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DIFFERENCES IN THE SPECTRAL CHARACTERISTICS BETWEEN HEALTHY AND DISEASED CROPS DETERMINED FOR SUGAR BEET AND WINTER BARLEY.

. DEFINITION OF THE GROUND TRUTH DATA ON THE COMMON SUGAR BEET TEST SITES (BOLOGNA, ITALY) AND DESCRIPTION OF THE RESULTS ACQUIRED IN THE THERMAL INFRARED RANGE.

1. Introduction

This communication is part of the European Joint Project on Sugar Beet Diseases, introduced precedently. The results obtained on the italian test sites are here reported.
Object of the investigation was the definition of the "spectral signature" of diseased and healthy sugar beets, in the visible and near and thermal infrared spectral ranges.
This study has been conceived within a framework of complementarity with a parallel study carried out by Friburg's University, in order either to integrate different detection techniques applied to the same test site (Italy-Po Valley) and to compare results obtained on test sites differing for ecological and epidemiological conditions (Italy:Po Valley - Germany:Rhyne Valley).

2. Sugar beet diseases object of investigation

Sugar beet diseases believed to be interesting for a Remote Sensing survey are the following: a)rhizomania (fungal+viral agents); b)nematode disease (Heterodera Schachtii); c)cercospora leaf spot (fungal agent).
From the point of view of the spectral behaviour, we may consider rhizomania and nematode disease as similar: in fact, in both cases the pathogen's presence induces deep modifications in the host's water balance, causing, in the hottest hours of the day, a strong wilt in the leaves of the attacked plants, which could be compared to that détectable in case of serious water stress.
In the case of cercospora leaf spot, instead, pathogens induce

necrotic spots on the host's leaves: if the attack is not controlled, the number of necrosis increases up to a point that the leaf blade first turns yellow and then dries up and dies.

3. Instruments used

To carry out our measurements, various instruments were employed, in order to cover completely, with the integration of the instruments used by our colleagues from Friburg's University, the whole spectral range from .4 to 14μ, determinant to detect vegetation anomalies.
In the visible range, colour pictures were taken and in the near IR, false-colour images were obtained.
For thermal IR measurements, instead, an Aga-Thermovision camera Mod.750 was used, which detects within the 2-5.6μ range and provides black and white thermoimages. The obtained information can also be quantitative as the instrument is endowed with an isotherm function. For some of the measurements the colour Aga Slave Monitor was available too: it provides thermoimages where to any of the ten levels, in which the thermal information has been devided, a different colour corresponds, thus giving a discrete representation rather than a continuous one like on the black and white monitor.
For the thermocamera calibration, a Black Body external Reference (Aga Thermovision Temperature Reference, Mod.1010) was used.

4. Experiences and results

Experiences have been carried out in two series: a first one in July 1979, concerning nematode disease and rhizomania, on test sites placed, respectively, at Rovigo and S.Alberto di S. Pietro in Casale, in Bologna's province; and a second one in September 1979, concerning rhizomania and cercospora leaf spot on test sites placed, respectively, at S.Alberto di S.Pietro in Casale and Anzola dell'Emilia, both in Bologna's province.
Test sites were chosen within experimental fields set up by the Experimental Institute for Industrial Cultivation, Sections of Rovigo and Bologna.

- Measurements carried out at Rovigo, concerning nematode disease, provided us with data showing the difference in the spectral behaviour between healthy and diseased areas. In the thermal infrared, such difference, while it was not detectable in the early morning, however it became evident in the hottest hours of the day, from I2 a.m. to 5 p.m., and reached 1°C black

body temperature.(Plate 1, 2, 3, 4)
An hypothesis which may explain such thermal behaviour, could be found in the dicreased efficiency of the hypogean apparatus of the diseased plant in the water absorbing process: in fact nematodes attack just the tap root diminishing its development and thus hampering its normal function.
Such anomaly , however, is detectable only in the warmest hours of the day, that is when water absorption must increase in order to adequately make up for the water loss of the plant due to the increased evapotranspiration caused by the high environ= ment temperature (thermoregulation mechanism).
On the other hand, not even the healthy plant is able to ade= quately balance its water content, in fact, around noon, the whole canopy looks stressed, until late in the afternoon, when the lower environmental temperature allows the restoring of the normal water balance.
We might, therefore, indicate the period from 11 a.m. to 5 p.m. as the most suitable, as far as nematode disease is concerned, for the identification, in the thermal infrared, of diseased and healthy plants.
However, as the diseased test site displays wide bare soil areas due to the smaller plant size, a higher radiant power in the diseased canopy compared to the healthy one, is detectable at any moment of the day, just because of the soil's contribution as soil emits more than a leaf surface.
Some criticisms to the method are necessary:
First of all, as in the 2-5.6 spectral range not only emission but also a certain percentage of reflection is detected, it would be more correct to speak about difference in radiant power rather than temperature.
Moreover, quantitative evaluations have been carried out on the base of the assumed equality between emissivity of a diseased plant and of a healthy one, which is rather unlikely to happen: in fact, a variation of the emissivity parameter is to be ex= pected in the diseased plant, due to the variation of the leaf structure caused by the lower water content.

Also from false colour infrared pictures the difference between healthy and diseased is clearly detectable by the different Ma= genta colour intensity in the diseased compared to the healthy plants,besides, of course, the grater amount of bare soil in the diseased area because of the smaller size of the plants.

- July's experiences, at S.Pietro in Casale, were carried out on sugar beets healthy and affected by rhizomania.
Measurements in the thermal infrared showed a higher radiance of the diseased area compared to the healthy one and it in= creased during the day until it reached 2°C black body tempera= ture at 3 p.m. (Plate 5, 6).

Measurements were carried out also on single plants, whose ther= mal behaviour was followed during a whole day. The obtained data show 2 and 2.5°C black body temperature difference, thus con= firming the results obtained on the canopy. (Plate 7)

On IR pictures, the recognition of the diseased area from the healthy one is easy due to the different look of the diseased plant (smaller size, stronger wilt in the warmest hours,etc.), to the presence of wide bare soil areas and to the different intensity of the Magenta colour of healthy plants compared to the diseased ones.

The experiences carried out in September on the same test sites affected by rhizomania, confirmed July's results: in fact the diseased area was "warmer" than the healthy one and the differ= ence in black body temperature reached 4°C in the hottest hours of the day.(Plate 8, 9).
Moreover, it was possible to determine, by means of an external black body reference, the temperature of the diseased and healthy plants which was, respectively, 29°C and 26°C at I:30p.m. Also in this case, the explanation of such thermal behaviour is to be found in the decreased efficiency of the diseased plant's root, which is more evident in the warmest hours of the day, when the water demand by the plant is stronger.
The highest difference between healthy and diseased areas re= ported in September's experiences, can probably be ascribed to the fact that sugar beets affected by rhizomania, yet showing a new vegetative vigour, with emission of new central leaves, nevertheless display the old leaves completely dried out; as it is known, dead or strongly dehydrated tissue can be heated much more easily than a leaf in its normal turgid state.
Here too, however, the criticisms to the method that have pre= viously been expressed for Rovigo's measurements, are valid.

Moreover, it's interesting to point out that, in the case of plants affected by rhizomania, there is no direct correlation between symptomatology and attack severity.

- In September, experiences have been carried out also on sugar beet test sites healthy and affected by cercospora leaf spot, at Anzola dell'Emilia (Bologna's province).
The obtained data in the thermal infrared, lead to the conclu= sion that the thermal behaviour either of healthy and dis= eased plants, follows that of environmental temperature. However the diseased ones show a higher variation range and reach, in the hottest hours of the day, the maximum temperature of 34°C, corresponding also to the strongest temperature differ= ence from the healthy plants. Such difference, in fact, in= creased up to 5.8°C. (Plate IO,II).

The obtained results agree with our hypothesis: in fact, as cercospora leaf spot is a necrotic disease, it causes the in= fected tissue to dry up. In our case, necroses were spread, sometimes, on the whole leaf blade.
Dead or anyway strongly dehydrated leaf tissue has a thermal capacity much lower than that of a normal leaf, just because of the scarce water content; consequently, it's easier to be heated and emets much more than a healthy leaf and this could explain the faster loss of heat in the diseased plant, corresponding to the decrease of external temperature in the afternoon.
Data are also accompanied by colour thermal images obtained on the slave monitor, (see instruments).

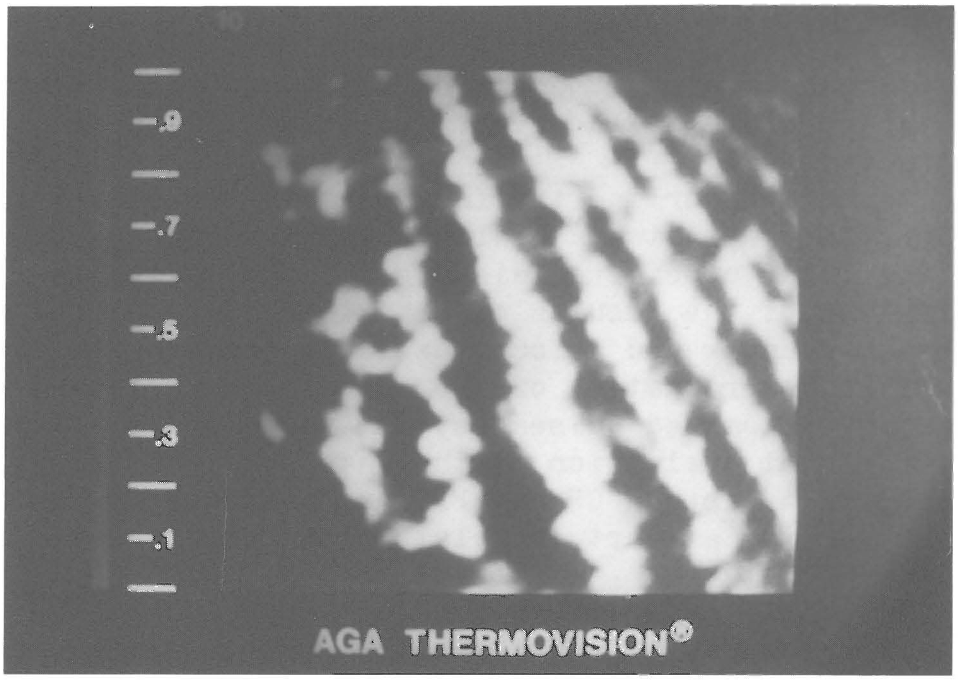
5. Ground truth data

Ground surveys have been made at different times, starting from the choice and preparation of the test sites to the post-harvest period.
Collected data may be listed as follows:
a) data related to the test sites. b) climatic data. c) ino= culum potential estimation. d) disease severity evaluation. e) production data.
These data have been integrated with all those checked on the ground by researchers from the National Institute for Industrial Cultivations and by Friburg's IPW.
In particular, as far as disease severity is concerned, we referred to conventional scales for rhizomania and cercospora (respectively 5 and 9 levels) and to the amount of present cysts and larvae, in case of nematode disease.
As to production data, the final evaluations showed a strong reduction in the diseased test site, expecially in case of ne= matode disease (112 q/ha vs. 500 q/ha) and in case of cercospo= ra leaf spot (435 q/ha vs. 864 q/ha).

6. Conclusions

For a correct evaluation of the obtained results, first of all it is necessary to point out that in the experiences carried out in July, the black body reference could not be used.
This means that reported data represent only a difference in radiant power, not absolute temperatures.
Anyway, we must speak of radiant power as no measurements of healthy and diseased plants' emissivity have been made.
Moreover, we must take into account the fact that the two cano= pies considered for each measurement, differed deeply for their vegetal covering. Consequently, it is hard to define how far

bare soil can affect the global radiance of the considered frame. These facts can assume prominent significance if we take into account the possible influence of reflection in the 2-5.6 μ wavelength interval.
However, we must underline the fact that in terms of radiance difference, the gap between healthy and diseased areas, for each of the three considered diseases, is considerable.
The evaluation of the results of a next-to-come aerial survey, with thermal scanner and a four Hasselblad camera cluster, aiming at the determination of the actual possibilities of monitoring the examined diseases, will be of great interest.
Finally, a global evaluation of the data obtained in the joint experiences with Ispra CCR and Friburg's University is being carried out in the attempt to relate ground truth data with Remote Sensing data.



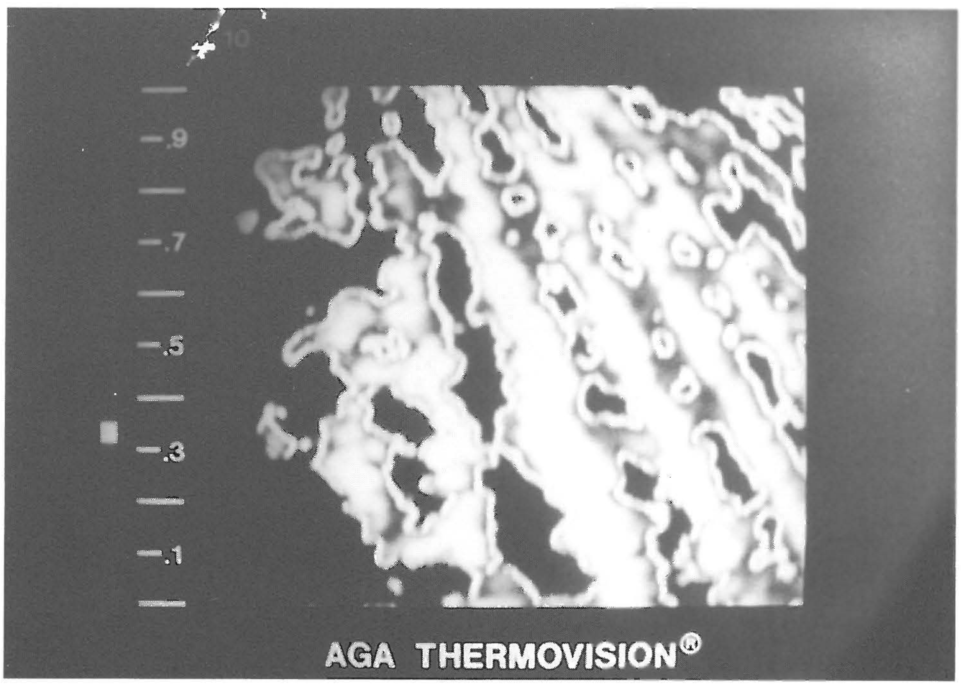
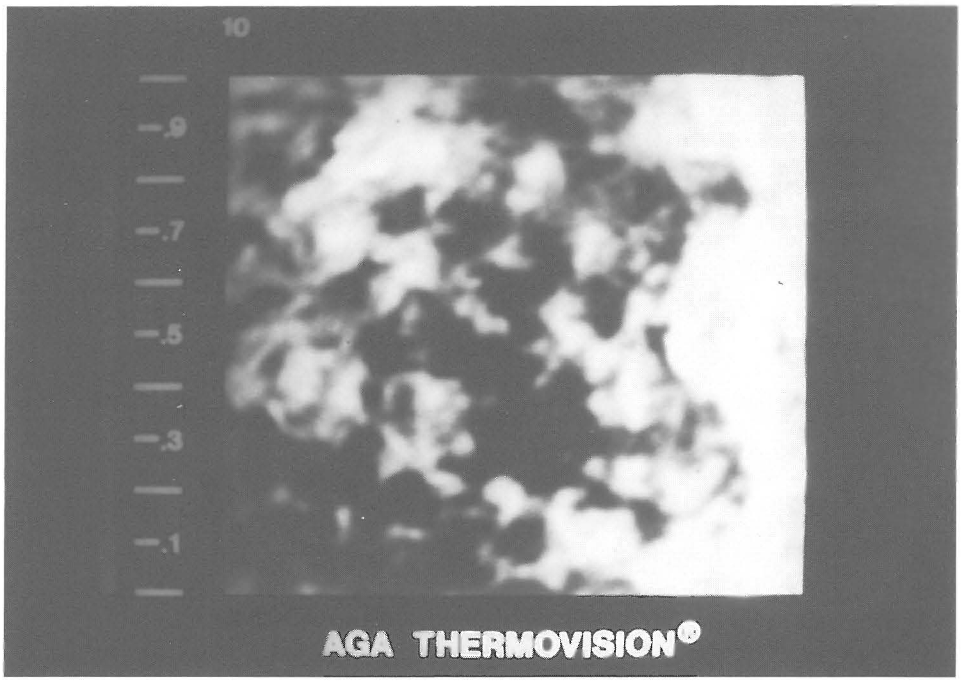


Plate 1 - Nematode disease (11 a.m.)

Top: Thermography of diseased area
Bottom: Isotherm of diseased area



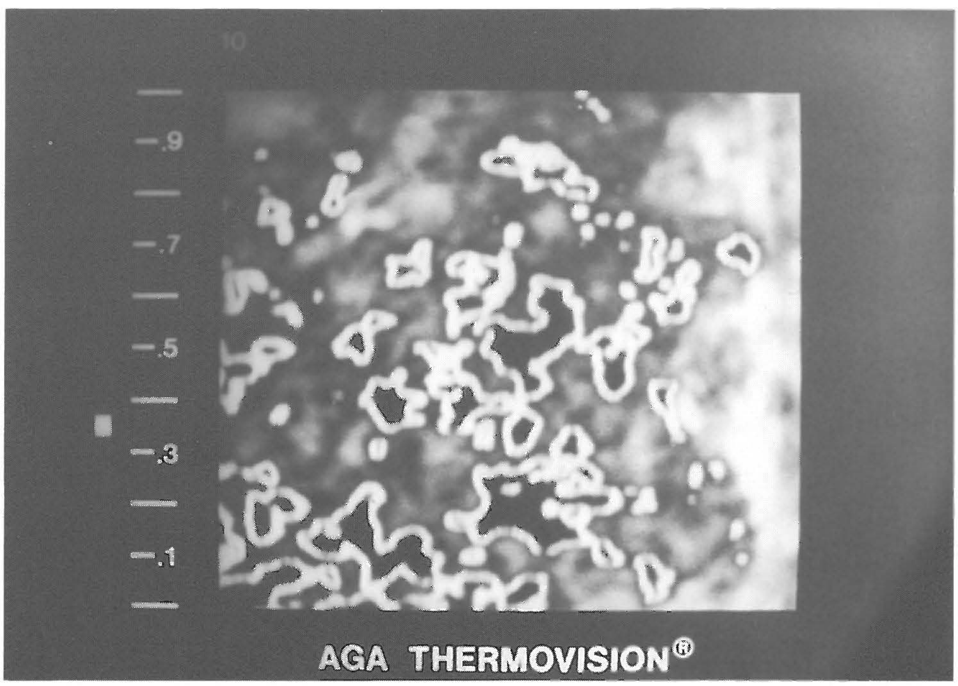
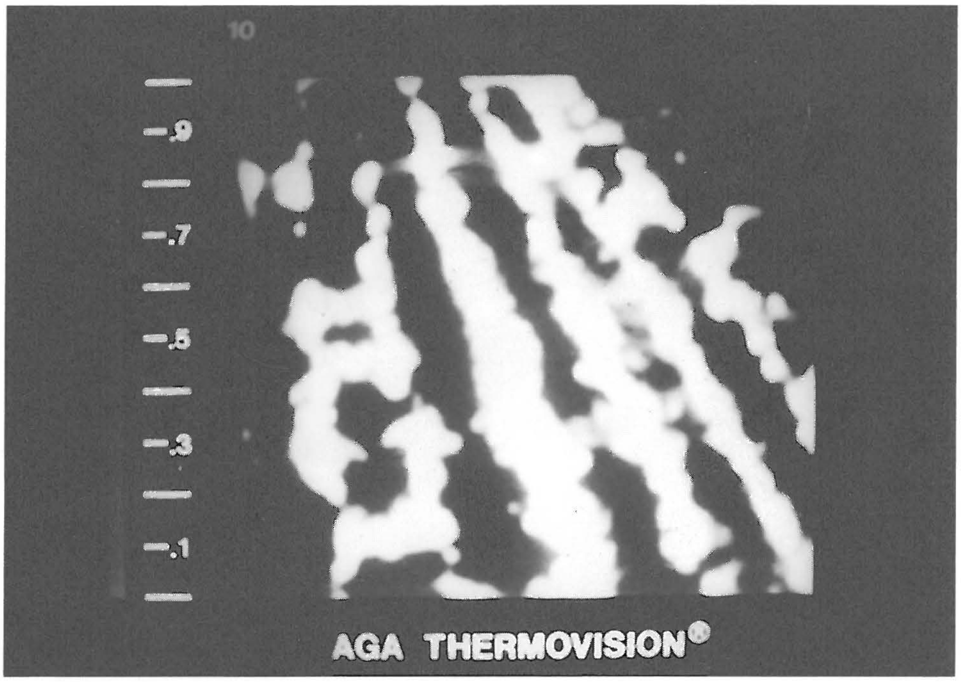


Plate 2 - Nematode disease (11 a.m.)

Top: Thermography of healthy area
Bottom: Isotherm of healthy area



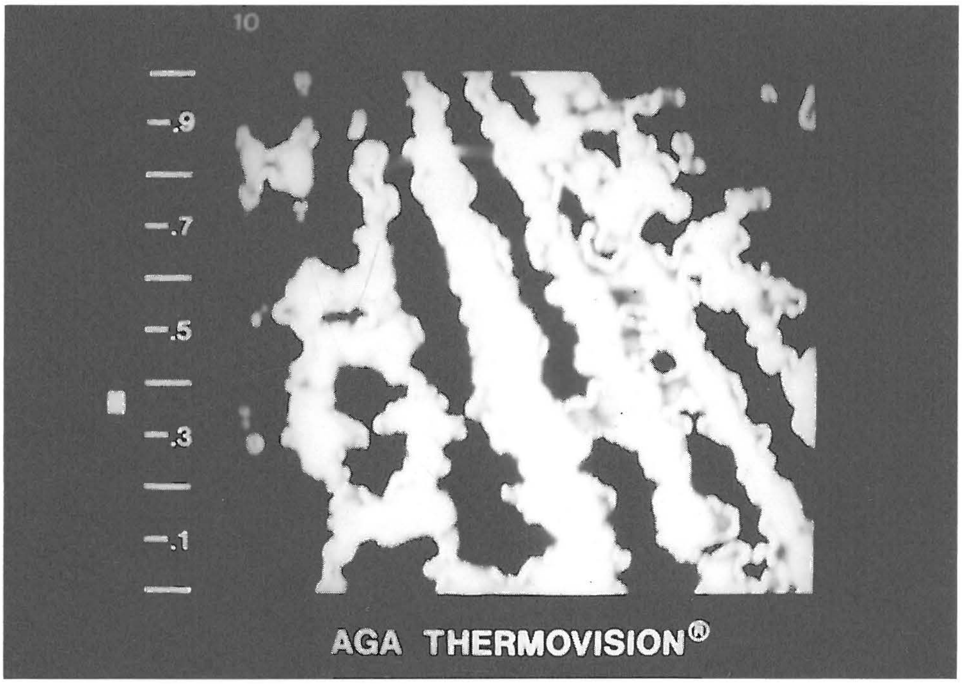
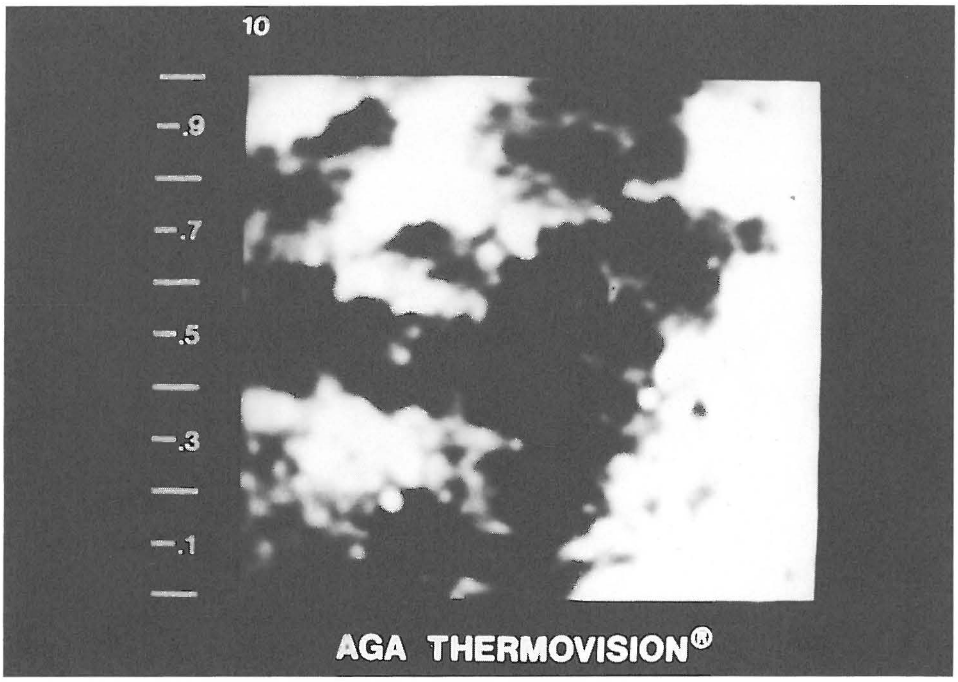


Plate 3 - Nematode disease (1.30 p.m.)

Top: Thermography of diseased area
Bottom: Isotherm of diseased area



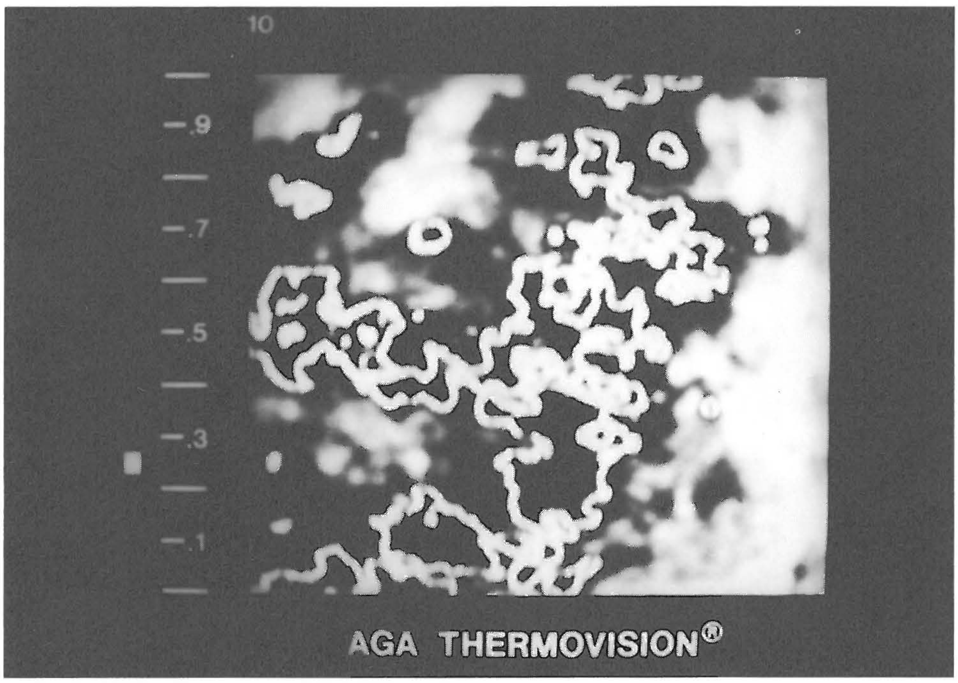
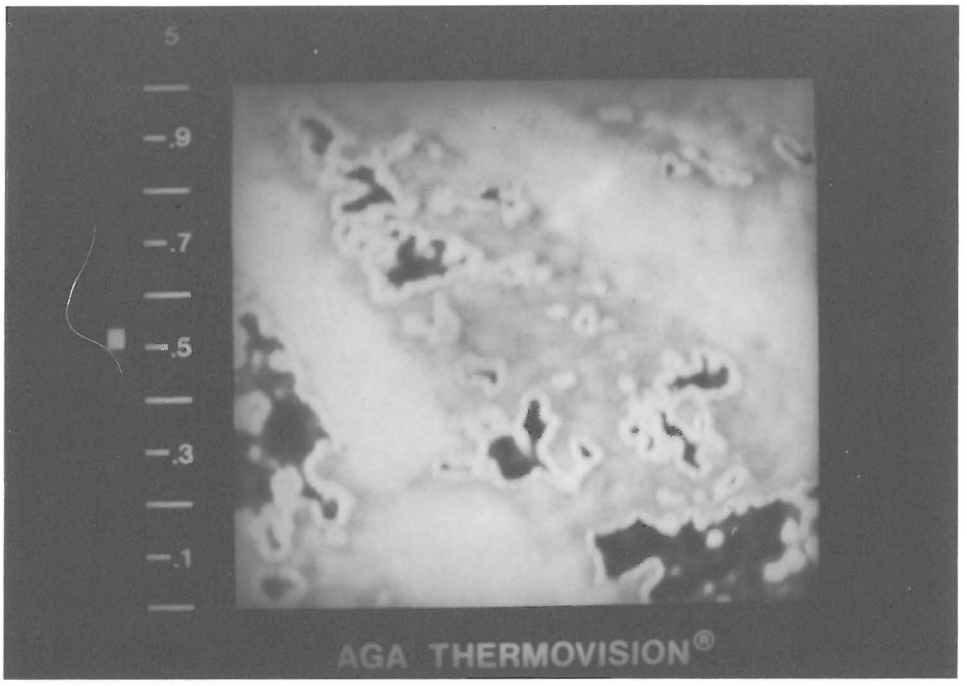


Plate 4 - Nematode disease (1.30 p.m.)

Top: Thermography of healthy area
Bottom: Isotherm of healthy area



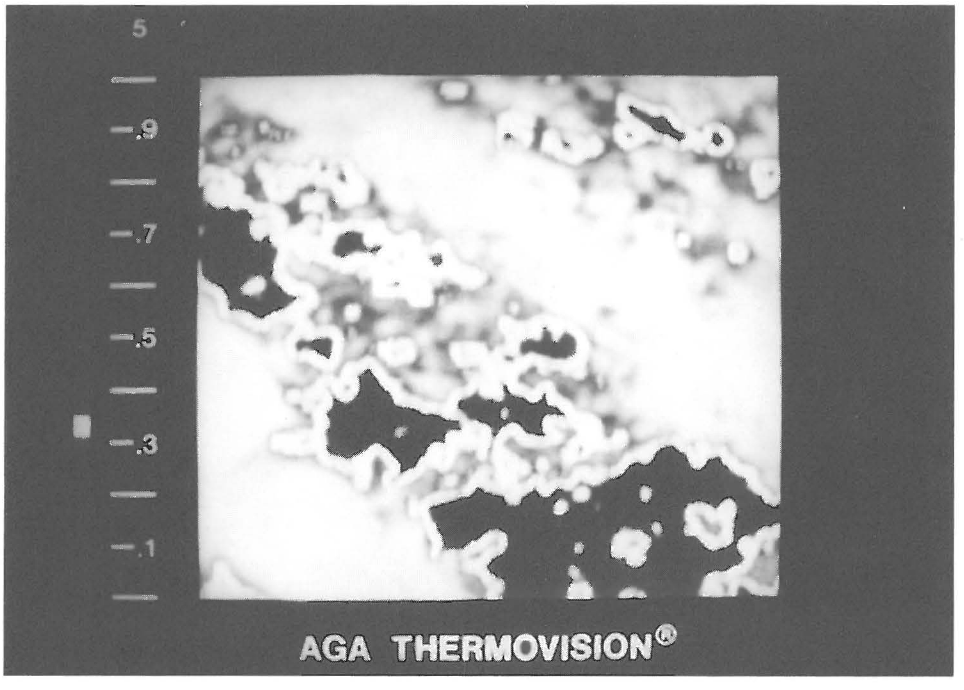
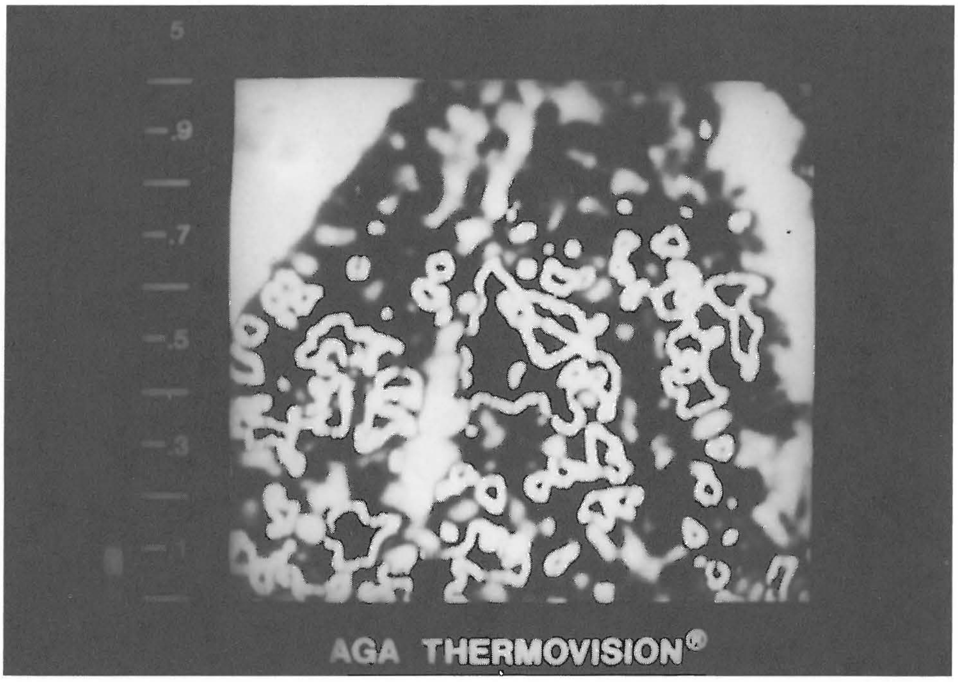


Plate 5 - Rhizomania disease (July, 3 p.m.)

Top: Isotherm of healthy area
Bottom: Isotherm of diseased area



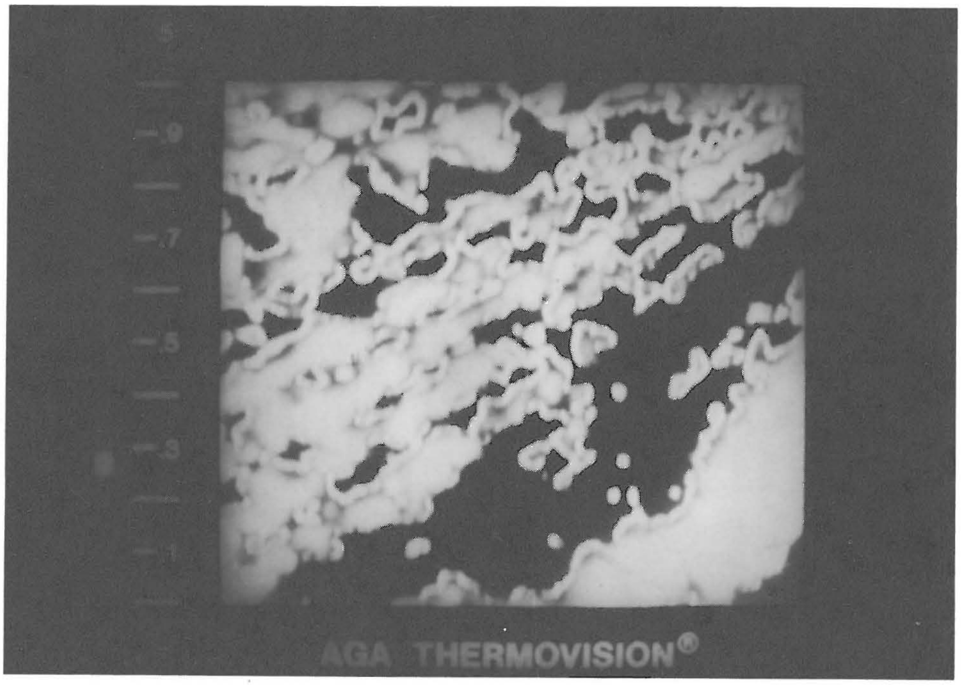
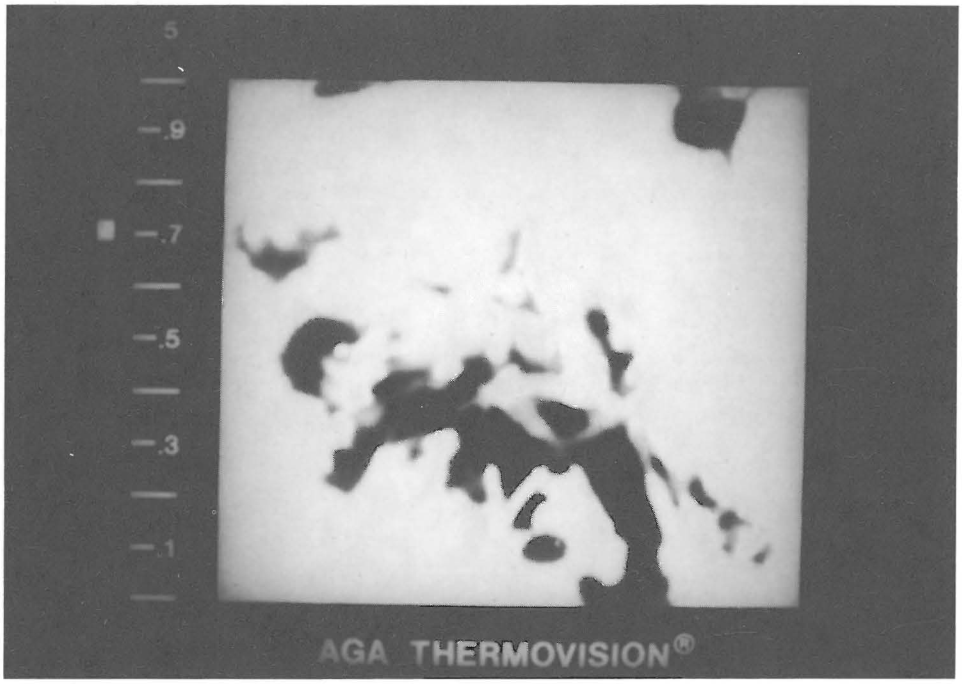


Plate 6 - Rhizomania disease (July, 4.45 p.m.)

Top: Isotherm of healthy area
Bottom: Isotherm of diseased area



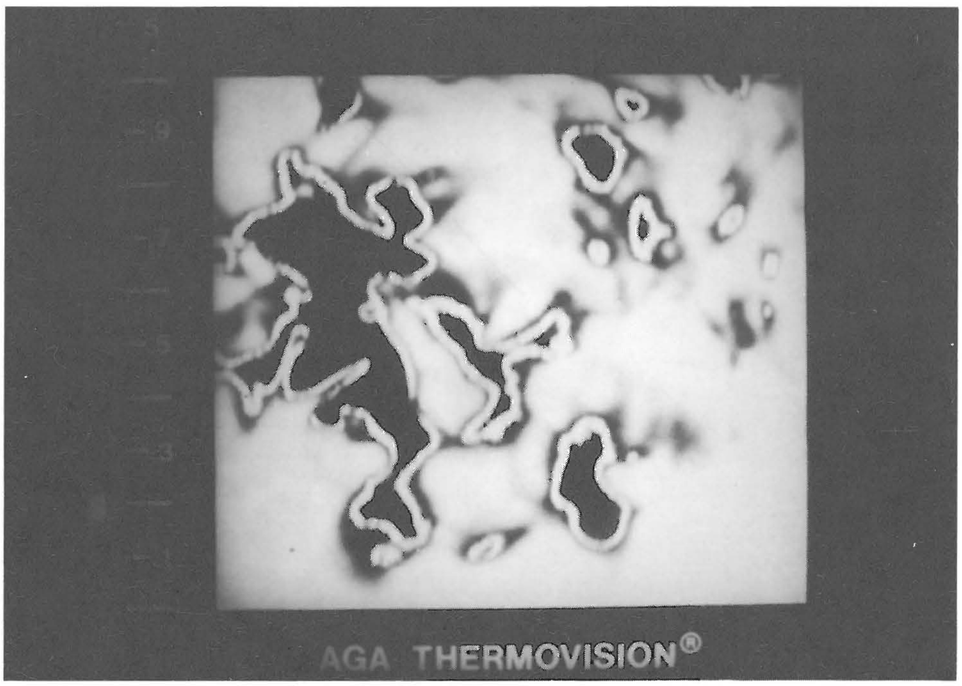
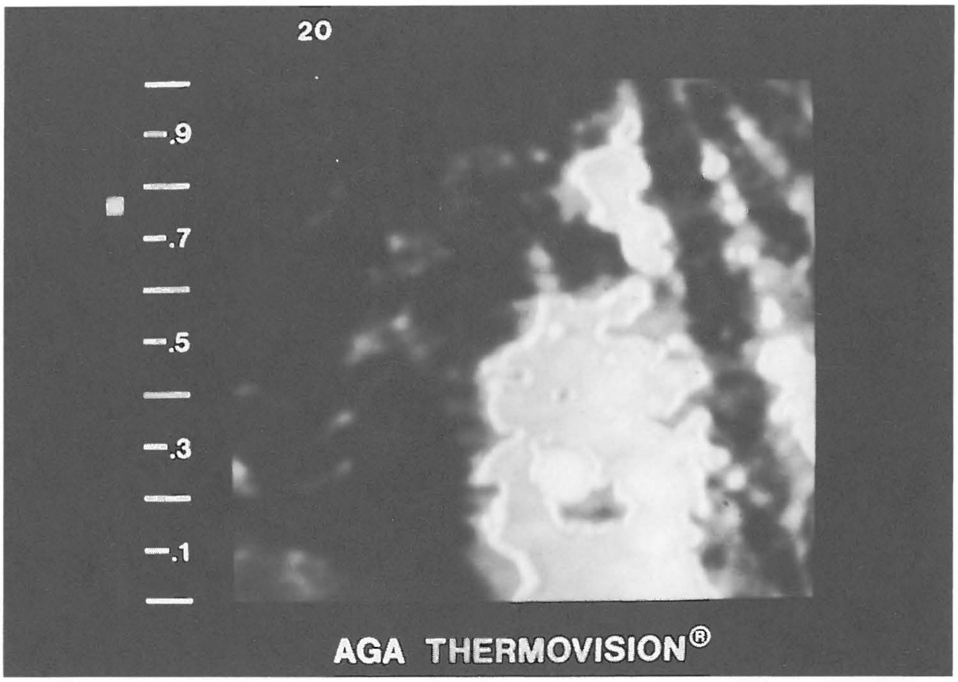


Plate 7 - Rhizomania disease (July, 1 p.m.)

Top: Isotherm of two diseased plants
Bottom: Isotherm of two healthy plants



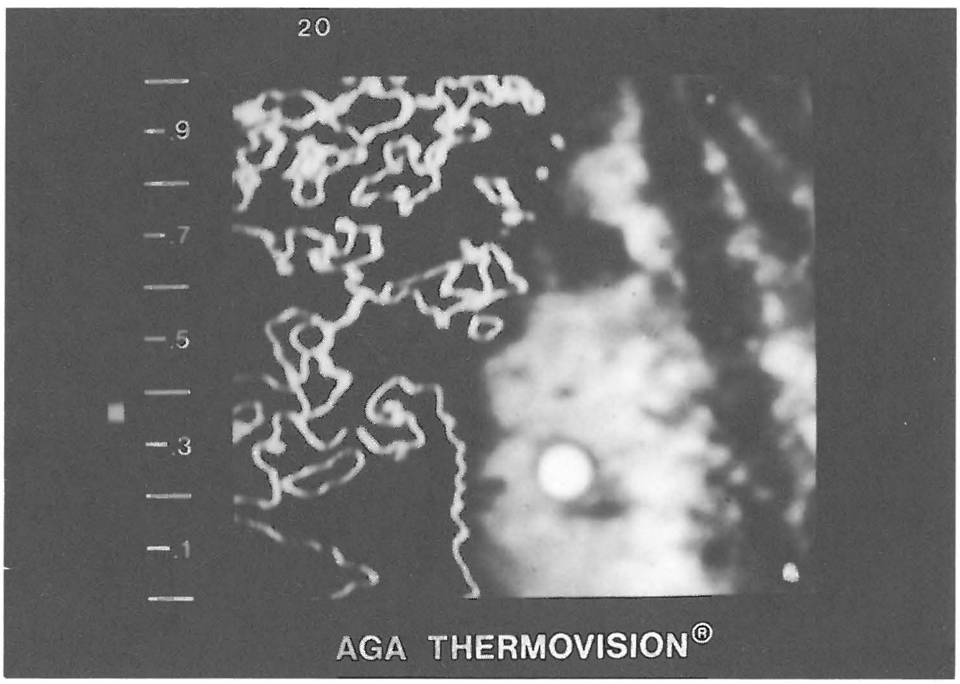


Plate 8 - Rhizomania disease (September, black body external reference at 30°C - 12 a.m.)
Top: Isotherm of black body
Bottom: Isotherm of healthy plants.

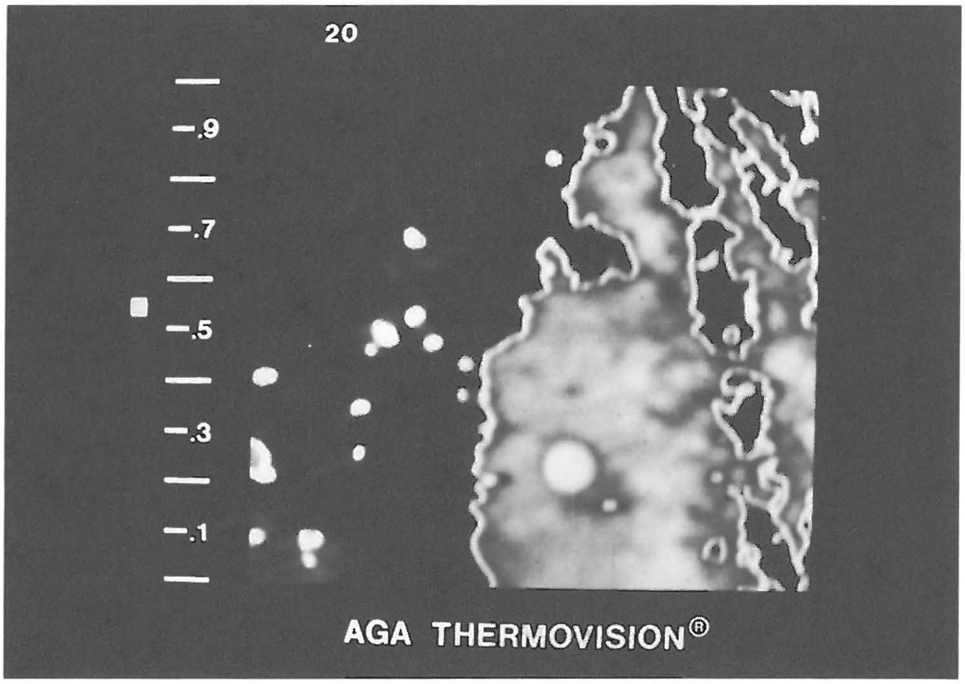
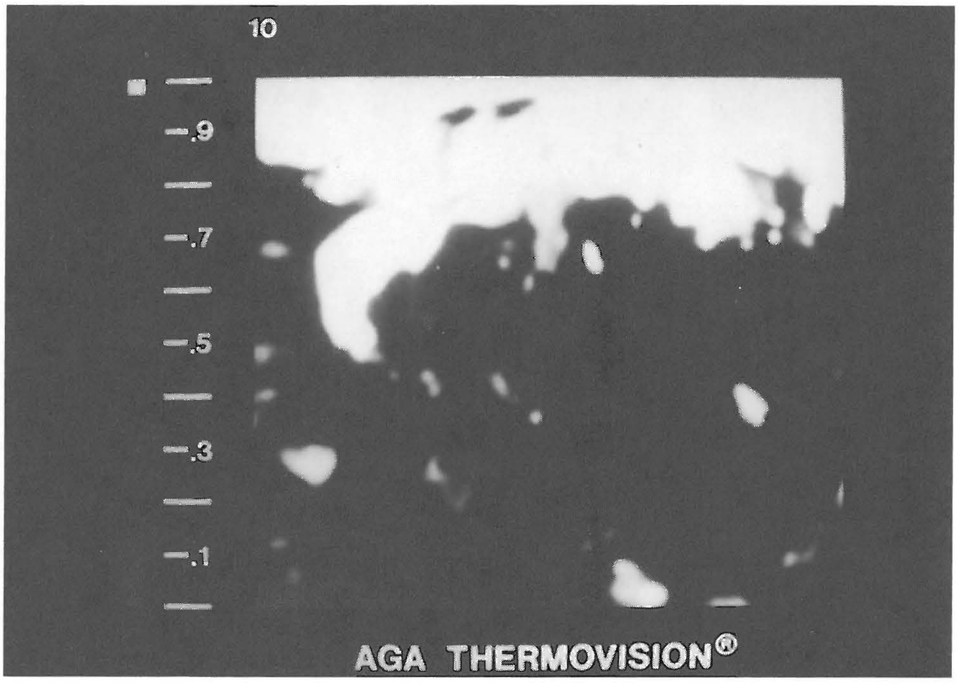


Plate 9 - Rhizomania disease (September, black body external reference at 30 °C - 12 a.m.)
Isotherm of diseased plants.



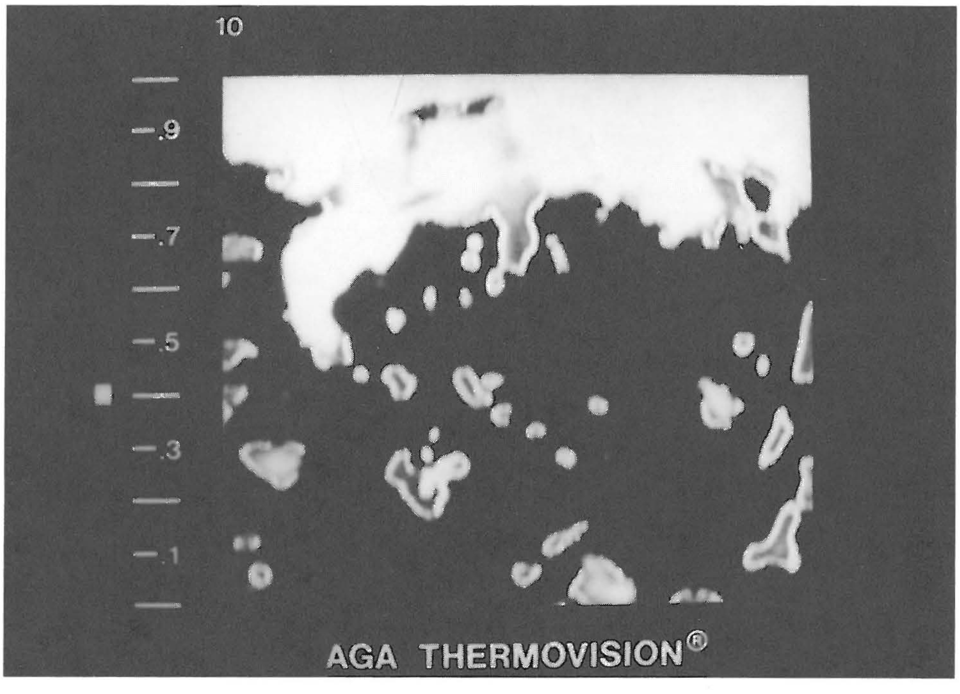


Plate IO - Cercospora leaf spot (Black body external reference at 34°C - I:30 p.m.)
Top: Isotherm of black body
Bottom: Isotherm of healthy plants.

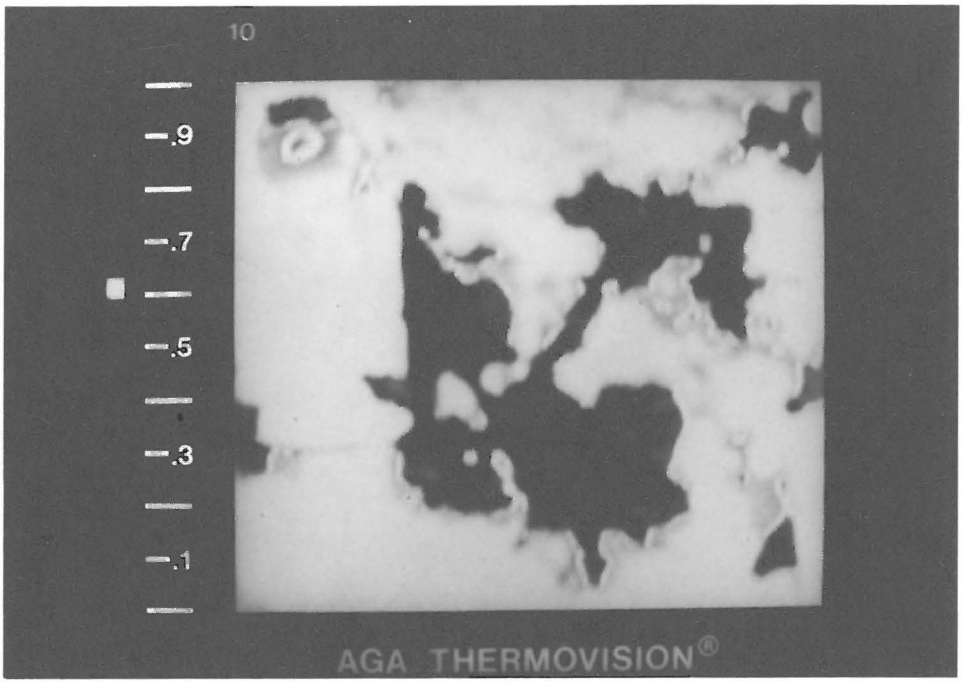


Plate 11 - Cercospora leaf spot (Black body external reference at 34°C - I:30 p.m.)
Isotherm either of black body and of diseased plants.