N (at

2.0 m) and NNE (at 1.0 and 2.0 m) at 0800, 0830, 0900, 0930, 1000 and 1030 hr(IST) respectively.

On the eclipse day, as the moon's shadow gradually covered the sun with the commencement of solar eclipse, the heat source was cut-off, which might be the cause of lesser air movement during the eclipse period.

3.10. *Evapotranspiration (ET)*

The evapotranspiration (mm) values were recorded during the study period and are presented in Fig.8. The lowest ET was recorded at 0830 hr (IST) (0.2 mm), closely followed by that observed at 1130 hr(IST) (0.3 mm), while in the other days at 0830 and 1130 hr(IST), the ET values were ≥ 0.5 and ≥ 0.4 mm, respectively. The total daily ET on the eclipse day was the lowest (1.9 mm) in comparison with the preceding and succeeding days.

4. Conclusions

The present study of the total solar eclipse in relation to crop environment revealed the following conclusions:

(*i*) A sharp temperature drop was observed at 0900 hr(IST) on the eclipse day within the crop canopy. The mean canopy temperature was low through out the day and marked fall of around 1.5 and 2.0°C was observed at 0900 hr(IST) on 24 October, 1995. The bottom of the canopy level maintained slight higher temperature during the experimental period.

(*ii*) The R.H.(%) within rice crop canopy increased sharply between 0830 to 1030 hr(IST) on the eclipse day. The mean R.H.(%) within the crop canopy recorded the peak of 97% (an increase of 15% as compared to that observed at 0830 hr(IST) at 0900 hr(IST). The variation in R.H.(%) at different levels within the crop canopy was not so prominent. On the eclipse day, the vapour pressure increased sharply between 0830 to 1030 hr(IST).

(*iii*) The observatory vertical temperature profiles at (1.0, 2.0 and 3.0 m) as observed on the eclipse day, also recorded sharp drop of around 2.0°C at 0900 hr(IST). The observatory air temperature decreased slightly with height and the mean air temperature on the day was lower as compared to the preceding two days.

(*iv*) The R.H. (%) profiles observed with in the observatory, at 1.0, 2.0 and 3.0 m heights, recorded sharp rise of around 14 to 17% at 0900 hr (IST) as compared to that observed at 0830 hr(IST) on 24 October, 1995.

(*v*) The soil temperature profiles as observed on the eclipse day (at 5.0, 10.0 and 20.0 cm depths of subsoil) recorded a sudden temperature drop, at 0930 hr(IST) (of around 0.4 to 0.5°C) which was most conspicuous at 10.0 and 20.0 cm depths of the subsoil. Delayed reversal of soil temperature gradient occurred on the eclipse day (after 1000 hr(IST).

(*vi*) The grass minimum temperature on the eclipse day was 21.2°C which was lower than the preceding day, grass minimum temperature.

(*vii*) The minimum temperature observed on the eclipse day was lower as compared to the minimum temperatures of preceding two days though the maximum temperature recorded during the study period showed negligible variation among the days.

(*viii*) Hours of bright sunshine reduced by 0.8 hr (equivalent to 48 minutes) on the eclipse day as compared to the preceding and succeeding days.

(*ix*) The profiles of wind as observed at 1.0 and 2.0 m air layers recorded reduced wind speed after 0830 hr(IST) on the eclipse day and between 0900 to 0930 hr(IST) the wind speed was approximately zero. The northerly wind component was prevalent at both 1.0 and 2.0 m air layers, on 24 October, 1995.

(*x*) The minimum ET value (*i.e.* 0.2 mm, which was less than half as compared to the other days) was recorded at 0830 hr(IST) on the eclipse day, closely followed by that observed at 1130 hr(IST) (0.3 mm). The total daily ET observed on the eclipse day (1.9 mm) was also the minimum in comparison with the preceding and succeeding days.

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