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**CONSULTANCY FOR UNIDO IN CONNECTION WITH ALTERNATIVES
FOR METHYL BROMIDE (3)**

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SUMMARY

The fieldwork part of the mission took place from 31 October to 5 November 1999 in Morocco. Prof. Dr. Mohamed Ammati and Dr. Kamal Belabbes (IAV Hassan II, Morocco), Mr. H. van Heijningen (Sosef company, the Netherlands) and the external expert Willemien Runia (PBG, the Netherlands) participated.

In Biougra-Agadir on the ARMONA nursery steaming trials were performed. The soil proved to be very suitable for steam sterilization. Recommendations are made to improve future steaming trials.

1. DATA ACTIVITIES

Monday 1 November:

- Transportation steaming materials from IAV Hassan II, Agadir to Armona nursery Biougra
- Determination steaming location
- Preparation steaming divisions and technical lay-out

Tuesday 2 November

Installation steaming systems. Six plots were prepared for steam sterilization.

Plot 1 en 2: Perforated steaming tubes were dug in at 50 cm depth (bottom tube).

Area $8 \times 3 \text{ m} = 24 \text{ m}^2$

Plot 3 en 4: Perforated steaming tubes were dug in at 50 cm depth (bottom tube).

Area $16 \times 3 \text{ m} = 48 \text{ m}^2$

Plot 5: Perforated steaming tubes were dug in at 65 cm depth (bottom tube).

Area $8 \times 3 \text{ m} = 24 \text{ m}^2$

In all plots two tubes were installed over the complete length of the plot with an interval of 150 cm; from the tubes to the outsides of the plot the distance was 75 cm.

Plot 6: Prepared for sheet steaming.

The trenches were dug in manually, after which the perforated tubes were installed horizontally and on one end connected to horizontal non-perforated tubes. At the other end the tubes were blocked with a stopper.

In the main tube connections were made for attachment to the non-perforated tubes. During steaming the connections which are not used are blinded with a cap to prevent false air in the main tube.

One end of the main tube was closed with a cap, at the other end a connection for the fan was fixed.

All six plots were ploughed to a depth of 15-20 cm before the steaming.

Thermistors were installed in the first two plots to steam. Per plot 10 thermistors were installed at five places in the plot and at two different depths: 20 and 40 cm.

N.B. For steam sterilization thermocouples are required in stead of thermistors. Thermocouples register up to 100 °C whereas thermistors only register up to approximately 75 °C.

After the installation of the thermistors, the soil was covered with steaming sheets and anchored with soil.

N.B. For commercial application anchoring should be done with plastic bags filled with clean sand in order to prevent re-infestation from the non-steamed soil.

Wednesday 3 November

Installation of the recorder and connecting thermistors to recorder by Dr. Belabbes, who also took care of the data back-up and will work it out in his institute (IAV, Hassan II) in Rabat. The data given in this report are just overall impressions of the results of the steaming trials.

Steam production in the boiler was handled by Prof. Ammati.

Steaming trials plot 1 and 2

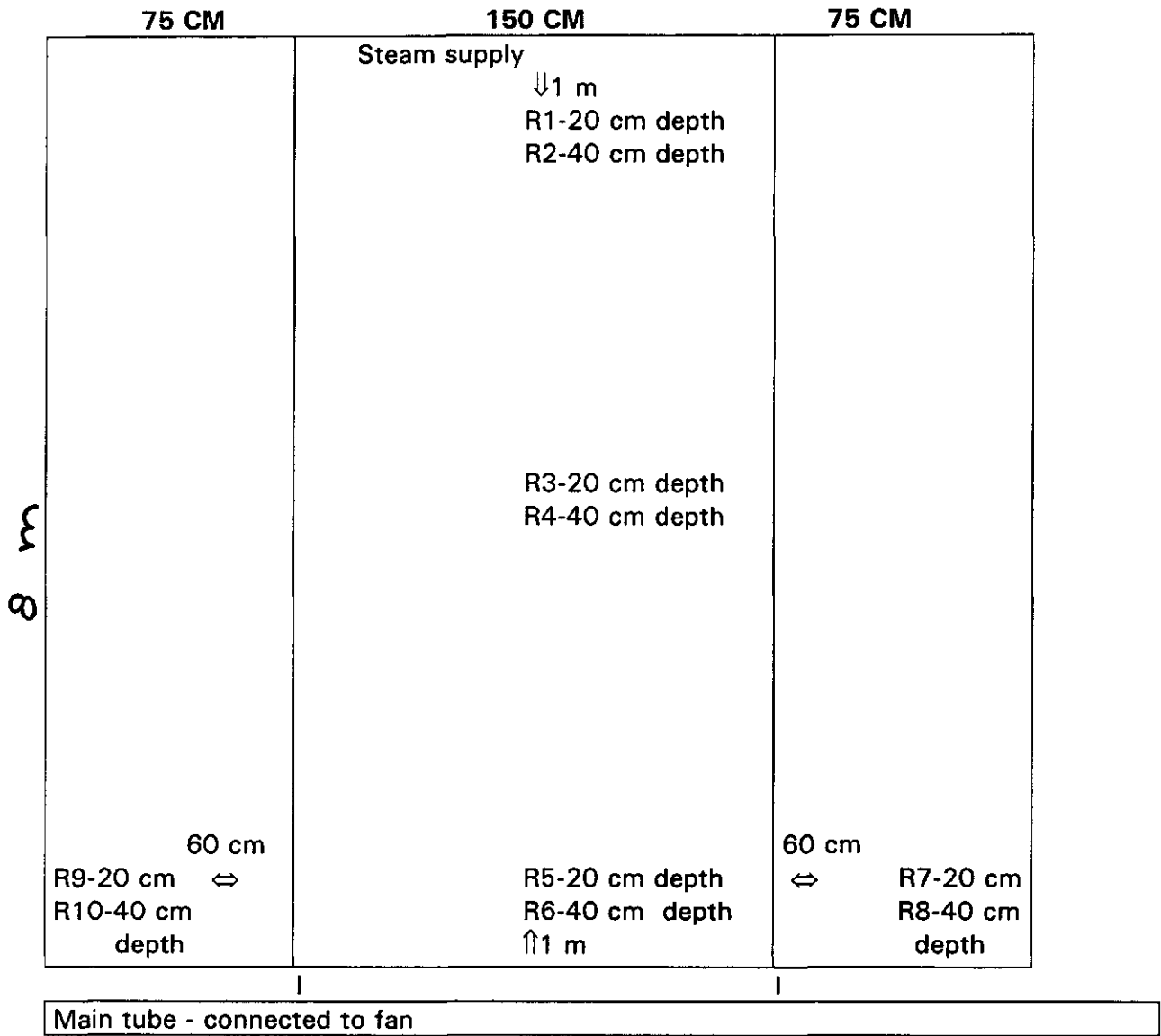
Thursday 4 November

Steaming trials 3 and 5

N.B. The plots 4 and 6 were not steam sterilized due to boiler failures and time deficit

2. STEAMING TRIALS

2.1. PLOT 1 - 8 X 3 M - SYSTEM DEPTH 50 CM



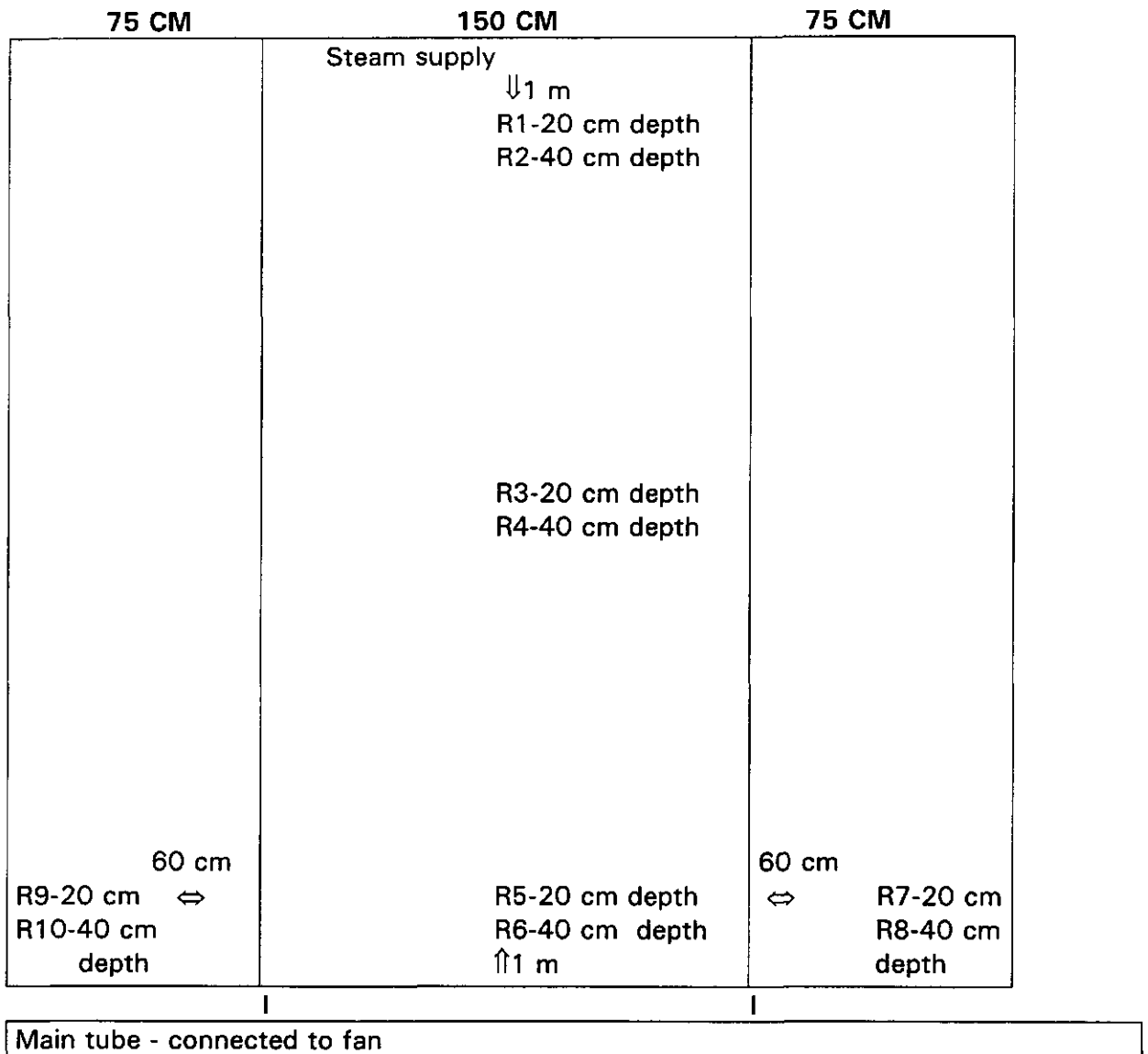
RESULTATEN PLOT 1

| Ther- mistor | Temperatures registered during steaming (°C) at different times (h) | | | | | | | | | After steaming |
|-----------------|---|-------|-------|-------|-------|-------|-------|-------|-------|-------------------|
| | 9.45 | 10.00 | 10.30 | 11.15 | 11.30 | 11.45 | 12.00 | 12.15 | 13.45 | |
| R1 | 22.2 | 22.3 | 22.5 | 34.1 | 56.0 | 69.1 | 73.7 | 74.3 | 68.4 | |
| R2 | 23.4 | 23.3 | 23.3 | 23.3 | 23.4 | 23.6 | 24.2 | 25.7 | 44.9 | |
| R3 | 22.5 | 22.7 | 62 | 76.4 | >76.4 | >76.4 | >76.4 | >76.4 | 73.3 | |
| R4 | 23.8 | 23.7 | 23.9 | 77.5 | >77.5 | >77.5 | >77.5 | >77.5 | 75.2 | |
| R5 | 21.5 | 49.5 | 72.4 | 77.0 | >77.0 | >77.0 | >77.0 | >77.0 | 68.4 | |
| R6 | 24.3 | 24.3 | 24.3 | 45.0 | 68.2 | 75.3 | >75.3 | >75.3 | 73.6 | |
| R7 | 22.5 | 22.9 | 39.9 | 76.9 | >76.9 | >76.9 | >76.9 | >76.9 | 72.5 | |
| R8 | 23.3 | 23.3 | 23.3 | 23.7 | 24.6 | 27.3 | 35.8 | 47.2 | 62.8 | |
| R9 | 23.7 | 23.6 | 24.4 | 76.2 | >76.6 | >76.6 | >76.6 | >76.6 | 70.8 | |
| R10 | 24.6 | 24.6 | 24.5 | 24.8 | 26.2 | 30.8 | 42.2 | 52.2 | 62.6 | |

REMARKS

- The capacity of the fan was more than sufficient for the area to be steamed.
- Between 10.13 and 10.32 hours the steam supply was interrupted due to low water alarm in the boiler.
- The total effective steaming period for this plot is approximately 2 hours and 15 minutes
- The water consumption was approximately 800 litres for 24 m², resulting in 33,3 litres/m² soil.
- The temperatures achieved between the two tubes are >70 °C at 40 cm depth with an exception of R2, where the steaming sheet was folded several times and therefore steam distribution was obstructed.
- **The steaming sheet should always be a single layer for optimal steam distribution and also for preventing the melting together of double layers.**
- The penetration of steam on the outskirts of the plot (R7-R10) is limited because only one tube sucks the steam downwards. Yet after 2.15 hours of steaming the results are sufficient for elimination of nematodes up to a depth of 40 cm.
- After the steam supply was shut off, the fan was on for another 1.30 hours which resulted in an increase of 10-20 degrees of the lowest temperatures.
- The results are very promising; the structure of the sand is solid enough for steam penetration.

2.2 PLOT 2 - 8 X 3 M - SYSTEM DEPTH 50 CM



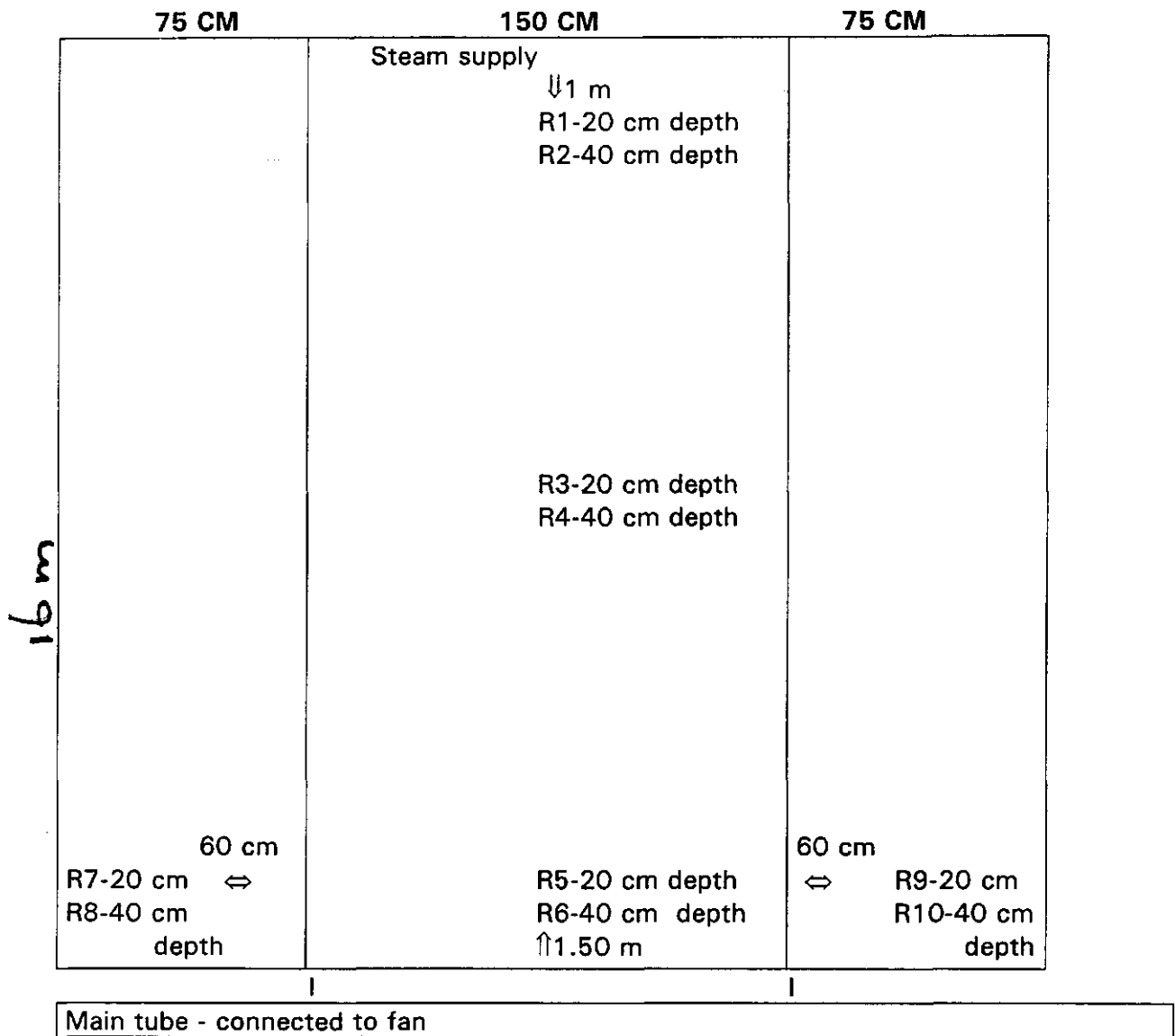
RESULTATEN PLOT 2

| Ther- mistor | Temperatures registered during steaming (°C) at different times (h) | | | | | | | | After steaming |
|-----------------|---|-------|-------|-------|-------|-------|-------|-------|-------------------|
| | 14.25 | 15.00 | 15.30 | 15.45 | 16.00 | 16.15 | 16.30 | 16.45 | |
| R1 | 23.7 | 24.8 | 32.1 | 43.3 | 53.4 | 62.7 | 70.6 | 75.3 | 67.8 |
| R2 | 24.2 | 24.2 | 24.2 | 24.2 | 24.2 | 24.2 | 24.2 | 24.3 | 26.1 |
| R3 | 23.1 | 27.0 | 74.9 | 75.3 | >75.3 | >75.3 | >75.3 | >75.3 | 73.5 |
| R4 | 24.1 | 24.2 | 24.2 | 24.8 | 28.4 | 45.9 | 67.4 | 75.5 | 63.2 |
| R5 | 23.0 | 37.3 | 74.9 | 75.3 | >75.3 | >75.3 | >75.3 | >75.3 | 73.8 |
| R6 | 23.9 | 23.9 | 22.9 | 24.1 | 24.5 | 26.2 | 31.0 | 42.3 | 53.1 |
| R7 | 22.7 | 41.5 | 74.7 | 74.9 | >75.1 | >75.1 | >75.1 | >75.1 | 72.8 |
| R8 | 23.7 | 23.7 | 24.4 | 28.8 | 45 | 59.9 | 69.0 | 75.0 | 64.9 |
| R9 | 25.2 | 51.9 | 74.7 | 75.1 | >75.1 | >75.1 | >75.1 | >75.1 | 69.8 |
| R10 | 25.2 | 25.2 | 25.2 | 25.5 | 25.4 | 25.5 | 25.7 | 26.1 | 34.2 |

REMARKS

- The capacity of the fan was more than sufficient for the area to be steamed.
- Between 14.40 and 15.00 hours the steam supply was interrupted due to alarm in the boiler.
- The total effective steaming period for this plot is approximately 2 hours and 15 minutes
- The water consumption was 700 litres for 24 m², resulting in 29.2 litres/m² soil.
- The temperatures achieved between the two tubes are >70 °C at 20 cm depth, at 40 cm at R2 the maximum temperature achieved is 39.7 °C at 4.00 hours and at R6 the maximum temperature achieved is 53.1 °C. Both measuring points should have reached 70 degrees or more when the steaming period had been longer.
- The penetration of steam on one of the outskirts of the plot (R10) is limited because only one tube sucks the steam downwards. On the inner outskirts at 40 cm depth the temperature exceeds 70 °C. This is due to the fact that this border receives heat from the first plot, which was steamed in the morning of the same day.
- After the steam supply was shut off, the fan was on for another 1.30 hours, which resulted in an increase of 10-20 degrees of the lowest temperatures.
- The results are more or less equal to the results of the first plot; again penetration of the steam into the soil is realized quite satisfactory.

2.3 PLOT 3 - 16 X 3 M - SYSTEM DEPTH 50 CM



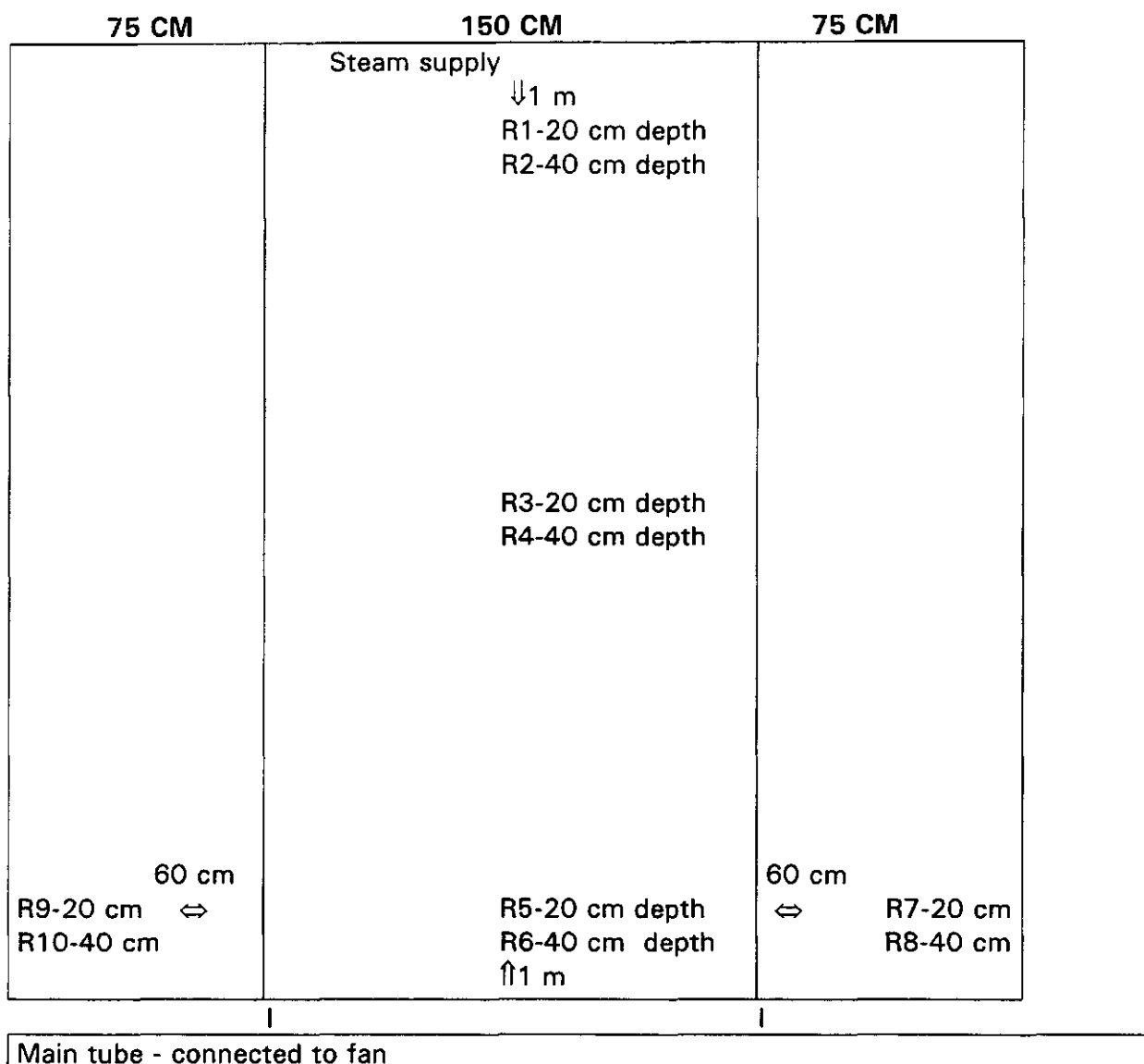
RESULTATEN PLOT 3

| Ther- mistor | Temperatures registered during steaming (°C) at different times (h) | | | | | | After steaming |
|-----------------|--|------|-------|-------|-------|-------|----------------|
| | 8.45 | 9.00 | 10.00 | 10.30 | 11.15 | 12.00 | |
| R1 | 23.1 | 24.5 | 75.7 | 75.9 | >75.9 | >75.9 | |
| R2 | 23.6 | 23.7 | 55.9 | 66.7 | >76.6 | >76.6 | |
| R3 | 23.5 | 23.5 | 34.4 | 68.3 | >76.5 | >76.5 | |
| R4 | 24.2 | 24.2 | 24.2 | 24.4 | 63.8 | >76.8 | |
| R5 | 22.9 | 22.9 | 40.7 | 74.1 | >76.4 | >76.1 | |
| R6 | 23.7 | 23.7 | 23.7 | 23.9 | 71.6 | >77.2 | |
| R7 | 22.8 | 22.8 | 22.9 | 23.1 | 32.9 | 61.5 | |
| R8 | 23.3 | 23.3 | 23.3 | 23.3 | 23.2 | 23.2 | 28 |
| R9 | 23.2 | 23.2 | 23.2 | 23.4 | 35.2 | 63.6 | |
| R10 | 23.8 | 23.8 | 23.7 | 23.7 | 23.8 | 24.2 | 35 |

REMARKS

- The capacity of the fan was more than sufficient for the area to be steamed.
- Between 8.45 and 9.15 hours the steam supply was interrupted due to alarm in the boiler.
- The total effective steaming period for this plot is approximately 3 hours.
- The water consumption was 1000 litres for 48 m², resulting in 20.8 litres/m² soil.
- The temperatures achieved between the two tubes are >70 °C at 20 and 40 cm depth.
- The penetration of steam on one of the outskirts of the plot (R7-R10) is limited because only one tube sucks the steam downwards. The required temperature of 70 °C could have been easily be achieved by elongation of the steaming period.
- After the steam supply was shut off, the fan was on for another hour, which resulted in an increase of 5-10 degrees of the lowest temperatures. In commercial situations the fan should continue for at least 2 hours after stopping the steam supply.

2.4 PLOT 5 – 8 X 3 M – SYSTEM DEPTH 65 CM



REMARKS

- The capacity of the fan was more than sufficient for the area to be steamed. Although the soil layer above the perforated tubes was 57 cm, The steaming sheet was strongly drawn to the soil before the introduction of the steam.
- Unfortunately the steam supply was interrupted frequently due to a blocked water supply to the boiler.
- After 1.5 hours of troubles with the boiler the trial was terminated.

3. CONCLUSIONS AND RECOMMENDATIONS

- The results of the steaming trials in Biougra (Agadir) indicate that this alternative for methyl bromide is very promising. Temperatures could have been higher when a longer steaming period had been realized. Due to time deficiency this could not be realized in this tests. Water consumption also was an indicator that the soil could accept much more steam. A water consumption of 40 to 50 litres per m² soil is average in the Netherlands.
 - Most important in this system is **to start the fan before the steam supply.**
 - The fan should continue for at least 2 hours after the shut off of the steam supply.
 - Anchoring of the steaming sheets should be with plastic bags filled with clean sand in order to prevent re-infestation of the soil.
 - Registering temperatures during steaming trials should be realized with thermocouples in stead of thermistors.
 - For optimization of the system the following suggestions are made.
1. Mechanical digging of the trenches
 2. Establishing the minimal requirement in tubes by testing several intervals between the tubes and at several depths.
 3. Establishing the maximum length of the tubes acceptable for efficient steaming.
 4. Establishing the maximum plot to be steamed at the same time; a complete tunnel or half a tunnel in relation to the boiler capacity.
 5. Establishing the required steaming period in relation to the crop length; for a 1 year crop 30 cm depth at 70 °C might be sufficient whereas a 2 year crop might need 50 cm of adequate steaming.
 6. The outer tubes should be installed at minimum distance from the plastic greenhouse screen because soil on the outside of the outer tubes is the most difficult to steam properly.
 7. Establishing feasibility of steam supply and fan at the same side (entrance) of the tunnel.
 8. Fuel consumption can probably be cut down by using solar screen energy for heating up the water before entering the boiler.
 9. Boiler failures restricted the efficiency of the steam trials. It is recommended to send Prof. Ammati to the Netherlands to meet a boiler specialist and discuss the problems, which may arise during steaming and also regarding maintenance of the boiler. Moreover he could visit the company which installs the steaming system to discuss all details.