HOT WATER
A
VIABLE ALTERNATIVE TO METHYL BROMIDE

Chapman Mayo, Aqua Heat Technology, Inc.

Background:
Aqua Heat Technology, Inc. has, for the last two years, been developing a technology to control nematodes and other soil pathogens in open fields by raising the soil temperature to a lethal levels for these organisms. The ability to raise the temperature of large volumes of soil requires the introduction of large quantities of hot water. This need has push Aqua Heat to develop very sophisticated, efficient and compact heat transfer equipment which is able to be transported in the field.

Heat has long been known to be effective in controlling soil bacteria, but elevating the soil temperature with hot water cannot be a selective process. In other words, beneficial bacteria as well as pathogenic bacteria will be effected by the heat, thus creating, to some degree, a biological vacuum in the sterilized area. Because of this result, Aqua Heat's comprehensive process involves repopulating the sterilized ground with selected non-pathogenic bacteria. It is this unique process of sterilizing the soil by injecting hot water and subsequently repopulating with beneficial bacteria for which Aqua Heat Technology, Inc. has been issued US Patent No. 5,259,327.

Tests conducted by Aqua Heat in conjunction with the University of Florida and the G. Howard Ferguson Forest Station in Kemptville, ONT have shown very promising results. The tests have been carried out in different crops including, tree seedlings, tomatoes and strawberries. The prototype equipment used and initial results of some of the trials are described below.

Equipment
The current prototype equipment used in the tests conducted to date consists of a 1700 gallon tank and trailer unit with a 4 Million BTU heat exchanger. Currently the injection and mixing system is pulled by a separate tractor. The commercially viable model will combine the heat exchanger and injection system on one unit and the water will be supplied via irrigation hose directly from an irrigation system to the heat exchanger.

The current heat exchanger is capable of heating up to 90 gallons of water per minute to 220-230 degrees. The injection system is comprised of two parts, the knives and the power harrow. Boiling water is pump out behind the knives through a series of small hoses each with a specific outlet below the ground. The power harrow follows immediately behind the knives to mix the soil and the hot water together thereby evenly distributing the heat throughout the soil profile.

TESTS:
G. Howard Ferguson Provincial Forest Station, Kemptville, ONT
The goal of this trial was to determine if the hot water treatment was capable of controlling weed seeds, which is one of the biggest problems facing this nursery. On June 16, 1995 Aqua Heat's prototype sterilization unit was tested on bed #10 in compartment #17.

Temperatures were recorded at depths of 1 cm, 2 cm, 5 cm and 10 cm, (see graphs 1 & 2). Soil temperatures increased dramatically in the top 5 cm to between 60 and 75 degrees Celsius immediately upon the injection of boiling water and cooled down gradually over roughly a 3 hour period.

In the first test (graph #1) hot water was not injected at the 10 cm depth as no initial temperature rise was observed. However, soil temperature at the 10 cm depth did increase over time due to water movement through the soil. In the second test, (graph #2), hot water was placed at the 10 cm depth as is evidenced by the initial increase in temperature. While further testing needs to be carried out in different soil types to determine the ultimate effective treatment depth, graph #1 shows that to some extent the hot water treatment is at work below the zone where the actual treatment took place.

The following week bed #10 was segmented into three components. The first was left untouched after the hot water treatment one week earlier. The second segment (50 meters) was reformed into a raised bed. Finally, the last 15 meters of this raised bed was seeded with silver maple. All three areas were monitored for weed growth relative to a control area, (see graph #3). There were slight differences in the raised and seed areas relative to the flat unformed area, but these differences were not significant when compared to the control area. In general the hot water treatment significantly reduced the weed population.

Additional tests were performed at the G. Howard Ferguson Nursery Station at the end of September 1995. In addition to monitoring temperatures and collecting data on weed population, soil organisms were monitored. Specific disease organisms were propagated and placed in sample bags. These bags were placed in the soil immediately after the soil was treated. (Bags could not be placed in the soil prior to treatment do to their inability to withstand the tilling treatment.) Data from these trials were not available as of this conference.

<u>Brock Farm, Plant City, FL</u>

Through previous studies conducted in 1994 in cooperation with Dr. Joe Noling, Nematologist with the University of Florida a graph generalizing the thermal tolerance of nematodes was developed. (see graph #4) This graph is consistent with other information regarding the heat tolerance of these organisms being approximately 130 degrees for two minutes.

With this in mind, a study was held on a tomato farm in Plant City, FL with the help of Dr. Joe Noling on June 6, 1995. The goal was to achieve a soil temperature rise to 125-130 and measure nematode population before and after the treatment relative to a control area. Temperatures were monitored during treatment to ensure the desired temperatures were reached however, no time-temperature graphs were recorded or produced. However, pre and post soil samples were taken to determine the nematode density of the soil. (see graph #5) As is graphically displayed, the control area had a pre and post treatment nematode counts of 149 and 62 per 100 cc's of soil respectively and the treated area recorded 119 and 0 per 100 cc's of soil respectively.

While no crop was subsequently planted on this test plot, it is important to note that the nematode counts reflected in this fallow field represented a significant threat to the viability of the next crop.

Two additional test were conducted in Florida strawberry farms this past September. Soil samples were take at each test and strawberries were planted on each site. However, as of this conference, no data is yet available.

<u>COSTS</u>

The cost of sterilizing soil with hot water is dependent on a number of obvious factors such as fuel and labor costs. But there are a few additional variable factors which are discussed below:

1)Area - Depending on the crop to be grown, various portions of the soil will be treated including, broad acre, rows only, top 4-6 inches, top 12 inches and any combination thereof. These combinations generate different volumes of soil for treatment which require different volumes of water. Very simply the large the soil volume to be treated the large the water requirement. Water volumes at this point can vary from 25,000 to 50,000 gallons per acre.

Note: While the water volumes appear large, it should be noted that most crops will be irrigated immediately after planting with water volumes in the lower portion of this range. In other words, assuming that planting takes place within a few days post sterilization, the hot water treatment alleviates the need for irrigating prior to planting.

2) Ambient temperature - The initial ground temperature and moisture content and to a certain degree air temperature are also factors in the overall cost of treating a given acre. The lower the ground temperature the larger the volume of water needed to heat soil to a given temperature.

3) Organisms controlled - The thermal threshold for various pathogens including weed seeds can vary dramatically. In addition, certain crops are adversely effected by certain pathogens. Therefore, depending on the crop grown, certain pathogens need to be controlled which will require a specific temperature rise. The water volume need to achieve this given temperature rise is dependent on factors 1 & 2 described above.

In summary, the overall cost of treating a given area is heavily dependent on the volume of water needed and the factors described above directly influence that volume requirement and thus the cost.

<u>THE NEXT STEP</u>

The company plans to continue extensive testing in various soil types to determine practical boundaries for expected temperature rises within the different soil conditions. Future testing will also be expanded to monitor soils for an even wider range of soil pathogens and the effects of the treatment on them. Other factors such as soil moisture and ambient ground temperature will also be monitored to determine their ultimate effects on the overall per acre cost of the treatment.

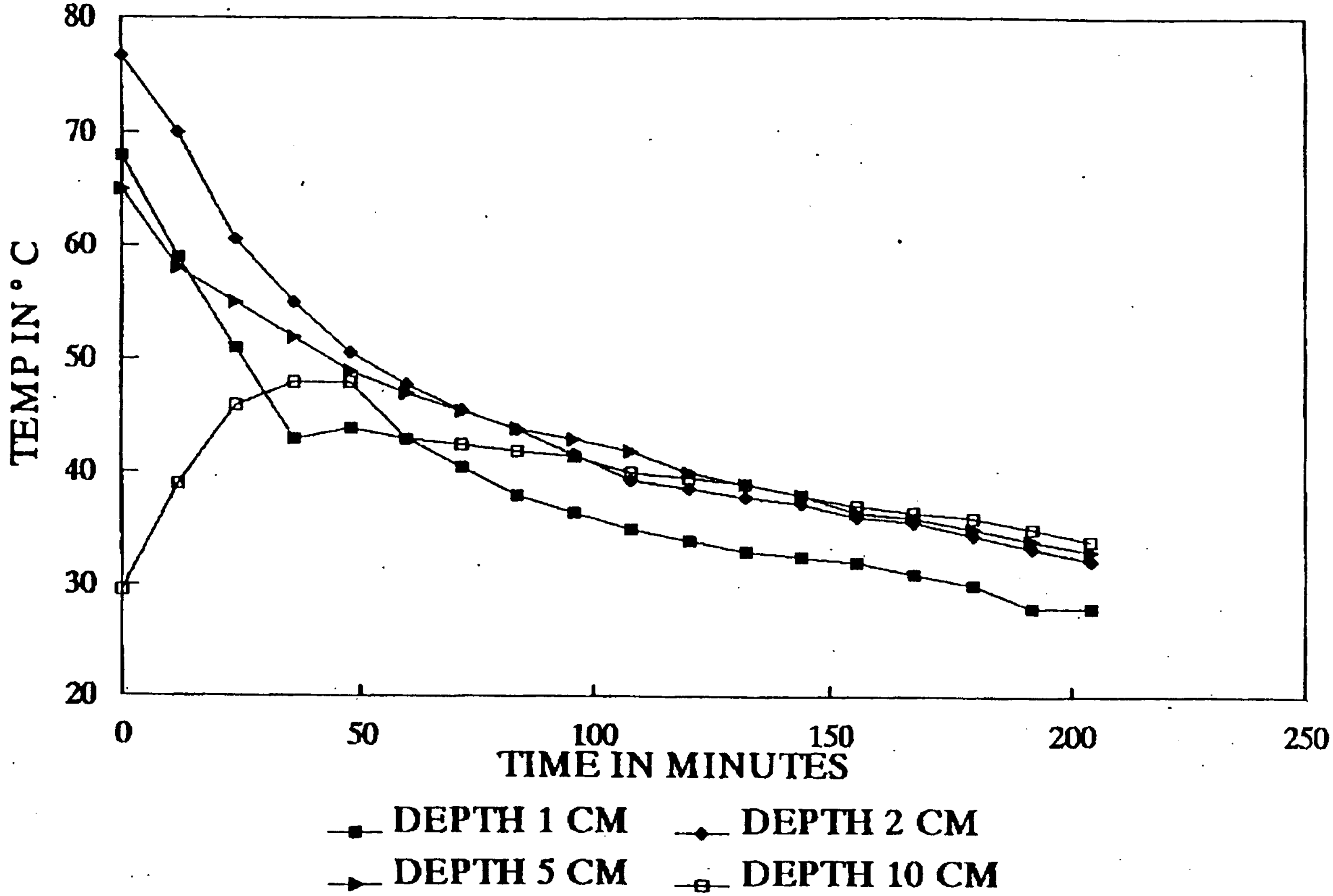
The company is currently undertaking to build a commercially viable prototype with the aim of commencing field testing in the spring and summer of 1996.

1995 SOIL TEMPERATURES

AQUA–HEAT HOT WATER MACHINE | **GHFFS – CPT 17** | **June 16, 1995**

First test – started at 2:50 pm | Machine travelling at 10 ft./minute | North end of bed

12 minute intervals



Soil temperatures in adjacent untreated bed at 3:00 pm were:

1 cm	40°C
2 cm	41°C
5 cm	36°C
10 cm	31°C

COURTESY OF G. HOWARD FERGUSON FOREST STATION, KEMPTVILLE, ONT.

GRAPH #1

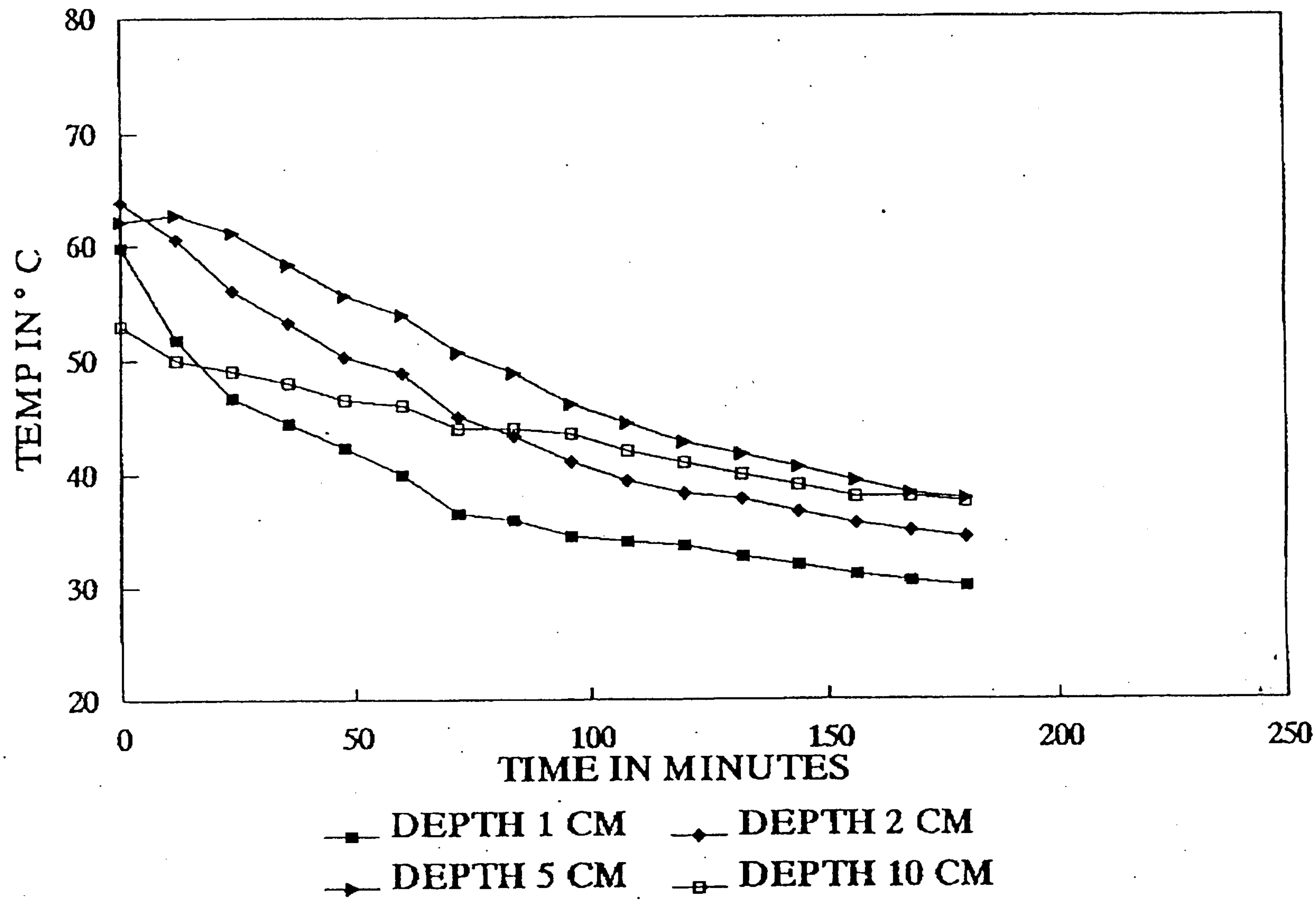
1995 SOIL TEMPERATURES

AQUA-HEAT HOT WATER MACHINE — **GHFFS - CP'T 17** — **June 16, 1995**

Second test – started at 3:24 pm — Machine travelling at 10 ft. / minute — South end of bed

Using tarp

12 minute intervals



Soil temperatures in adjacent untreated bed at 3:00 pm were:

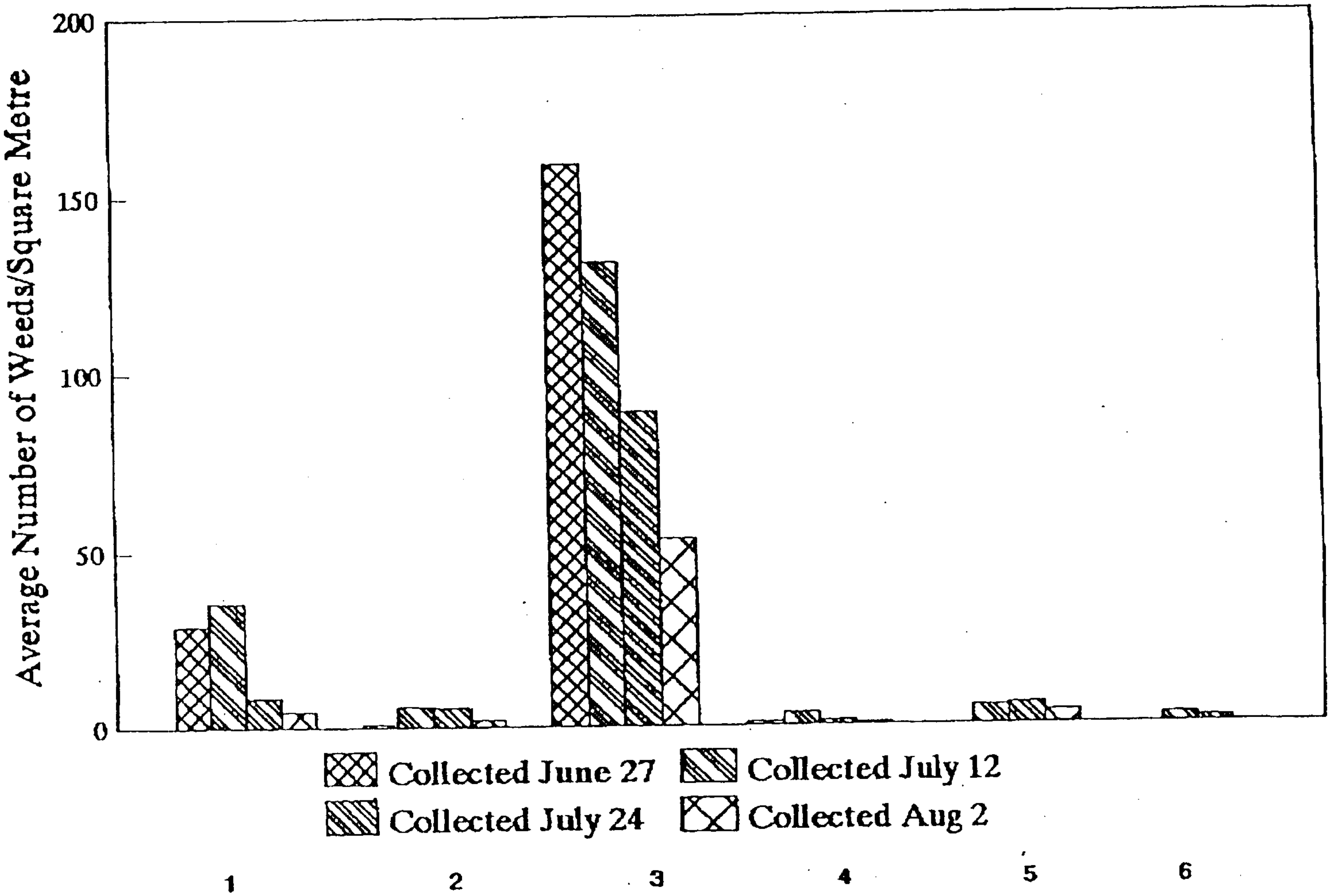
1 cm	40°C
2 cm	41°C
5 cm	36°C
10 cm	31°C

COURTESY OF G. HOWARD FERGUSON STATION, KEMPTVILLE ONT.

GRAPH #2

Trial # KN95-1
Cp't. # 17

WEED POPULATIONS IN AQUA-HEAT TRIAL



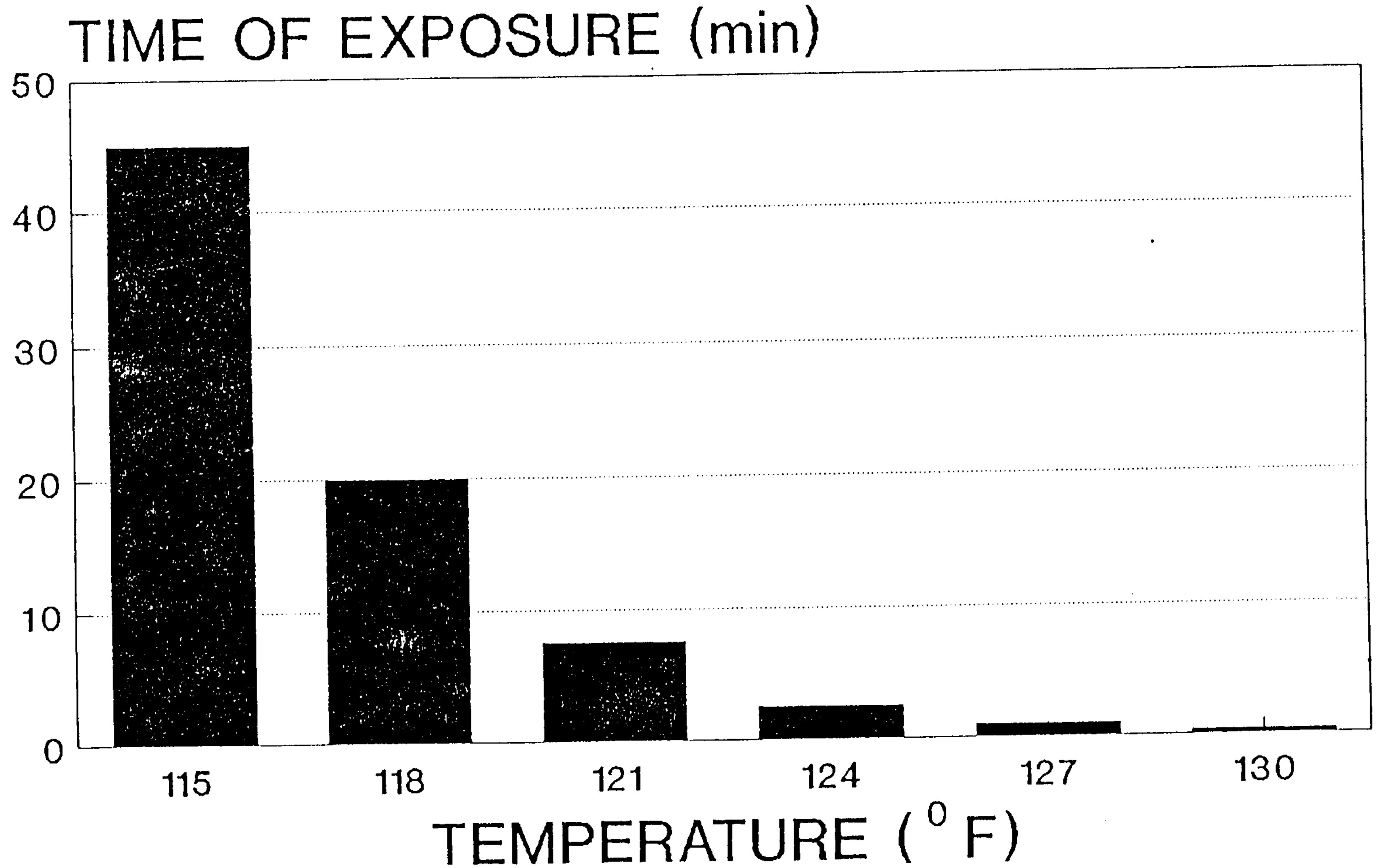
TREATMENTS
{see map}

1. Control south
2. Hot Water South - left flat
3. Control North
4. Hot Water North - left flat
5. Hot Water - bed formed + maple
6. Hot Water - bed formed - no crop

COURTESY OF G. HOWARD FERGUSON FOREST STATION, KEMPTVILLE ONT.

GRAPH #3

Generalized Thermal Death Times of Nematodes



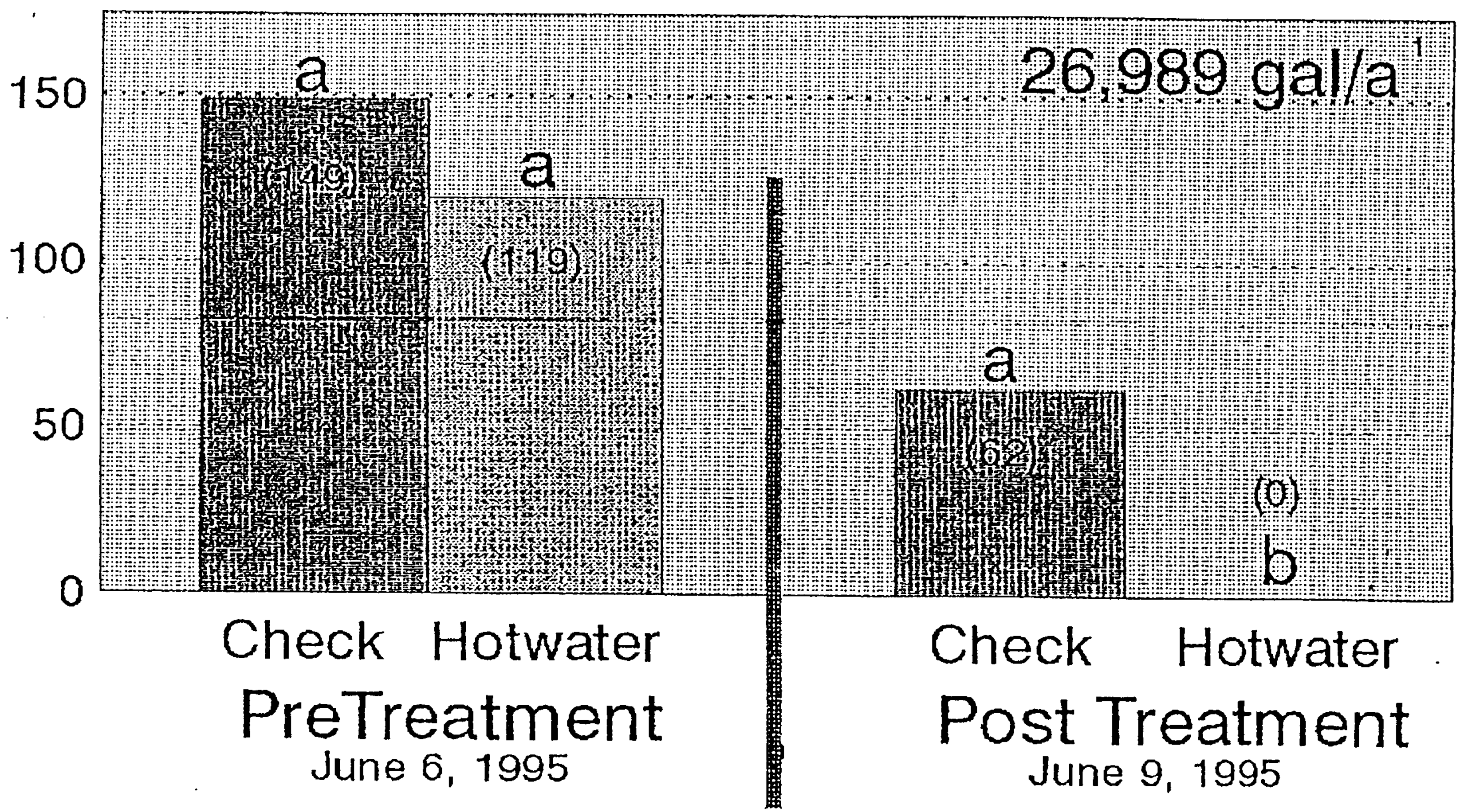
COURTESY OF DR. JOE NOLING, UNIVERSITY OF FLORIDA

GRAPH #4

Brock HotWater Soil Test

June 6, 1995 - Plant City, FL

RK Nematode Density / 100 cc soil



90 Gal/min; 225 F, 0.4 ft/sec (0.273 mph); 4 ft band treatment

GRAPH #5

Field underlain by impermiable layer at 8 in. soil depth

1 Broadcast Equivalent Application Rate

COURTESY OF DR. JOE NOLING, UNIVERSITY OF FLORIDA