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Micro-Climatic Survey of a Sugarcane field

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ABSTRACT. The distribution of temperature and vapour pressure inside a sugarcane field during its various growth stages has been studied. It has been observed that in the earliest stage of crop, the climate of the sugarcane field differs little from that of the " open ". The differences begin to appear when the crop attains a height of 2 to 3 ft above ground i.e., about after 3 or 4 months ' growth. The changes from the open to the crop are most rapid across the rows. The climate of the matured sugarcane crop becomes more or less uniform at within a distance of three row widths from the border.

The secondary " active " surface is formed at 12 ft above ground in the mature crop and gives rise to the forced inversion inside the crop.

1. Introduction

The study of the micro-climates of crops was one of the earliest investigations to be taken up by the Agricultural Meteorology Section at Poona. Ramdas, Kalamkar and Gadre have discussed the subject in a series of papers [1-4]. It is found that crops tend to develop characteristic micro-climates which deviate significantly from and are not correlated in a simple manner with the climate of the open.

In other words the climate of a place, not only determines the vegetation thriving there, but the vegetation also in its turn modifies the climate of the area and in particular develops its own characteristic " Micro-climate ".

Micro-climate in relation to crops is influenced by the following factors—

(1) Plant foliage

(2) Vertical and lateral growth development

(3) Amount of foliage

(4) Plant density

(5) Percentage of " canopy "

(6) Cultural treatments—such as irrigation, etc.

The surface of the vegetation greatly alters the thermal conditions of the earth. These surfaces absorb the solar insolation. A part of this energy is spent in transpiration and photo-synthesis, while the remaining goes to increase the plant temperatures a portion of which is again lost by the plant by way of thermal radiation.

In addition to this heat lost by thermal radiation, the transpiration and evaporation from plant and evaporation from plant and soil surfaces play an important part in the micro-climate inside a crop.

Apart from the direct effect of solar radiation on the plant itself, there is also a shading effect of plants on the soil surface. This varies with plant size and the plant types, which cover more or less of ground according to their habit of growth. The foliage obstructs sun's rays reaching the ground and decreases ground heating. The height and density of plants influence the micro-climate and therefore the latter is governed by the growth stage of the crop.

In order to have a broad division in a plant-climate cycle we can consider four stages in the growth cycle of a plant, as suggested by Geiger.

Stage 1. The seed has just sprouted, the ground is bare and gets heated by solar insolation.

Stage 2. Along with the vertical growth of the plant, there is also some lateral spreading. This lateral spreading shades the ground to a certain extent and obstructs solar insolation partially. Ground gets partially heated showing some difference between the climate inside a crop and on a bare ground.

Stage 3. In this stage, the plant height has further increased, and the foliage has become thick and more or less uniform. This practically prevents solar insolation reaching the ground. The foliage forms a secondary active surface—similar to ground surface in open area. There is an interspace created between the ground and the plant crown.

Stage 4. The foliage near the ground is less and the crown goes higher up. This raises the so-called "secondary active surface" higher up above the ground. There is appreciable air movement in the interspaces (as observed in forests, etc.).

2. Micro-Climatic observations inside sugarcane

In the present paper an attempt has been made to show the detailed variations in the micro-climate from place to place and at different levels inside a sugarcane field and to show how the climate in the "open" changes rapidly to the "crop" climate as soon as one enters the field.

The word "open" mentioned above refers to an area devoid of vegetation and fully exposed to the sky. It represents the standard condition of a bare plain field which does not receive any irrigation.

It will be useful at this stage to give a brief description of the locality where the observations discussed in this paper were recorded.

The sugarcane fields were located at a distance of about 180 ft to the west of the observatory. The dimensions of the field taken for this micro-climatic survey were 128 ft × 312 ft, the longer side running east to west. The field had 33 rows of sugarcane each 4 ft apart, running along the longer side of the plot. The cane was planted towards the end of January. Germination was complete after a fortnight. The crop was taken up for micro-climatic study from the month of March when the mean height of the crop was about 12″. The plant density was about 6 to 8 plants per square yard.

The field itself consisted of two quarter acre plots. Each quarter acre area was again divided into 3 sub-plots, *i.e.*, the total unit consisted of 6 sub-plots.

3. Method of observations

A, B, C, D, E and F (Fig. 1) represent the positions of the observers in the Central

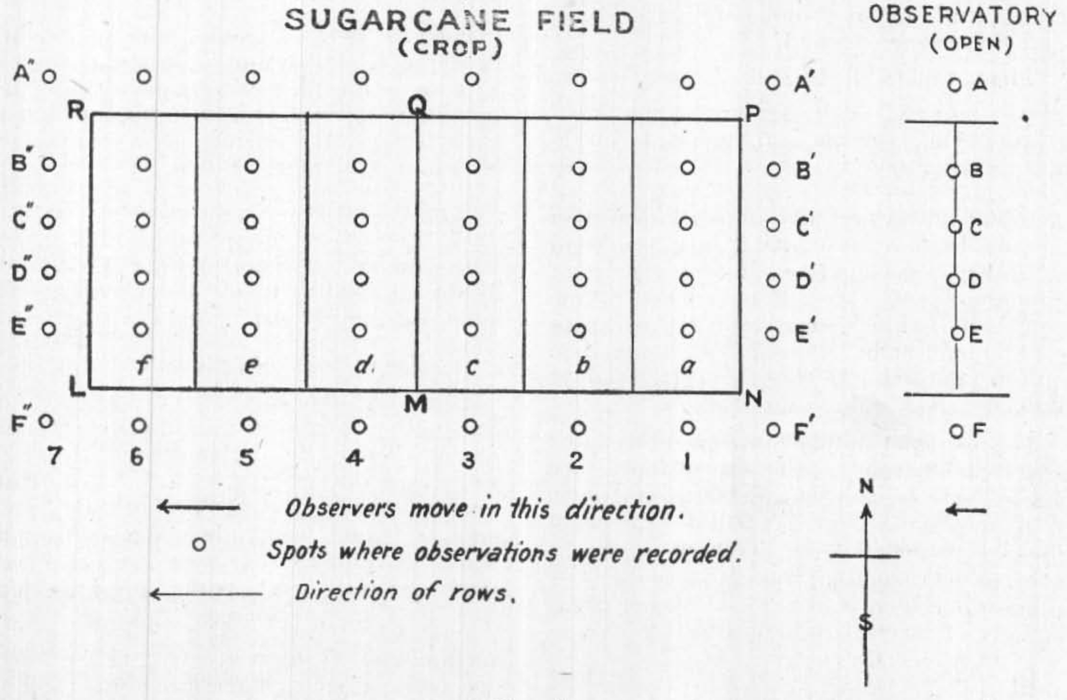

Fig. 1

Agri-Met Observatory, at a distance of 180 ft to the east of the cane field. A′, B′, C′, D′, E′ and F′ show the corresponding places on the cane field border adjacent to the observatory. The field L N P R which is ½ acre consists of two plots L M Q R and M N P Q each of ¼th an acre. Each quarter acre is again divided into the 3 sub-plots a, b, c and d, e, f. The location of A′, B′, C′, D′, E′ and F′ in the figure is 6 ft away from the eastern border of the field and A″, B″, C″, D″, E″ and F″ is 6 ft away from the western border of the field. The lines A′ A″ and F′ F″ run at a distance of 6 ft away along the northern side and the southern side of the field respectively. The positions marked "O" show the spots located along the central line (running north south) of each sub-plot, a, b, c, d, e and f where psychrometric observations were recorded simultaneously by 6 observers. The instrument used was Assmann Psychrometer (R. Fuess-small pattern).

Two observers moved along the rows A-A″ and F-F″ outside the field, while the remaining 4 moved along the rows B′, C′, D′ and E′ inside the field, taking observations at places marked "O". These observations were recorded at the maximum temperature epoch, and at the ground surface 1, 2, 3, 4, and 6 ft above ground.

The rows B′, C′, D′ and E′ represent the 6th, 13th, 21st and 28th row in the field.

To begin with all the observers started the observations in the observatory plot at the positions A, B, C, D, E and F. After finishing the work there, they all moved in a batch to the positions A′, B′, C′, D′, E′ and F′ near the crop and took similar observations simultaneously. Then they moved inside the field taking observations at each spot "O" and finally emerged out of the crop in the positions A″, B″, C″, D″, E″ and F″ on the western side of the field.

It has been already stated that these observations were started when the crop was about a foot high. These were taken every week till the crop attained a height of 14 ft—when it was harvested.

The data collected is discussed in the following section.

4. Discussion of the data

Figs. 2, 3, 4 and 5 show the isochrones of dry bulb temperature in °C and vapour pressure in mm of mercury recorded at the ground surface and at various levels above ground in the "open" and inside the crop at its various stages of growth. The topmost diagram shows the difference between the ground temperature and temperature at 6 ft above ground in both the environments.

(i) Stage 1—crop height about 1 *ft*

Fig. 2 shows the micro-climatic conditions in the "open" and inside crop when the crop was about a foot high. These observations were recorded in the month of March, during which there was practically clear sky and little wind during the observations.

Dry Bulb Temperature. Due to partial shading (though of a poor type) of the field, by the crop the temperature has fallen slightly inside the crop only at the ground surface. At the upper levels there is no difference between the "open" and the "crop". The ground surface 20 ft inside the crop shows the coolest temperature apart from the local variations.

The last diagram shows that the difference between the surface temperature inside a crop and temperature at 6 ft above surface is much less than in the open.

Vapour Pressure. Vapour pressure at the soil surface increases inside the field owing to irrigation, and the isochrones run along the direction of furrows. Local variations due to water logging in furrows are well-marked even up to 6 ft above ground.

Vapour pressure decreases with height. This decrease is more rapid inside the crop, than in the open, and at 6 ft above ground the values in the "crop" approach values in the "open".

(ii) Stage 2—crop height about 3 *ft*

Figure 3 shows the isochrones of the Dry bulb temperatures and vapour pressure values in both the environments, observed in the month of April. There was slight clouding during the observations and some westerly wind, 4-6 mph. The crop had grown to about 3 ft with an increased lateral expanse, the shading has increased but was still incomplete.

Dry Bulb Temperature. It will be seen that the surface temperature has rapidly fallen across the furrows inside the crop.

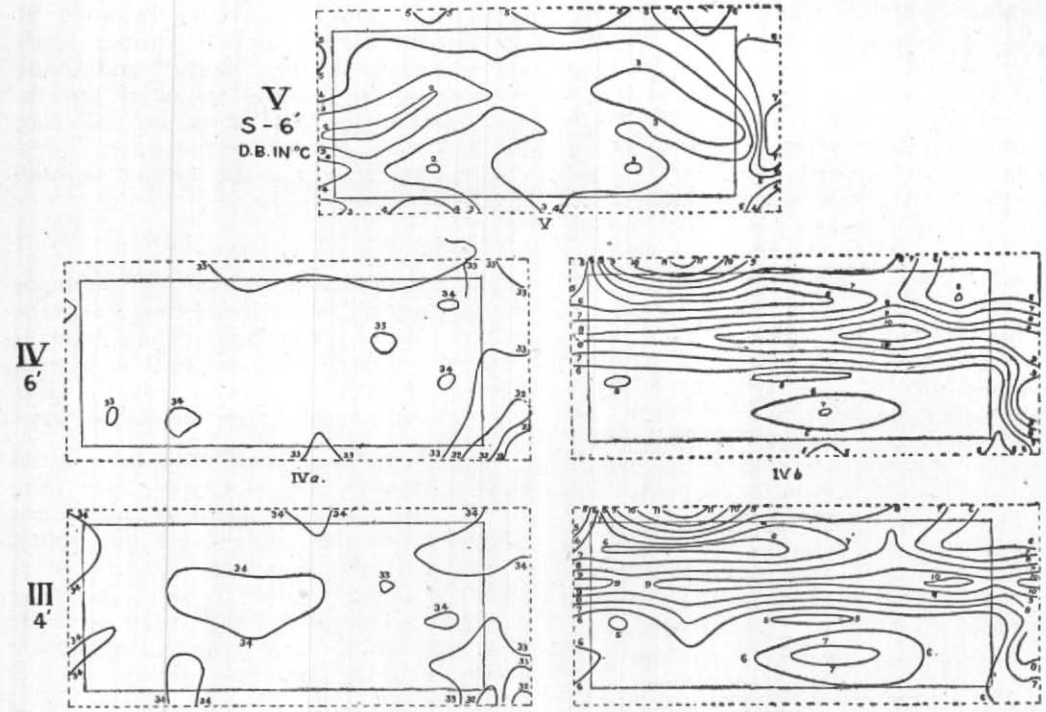

Fig. 2

This variation in the temperature between the two environments has decreased with height and at 6 ft the values in the "open" and inside "crop" show very little differences. The temperature differences which were of the order of 5 to 6°C at the surface decreased to about 1 to 2°C at 6 ft above ground.

The difference between the ground surface and 6 ft temperature is more marked in this figure than in the previous one. This is due to the greater shading of the ground due to increased foliage, which keeps the ground at a lower temperature, with the ultimate result that there is very little difference between the ground temperature

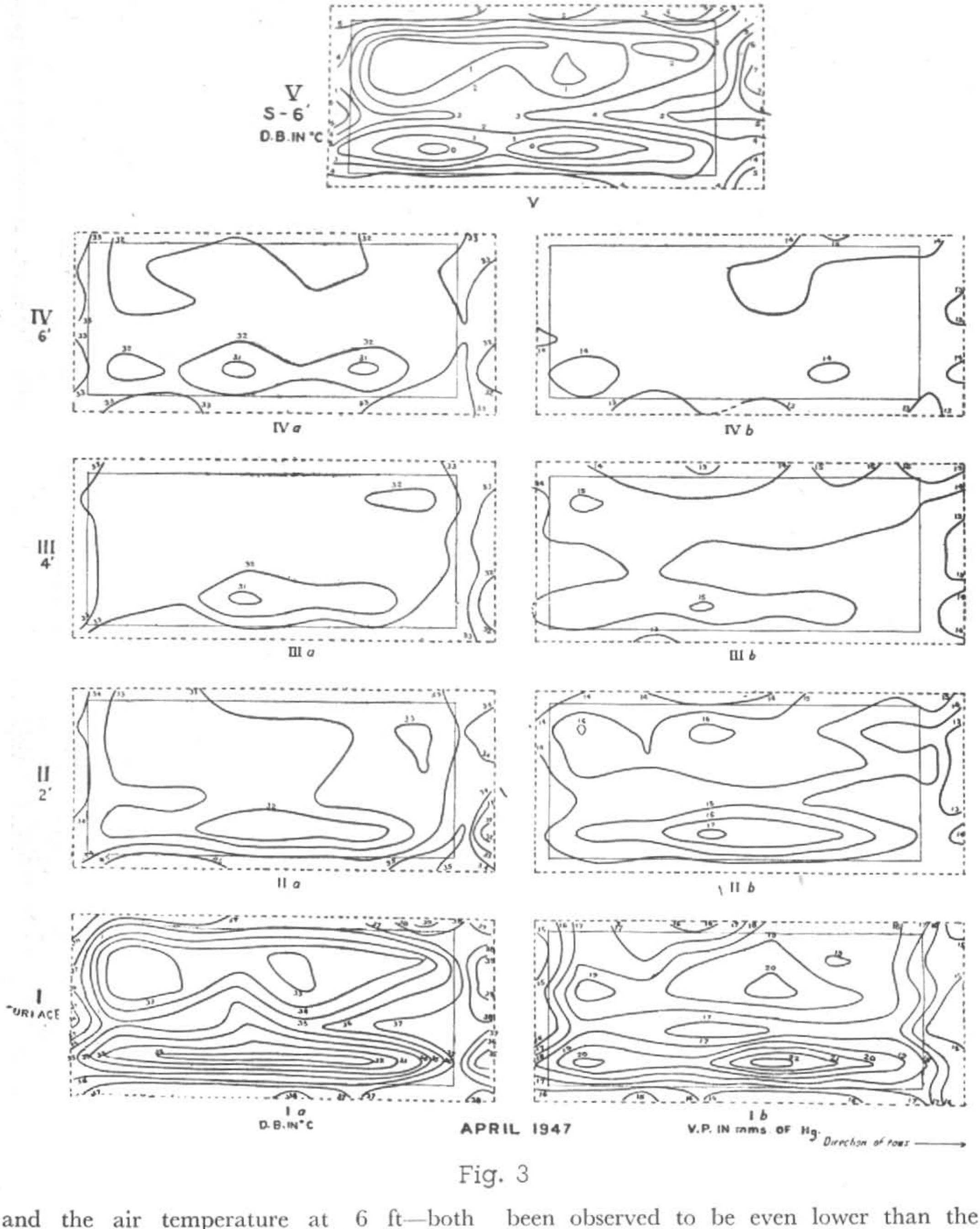

Fig. 3

and the air temperature at 6 ft—both recorded inside the crop. In the "open" the corresponding values are of the order of 6 to 7°C while inside the crop they are only 1 to 3°C.

Wherever the soil surface was wet due to water-logging the surface temperature has been observed to be even lower than the temperature at 6 ft.

Vapour Pressure. As usual the surface vapour pressure inside the crop is higher owing to wet condition of the soil due to irrigation. The isochrones run along the direction of the furrows. Vapour pressure

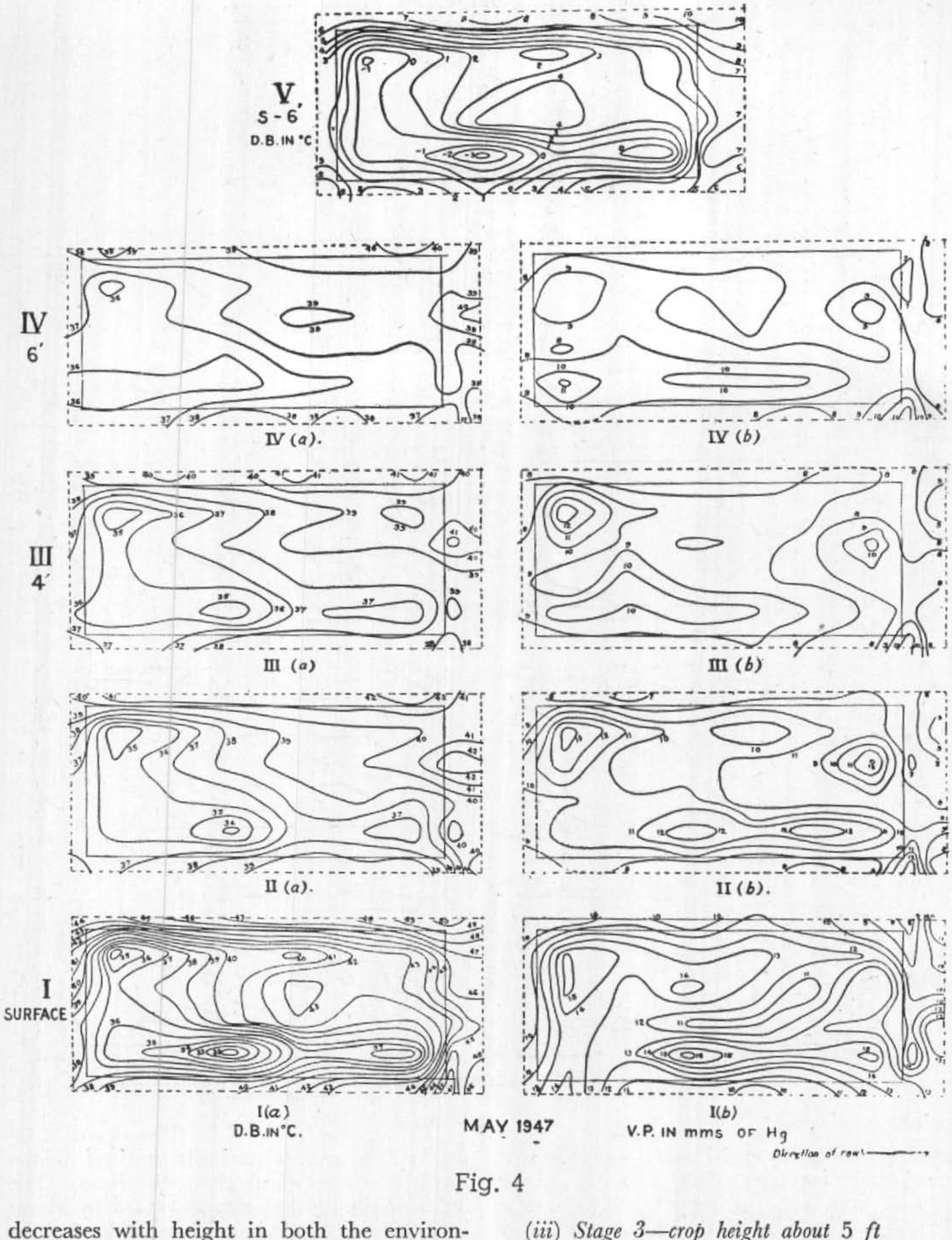

Fig. 4

decreases with height in both the environments, especially more rapidly inside the crop, with the effect that at 6 ft above ground *i.e.*, 2 ft above the crop there is very little difference between the two environments.

(iii) Stage 3—crop height about 5 ft

Fig. 4 gives an idea of micro-climate of these two environments in the month of May. The clouding has further increased and there has been occasionally intermittent sunshine. Slight increase in the wind

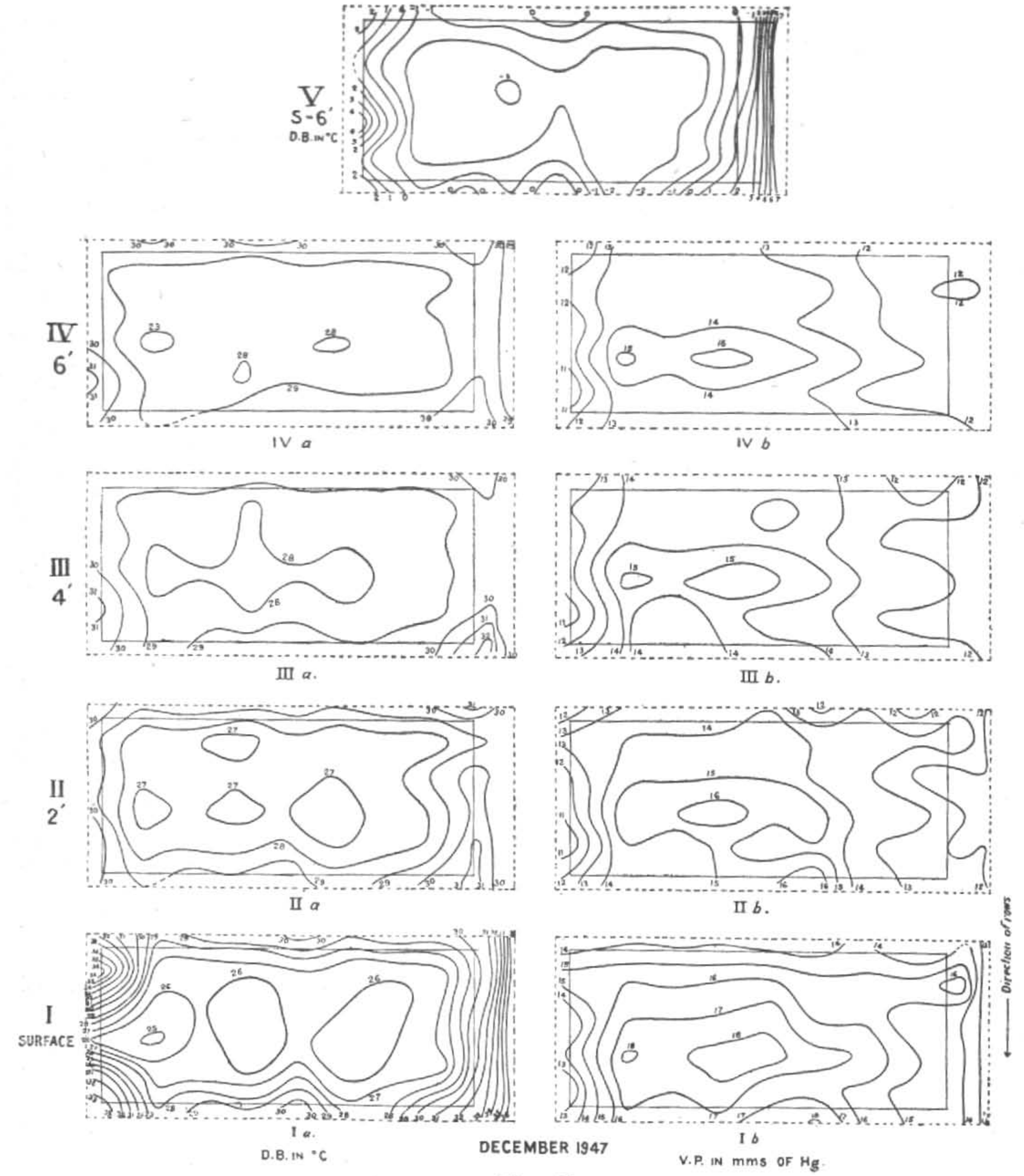

Fig. 5

speed (westerly 8 to 10 mph—occasionally gusty) was observed. The crop has grown to 5 ft and the foliage has considerably increased. Shading of the ground has also increased in proportion.

Dry Bulb Temperature. As already shown in earlier figures the temperature has rapidly fallen immediately inside the field, and this fall is more markedly noticed across the rows rather than along the rows. The order of the fall has also increased by about 2°C over the previous stage (Fig. 3), the value being 7 to 8°C within a distance of 15 ft inside the field border. Further inside, the temperature remains fairly steady due to the crop acting as a barrier to air circulation.

It will also be seen that the differences between the "open" and the "crop" temperatures decrease with height. The differences which were 7 to 8° C at the ground surface have decreased to 2 to 3° C at 6 ft above ground.

The temperature fall between surface and 6 ft is less pronounced inside the crop due to the fact that the crop with its vegetative leafy growth has cut off a considerable portion of sun's rays reaching the ground. The difference between the surface and 6 ft temperature which is 7 to 9° C in the "open" has come down to about 1 to 2° C inside the crop. It is clear, as in previous cases, that the fall of temperature is across the rows. The lapse values are also less than on the previous occasion. This can be easily explained as due to increased shading of the ground causing less heating of the soil surface. Even though the differences of temperature at 6 ft in the open and inside crop are not so well-defined (see IV*a* in Fig. 4) the combined effect is very well brought out in the top diagram (see V in Fig. 4).

It may be observed that the surface temperatures inside the field are sometimes lower than the air temperatures at 6 ft recorded over the same spot. This is the temperature inversion which starts at this stage of the crop.

Vapour Pressure. Surface % vapour pressure increases as one enters the crop due to irrigation etc. The vapour pressure decreases with height and the variation between "open" and "crop" becomes less and less at higher levels.

Local variations due to water-logging are shown, though in lesser magnitude, even up to 6 ft above ground.

(*iv*) *Stage* 4—*crop height about* 14 *ft*

Figure 5 shows the conditions when the crop has grown to 14 ft. The month is November with good amount of sunshine and clear skies. Very light northerly wind prevails during this season.

At this stage of the crop, it has formed a thick secondary surface of the leaf-zone at a height of approximately 11 to 12 ft above ground.

Dry Bulb Temperature. The temperatures have fallen rapidly even from the field border owing to the shading of the ground by the tall crop. The temperatures remain fairly steady beyond 15 to 20 ft inside the crop. The variations between the two environments decrease with height but are evident even at 6 ft above ground.

As has already been stated, the crop at this stage has formed a thick canopy of leaves at about 12 ft above ground. The sunshine is hardly able to penetrate through this thick leafy zone and reach the soil surface inside the field.

In the "open" (bare plot) we find that the ground is fairly directly heated by the sun and forms what is called the "active surface". Conditions are quite different inside the sugarcane field at the above stage. The ground being mostly shaded is much less active. The leafy zone (canopy) at a height of 12 ft above ground receives the sunshine and forms a second active surface in the place of the usual ground.

Under the conditions a marked contrast is observed between the "open" and sugarcane temperatures at the maximum temperature epoch.

Fig. 6 will clearly show this contrast. The temperatures in the "open" have a lapse while those inside the crop have an inversion up to the height of the leafy zone (secondary active surface), lapse setting in above this surface.

From the top diagram (S-6′) of Fig. 5, it will be seen that S-6′ values are actually negative inside the crop, showing that the air layers inside the crop are stratified and stable. The temperature increases with height. Such conditions prevail in the "open" during night only due to radiative cooling. Owing to these stable conditions it is also noticed that the movement of smoke inside the crop is rather slow and its dispersal takes a pretty long time.

This daytime inversion inside a crop due to canopy effect has been called by Ramdas[5] a "Forced inversion".

Vapour Pressure. There has been no change in the behaviour of vapour pressure element

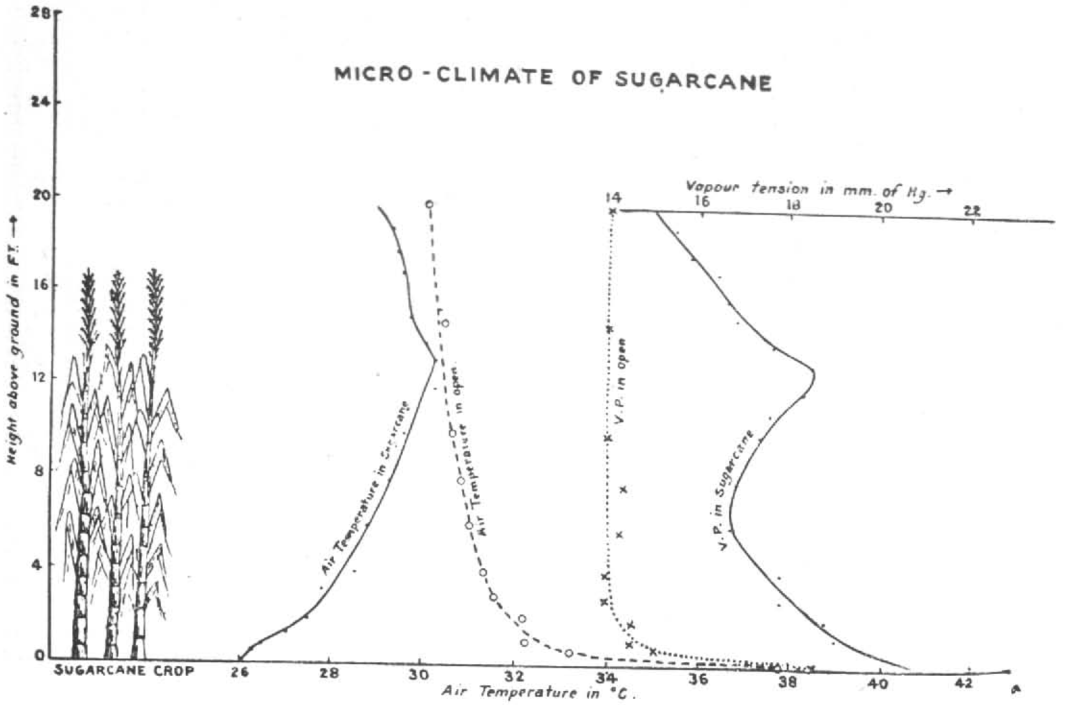

Fig. 6

apart from that already stated—*i.e.*, it is maximum near the soil surface and decreases with height. From Fig. 6, it will be seen that this fall in vapour pressure values continues up to 7 ft above ground and then the values increase slowly up to 13 ft where it reaches the leaf zone. This is due to water vapour transpired by the foliage. Above the foliage free air conditions as in the " open " prevail.

Further work on this problem is in progress.

5. Acknowledgement

In conclusion the author wishes to express his gratefulness to the members of the staff of Agricultural Meteorology Section for their valuable co-operation in recording the observations discussed in this paper and to Dr. L. A. Ramdas, Director, Agricultural Meteorology, for suggesting this micro-climatic survey of the sugarcane crop and helping in the interpretation of the results.

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