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The control of the micro-climate for given practical purposes

A. K. MALLIK

Meteorological Office, Poona

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ABSTRACT. Experiments carried out at the Central Agricultural Meteorological Observatory show that it is possible to lower or raise the temperature of the soil surface quite appreciably by covering with a layer of chalk powder or charcoal powder respectively. A thin cover of vegetation further lowers the soil temperature. It is also noted that a thin layer of chalk can bring about an appreciable reduction of evaporation from the soil. Experiments in "orchard heating" indicate the possibility of minimising frost damage by controlling air temperature during cold waves.

A brief account is also given of a micro-climatic test for drought resistance by subjecting two lots of plants to the conditions in two artificially produced environments, *viz.*, one in which air is hot and dry and another in which the air is kept cool and humid within an enclosure of wet screens. It is found that plants which are drought-resistant have a control on transpiration while non-resistant types do not indicate such control. By comparing the transpiration ratio with the evaporation ratio it is possible to identify the resistant from the non-resistant varieties. It takes about one week per lot of plants, to complete the above test.

1. Introduction

Work done [1–5] during the past few years at the Central Agricultural Meteorological Laboratory at Poona has shown how crops tend to alter the general or *macro-climate* and develop their own *micro-climates*. In the course of biological investigations, it is often necessary to create some suitable micro-climate for experimental purposes. The construction of suitable chambers with controlled temperature, humidity etc., are examples of such attempts to create a desired micro-climate for carrying on some scientific investigations. Such control chambers which are in use in many laboratories require elaborate arrangements and are too costly to be within the means of the common experimenter. In this paper certain simple and comparatively inexpensive methods of partially controlling the micro-climate for given practical purposes are described in the hope that these may be found useful by biological workers.

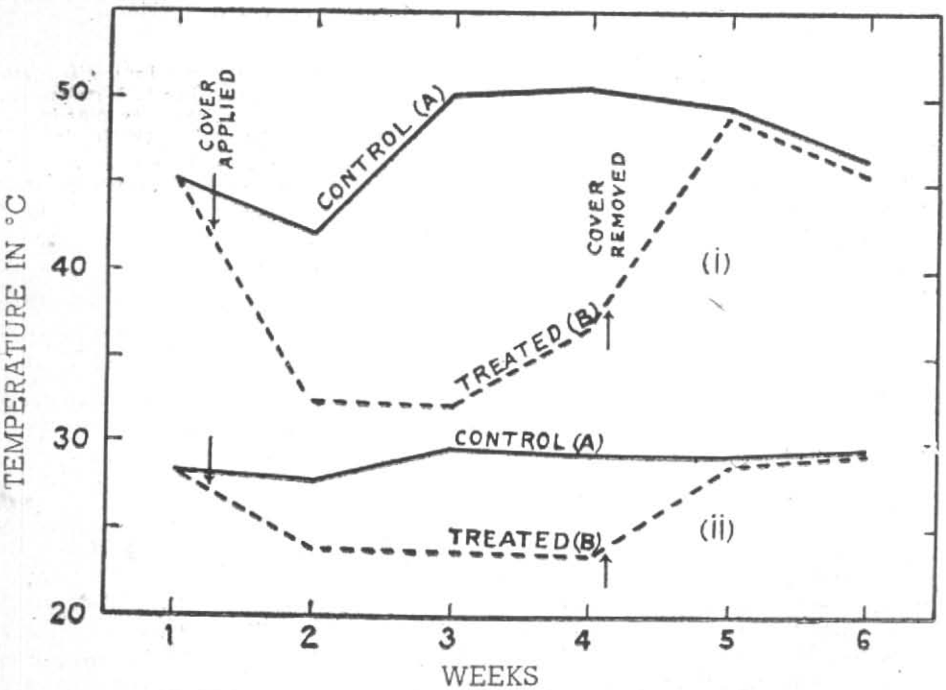
2. The control of soil temperature

(i) *By changing the surface colour*

Of all the factors affecting the temperature of the soil surface, the '*albedo*' is one of the most important. This factor determines the fraction of the incident solar radiation which the soil surface can absorb. Thus, a perfectly white surface would not absorb any incoming radiation and so will not undergo any significant rise in temperature. A black surface, on the other hand, by absorbing a considerable portion of the incident radiation, will attain high temperatures. Experiments were laid out at the Central Agricultural Meteorological Observatory, Poona, to find out how far the soil temperature can be modified by the application of thin surface covers of suitable colour. Blocks of the local black soil were covered with very thin layers of the red soil of Bangalore, the alluvial soil of Sakrand and the white sand of Trivandrum and by other suitable covers. Temperatures at different depths in all these soils were recorded four times a day at minimum and maximum temperature epochs and at 0900 and 1700 IST. These results have been fully discussed in a paper by Dravid[6]. Fig. 1 is a typical example of soil temperatures in two identical blocks (A and B) of the black Poona soil, the surface of one of which (B) was covered by a thin layer of French chalk powder. Fig. 2, on the other hand, gives the temperatures in the black Poona soil and in the white Trivandrum sand with the white surface covered by a thin layer of the black Poona soil. In both these cases the values refer to the maximum temperature epoch (about 1400 IST) because the effect of surface colour on the temperature of the soil is most marked at this time of the day. It will be seen from Fig. 1, that on a clear afternoon in summer at Poona the surface temperature of the black Poona soil can be lowered by about 14°C by covering the surface with a thin layer of some white powder like French chalk. This cooling effect penetrates even to a depth of 30 cm and the mean soil temperature between surface and depth of 30 cm is lowered by about 5°C. On the other hand, as shown in Fig. 2, the temperatures of a white soil can be considerably increased by the application of a thin layer of some black powder like Poona soil or charcoal to the surface. Thus it is quite possible to control the temperature of some particular soil to a considerable extent by the application of surface covers of suitable '*albedo*'. Applications of the above method have been made in other countries. It was reported some years back that Russian scientists have been able to hasten maturity of the cotton crop by about 6 weeks by covering the surface of cotton fields with a thin layer of charcoal powder which helped to increase the soil temperatures considerably.

(ii) *By growing vegetation*

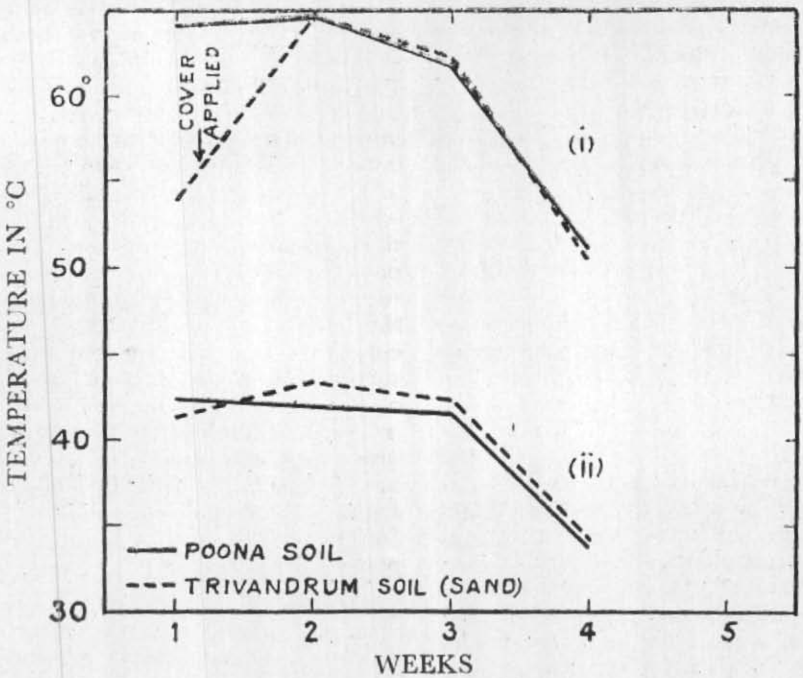
Where water is available, it may be possible to cool down the soil further by growing a



(i) Surface temperature (ii) Mean temperature from surface to 30 cm

Fig. 1

Effect of spreading French chalk powder on Poona black cotton soil



(i) Surface temperature (ii) Mean temperature from surface to 20 cm

Fig. 2

Effect of applying a layer of Poona black soil on Trivandrum white sand

thin cover of vegetation. Table 1 gives the soil temperatures of two plots of Poona soil both receiving equal amounts of watering, one kept bare (A) while a growth of plants 20 cm high covered the other plot (B). These values refer to the maximum temperature epoch, *i.e.*, at about 1400 IST.

It is seen from Table 1 that the layer of vegetation brings down soil temperatures further than when the surface is wet but bare.

3. Influencing evaporation from wet soil

It has been shown in a previous section how soil temperatures can be altered by applying covers of suitable colour. As soil temperature is one of the factors controlling evaporation from soil it was felt desirable to try the effect of surface colour on evaporation. These experiments were made with a soil evaporimeter described in a paper published a few years ago[7]. The soil evaporimeter consists of a metallic cylinder 5″ in diameter containing soil which rests with its perforated bottom on water in a close fitting reservoir below. Two sets of these instruments with 9″ and 15″ depths of the local black cotton soil were used in triplicate. The surface of the soil in one instrument in each set was made white by a thin layer of boric acid; in another a thin layer of charcoal powder was applied to make the surface black while the third instrument of each set was left untreated to serve as the control.

Table 2 gives the mean daily evaporation in inches from all the 6 instruments as well as the evaporation from the U.S.A. evaporimeter for the months of May and June. Thus it is seen that evaporation from the black surface is considerably more than from the white surface.

To sum up the effect of a white or black cover on the soil, it can be said that the application of a black cover on the surface tends to increase the soil temperatures as well as the loss of moisture from the soil by evaporation. Conversely, a white surface cover tends to decrease the soil temperatures and also the loss of moisture from the soil by evaporation. These methods immediately suggest practical applications. In our country, specially in north India, severe short spells of hot and dry weather set

TABLE 1

Effect of a cover of vegetation on soil temperatures in °C

Depth	Week No. 1		Week No. 2		Week No. 3	
	Bare soil (A)	Bare soil (B)	Bare soil (A)	Soil covered with vegetation (B)	Bare soil (A)	Soil covered with vegetation (B)
0 (Surface)	40.8	40.8	37.8	27.8	38.8	24.1
5 cm	31.7	31.7	24.9	24.1	26.4	24.2
10 cm	29.3	29.3	21.4	20.3	21.9	20.7

Note—Watering started at the end of first week

in quite often during the summer months. Some valuable plants may sometimes be killed during such spells specially in botanical or horticultural gardens. If water is available in plenty, watering the plants frequently is one way of saving these. In places, however, where there is scarcity of water during such periods, covering up the soil surface with a white powder of chalk etc., will help the plants to tide over such critical periods by cooling the soil and reducing its dessication. This method was in fact tried by the Assistant Agricultural Chemist at Chaubatia, U.P., and quite encouraging results were obtained.

TABLE 2

The effect of surface colour on the evaporation from soil

Month	Colour of soil surface	Mean daily evaporation in inches from		
		The top of soil columns with depths of		U.S.A. evapo-rimeter
		9 inches	15 inches	
May	White	.29	.10	
	Black	.60	.20	.51
	Control	.56	.17	
June	White	.20	.07	
	Black	.41	.14	.36
	Control	.36	.11	

4. The control of air temperature during cold waves to minimise frost damage to crops

Frost damage is quite common in north India but not so in the south. In the tracts lying between these two parts like Bombay Deccan, intense cold waves are not very common but when frosty conditions do set in, crops are seriously damaged, if not destroyed altogether. Such a condition was experienced during the winter of 1935. The damage done to vine-yard in Nasik has been briefly described by Ramdas[8]. Fig. 3, taken from the above publication, shows the diurnal variation of the humidity and temperature respectively from 0800 IST of 15th to 0800 IST of 16th January 1935, when the cold wave was most intense. The records were obtained from hygrographs and thermographs kept inside two Stevenson screens at the ground level. The dotted lines refer to conditions inside the plantation, while the full lines represent conditions in the open.

It is seen that inside the plantation humidity was higher than in the open at all hours. The temperature inside the vegetation was lower during the day and higher during the night compared to the conditions in the open. On the 16th morning air temperature in the open was below freezing point for nearly five hours. Inside the plantation the temperature was below 40°F for about 5 hours but it has to be borne in mind that the temperature attained by the plants (*i.e.*, the radiation minimum temperature) will be about 10°F lower than the air temperature so hat the temperature of the plants must also have been below freezing point for several hours and hence the severe frost damage. In the following year (1936), some experiments on orchard heating for the protection of vineyards from the effects of cold waves were conducted. There was no frost during that particular winter but the experiments clearly indicated how far the air temperature can be controlled. The following treatments were tried—

(1) Burning Harrington type of crude oil heaters and

(2) Lighting fires with wood and cowdung cakes both with and without " wind breaks ".

The wind breaks were prepared with dry " jowar " stalks and were erected 10 ft high all round the plots. The temperature readings were taken with an Assmann Psychrometer. Table 3 gives the temperatures in°C in the open and inside the plantations at 4 ft above ground at 0530 IST on 1 February 1936 both with and without wind breaks. In this table " control " means inside the plantation but without heating.

It will be seen from this table that it may be possible to warm up the air layers inside crops by as much as 4°C by having suitable wind breaks and lighting country

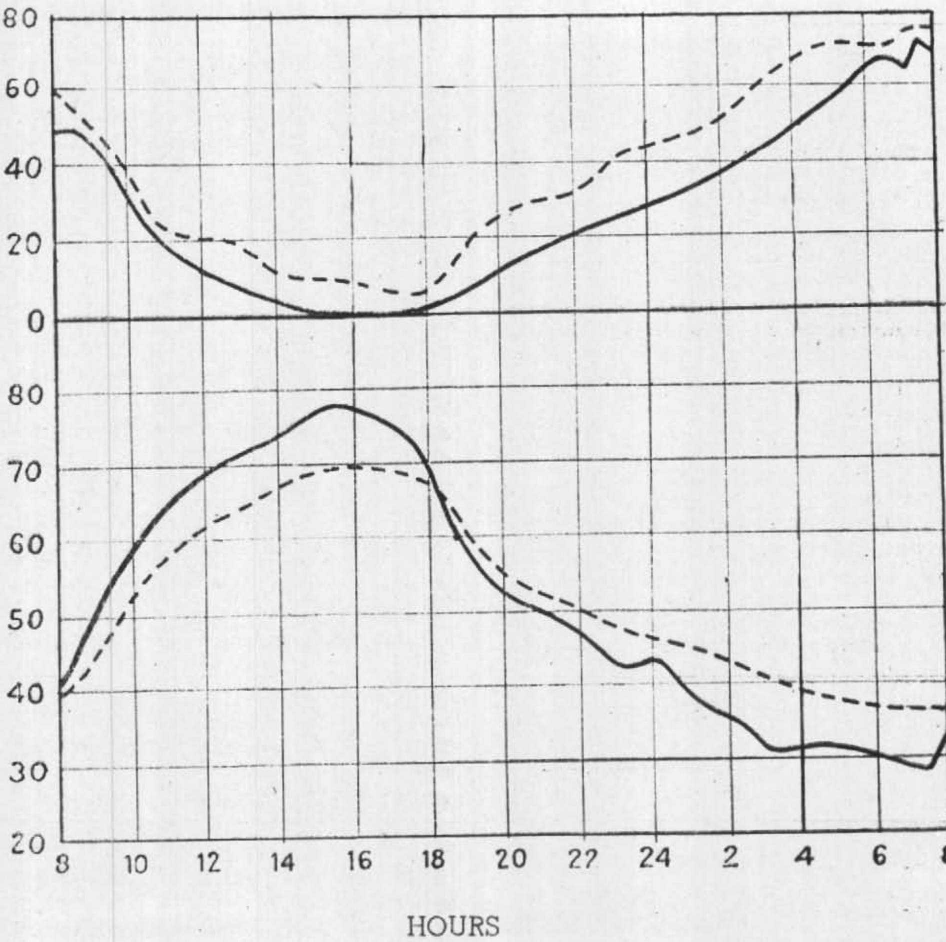


Fig. 3

Hourly variations of humidity and temperature from 8 A.M. of 15.1.1935 to 8 A.M. of 16.1.1935 at Nasik. Full lines refer to conditions inside a screen kept at ground level in the open. Dotted lines refer to conditions inside a grape garden in a similar screen at ground level fires in sufficient numbers. Thus unless the frost is very severe (*i.e.*, temperatures lower than 10° below freezing point) it may be possible to save the crop from getting badly damaged by taking precautionary measures mentioned above. Where a valuable cash crop like grapes is involved, the money spent on precautionary arrangements may be much less than would otherwise be lost through frost damage.

TABLE 3

Treatments	Temperature in °C inside plots	
	Without wind breaks	With wind breaks
Open	11.5	10.5
Control	9.5	10.0
400 country fires per acre	12.5	14.0
160 crude oil heaters per acre	12.0	13.5

5. Artificial production of micro-climate for testing drought resistance of crop plants

Plant breeders, specially in arid tracts, are often vitally interested in developing drought resistant varieties. Having obtained varieties which may turn out to be drought resistant, the plant breeder has to wait for a few seasons before he can test and confirm the resistance to drought of the varieties developed by him. In a recent paper[9] the author has described a simple method for testing drought resistance of plants and used the method for testing the resistance of two varieties of sugarcane. For testing drought resistance, plants were kept in two contrasting environments, one an arid and the other a humid one. Conditions in the 'open' in Poona during the days of April and May are hot and dry and this was utilised as the dry environment. The humid environment was created by surrounding an area 6 ft by 6 ft by "*khas khas tatees*," keeping the top open. These *tatees* were kept wet by a continuous flow of water from a system of perforated pipes fixed all along the tops of the *tatees*; the flow of water was maintained from 0800 to 1700 IST daily. This humid area was due north of the arid area freely exposed to weather. The prevailing winds being W to SW, this precluded the humid air affecting the control plot.

Table 4 gives the mean values for some meteorological elements in the humid and the arid plots for four days. Evaporation from the arid plot is more than twice that in the humid plot.

Two plants of each of the two varieties of sugarcane Coimbatore 421 (*Co* 421) and Saccharum Spontaneum were placed in the humid environment and a similar set was kept in the dry environment. The loss of water from these plants by transpiration was recorded daily.

Table 5 gives the mean values for each day of (1) transpiration in gm per sq cm of leaf surface from the plants of the two varieties under the two conditions of exposure

TABLE 4

Mean value for the day of meteorological elements in the "humid" and "arid" plots

Date		Temperature °C		Relative humidity %		Saturation deficit of water vapour (gm)		Evaporation in 24 hours (cc)	
		Humid	Arid	Humid	Arid	Humid	Arid	Humid	Arid
13.5.42	..	32.0	35.6	30	18	25.0	35.7	14.0	33.8
14.5.42	..	32.2	36.1	32	21	24.6	35.5	11.1	25.6
15.5.42	..	31.2	35.1	40	34	18.4	27.9	8.6	20.4
16.5.42	..	27.8	31.5	50	45	11.5	19.0	7.6	17.9

TABLE 5

Date	Transpiration in gm per sq cm of leaf surface				Evaporation in gm per sq cm of exposed surface (Piche)		Relative transpiration = (Transpiration/Evaporation)			
	Co. 421		Saccharum Spontaneum				*Co* 421		Saccharum Spontaneum	
	Humid	Arid	Humid	Arid	Humid	Arid	Humid	Arid	Humid	Arid
13.5.42	0.32	0.37	0.81	1.86	1.07	2.59	0.30	0.14	0.77	0.72
14.5.42	0.31	0.37	0.68	1.67	0.85	1.96	0.36	0.19	0.81	0.87
15.5.42	0.25	0.32	0.65	1.33	0.66	1.56	0.38	0.20	1.00	0.87
16.5.42	0.23	0.29	0.43	1.14	0.58	1.37	0.39	0.21	0.72	0.81
Mean	0.28	0.34	0.64	1.50	0.79	1.87	0.36	0.19	0.83	0.82

(2) evaporation per sq cm of evaporating surface from Piche's evaporimeter under the two environments and (3) the relative transpiration of Livingston, *i.e.*, the ratio of transpiration to evaporation for the two varieties under the two (humid and arid) environments.

It is seen from this table that the variation in the values of relative transpiration of the two varieties under the contrasting kinds of exposure is very well-marked. In the case of Saccharum Spontaneum, the relative transpiration is more or less the same under the humid as well as the arid conditions. This means aridity is affecting both the transpiration as well as the evaporation *similarly* and there is no biological control to cut down the transpiration loss under unfavourable circumstances. In contrast to the above, the relative transpiration in the case of *Co* 421 is very much smaller under arid than humid conditions. This means that aridity, while considerably increasing the evaporation is not producing a similar increase in the transpiration. This is invariably true for all the days of observation and on an average the relative transpiration under arid conditions (0.19) is about half of that under humid conditions (0.36). According to Livingston[10] the variation in the relative transpiration is an indication of regulatory activities of plants trying to adapt themselves to a changed environment influencing transpiration. As the relative transpiration in the case of *Co* 421 is reduced by about 50% when kept in an arid environment, the plant is clearly trying to resist the dessicating influence of an arid atmosphere by the exercise of some biological control on the loss of water by transpiration. In short, *Co* 421 appears to be a drought resistant variety as was stated by Sri T.S. Venkataraman who had kindly supplied the planting material.

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