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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

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FINAL REPORT

DATE: 25 August 2001

PREPARED BY: R. SMET

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1. Introduction:

Hortulus (PTY) Ltd. is using methylbromide as a soil disinfectant in tomato production. Hortulus (PTY) Ltd. produces tomatoes year-round under controlled climate. The main reason for using methylbromide is the presence of nematodes (*Melidogyne incognita*) .

The experiments have been done in two phases. In the first phase several alternatives were tested , in the second phase the most promising alternative was selected and repeated on a larger scale.

The alternatives tested were suggested by the international expert for the project (Mr Rafael Sanz de la Morena).

2. Phase One:

The following alternatives have been compared to methylbromide and a control (no treatment):

-Solarisation + Biofumigation.: 6.25 Kg /sqm horse manure was incorporated very well into the soil, watered and covered by plastics ('GUNFUME' 30 MICRON).
-Chemical alternative (Dazomet). The chemical was applied at a dose of 30Gr/sqm, well worked in, watered and covered with plastic ('GUNFUME' 30 MICRON).
-Soilless.: Plastic pipes of 160 mm diameter were cut into 60cm lengths, closed at the ends with plastic sheets . The pipes were provided with drainage holes and two planting holes per pipe and filled with a mixture of crusher dust (the dust from the stone crusher in a local quarry) and coir (cocospeat).

-Methylbromide was applied as per our standard method: perforated, inflatable ducts are laid out on the surface and covered with a plastic sheet ('GUNFUME' 30 MICRON). Methylbromide is than fed into these ducts from a cylinder (100 Kg) at a rate of 60 Gr/ sqm.

The total area of the experiment was 900 sqm. The experiment was conducted as a Fisher blockdesign with three blocks and five treatments. For practical reasons in terms of irrigation/fertigation the soilless treatments were outside the randomised blocks but within the same growing area.

The treatments were prepared on 19, 20 and 21 January 2000.
During treatment the following records were kept:

Air temperature inside the greenhouses and outside (min/max)

Soiltemperature for the different treatments at a depth of 20 cm (1 measurement per treatment). Temperatures were recorded at 8.00 am, therefore soiltemperatures should be regarded as minimum temperatures.

Airtemperatures are plotted in graph 1.
Soiltemperatures are recorded in table 1.

On February 5, 2000 the plastics were removed of all treatments. It was anticipated to start soilpreparation on February 9, 2000 and plant on February 19, 2000.
However due to torrential rainfall, groundwater levels were raised to the point that no activity on the plots was possible.
Soilpreparation was therefore done on February 28, 2000 and planting on March 4, 2000.

Following parameters were monitored to evaluate the treatments:

For the soiltreatments, a nematode count before and after treatment and after removal of the crop.

For all treatments the following cropstatistics were kept: Total production, % Second grade and Average fruitweight.

Shortly after removal of the plastics we noticed a serious difference between treatments in the number of weeds emerging. In graph 2 the total numbers for each treatment (sum of three replications) are shown.
The weeds were classified in three categories:
-grasses
-broad-leaved weeds
-tomato
The "tomato weeds" are the result of remaining seeds from dropped fruits during the previous crop.
They could be used as an indicator for the effect of the different treatments on weed control.

As can be seen in graph 2 , a potential danger of biofumigation is the importation of weeds. Careful selection of the source of organic material is therefore necessary.

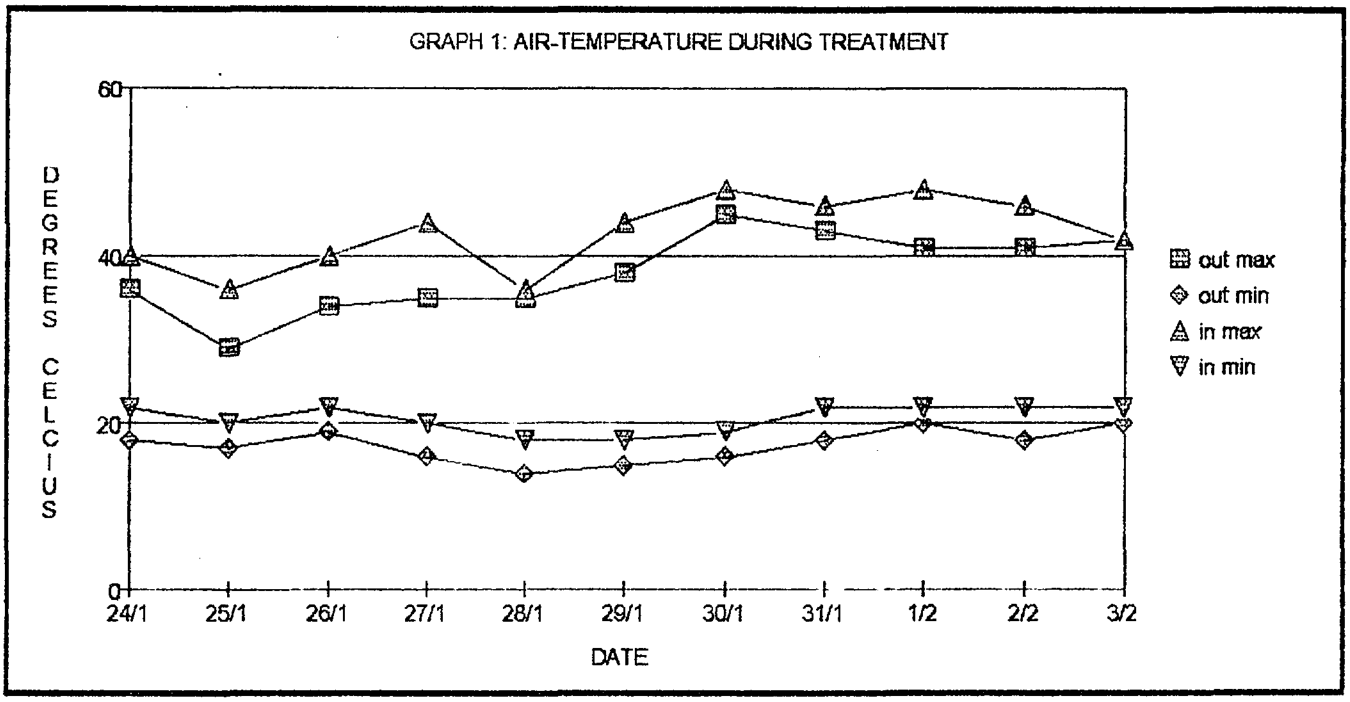
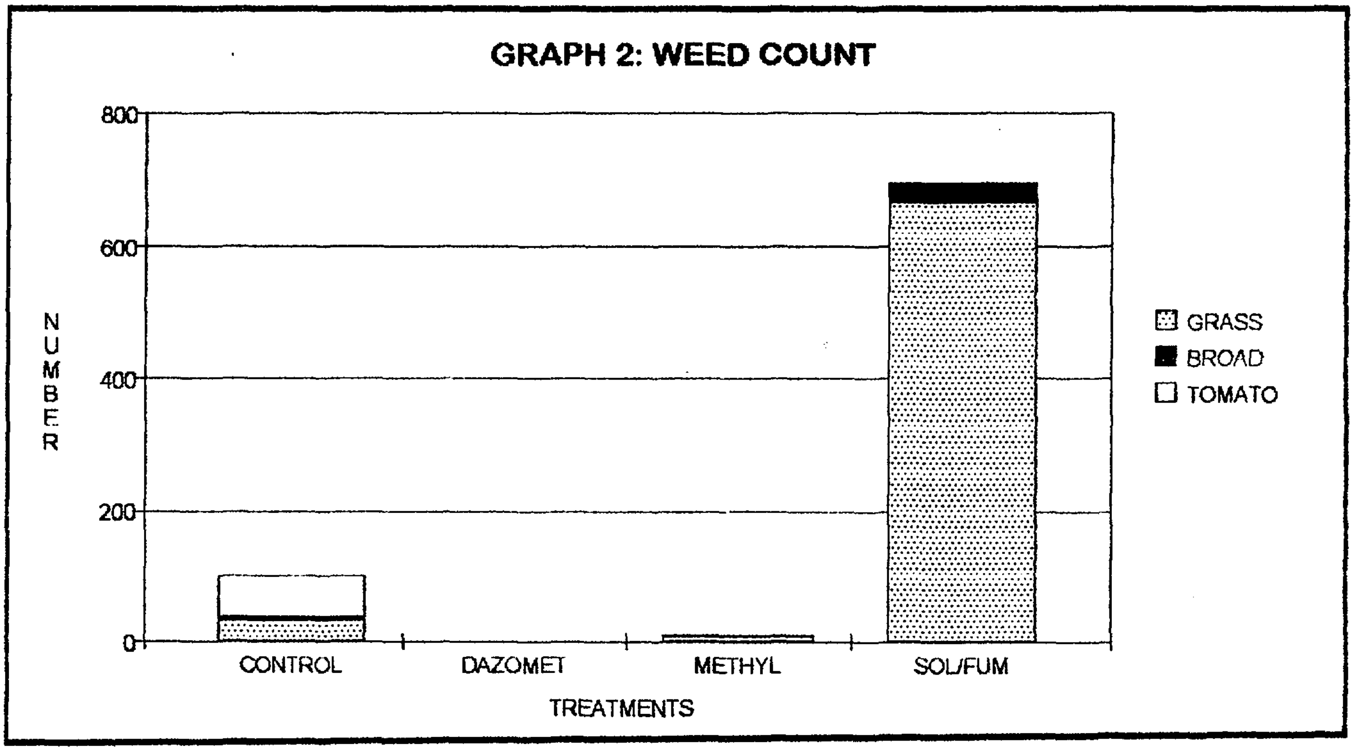

GRAPH 1: AIR-TEMPERATURE DURING TREATMENT
DEGREES CELCIUS
60
40
20
0
24/1
25/1
26/1
27/1
28/1
29/1
30/1
31/1
1/2
2/2
3/2
DATE
out max
out min
in max
in min

TABLE 1: SOIL TEMPERATURE (IN DEGREES CELCIUS)

date/treat.	CONTROL	DAZOMET	METHYLBROMIDE	BIOFUMIGATION
24/1	29	28	28	29
25/1	29	28	28	30
26/1	29	28	28	33
27/1	29	28	28	35
28/1	29	28	28	35
29/1	29	28	28	35
30/1	29	28	28	35
31/1	29	28	28	35
1/2	29	28	28	35
2/2	29	28	28	35
3/2	29	28	28	35


GRAPH 2: WEED COUNT
800
600
400
200
0
NUMBER
CONTROL
DAZOMET
METHYL
SOL/FUM
TREATMENTS
GRASS
BROAD
TOMATO

2.1. Nematode counts:

Below is the layout of the experiment with for each treatment the counts at the three specified times:

Treatment lay-out for the 4 soiltreatments in phase 1, each plot with a size of 48sqm

block III	treatment1: control	treatment2:dazomet	treatment3: methylbr.	treatment4:biofum.+ solar.
block II	treatment3: methylbr.	treatment1: control	treatment4:biofum.+ solar.	treatment2:dazomet
block I	treatment2:dazomet	treatment4:biofum.+ solar.	treatment1: control	treatment3: methylbr.

Number of root knot juveniles for each treatment : Pretreatment, Posttreatment and Postharvest.

block III	pre-treat:	830	pre-treat:	500	pre-treat:	1261	pre-treat:	500
	post-treat:	17	post-treat:	0	post-treat:	0	post-treat:	16
	post-harv:	54	post-harv:	39	post-harv:	53	post-harv:	200
block II	pre-treat:	450	pre-treat:	2510	pre-treat:	770	pre-treat:	480
	post-treat:	0	post-treat:	120	post-treat:	12	post-treat:	16
	post-harv:	5	post-harv:	162	post-harv:	470	post-harv:	174
block I	pre-treat:	3670	pre-treat:	310	pre-treat:	502.5	pre-treat:	430
	post-treat:	12	post-treat:	76	post-treat:	140	post-treat:	0
	post-harv:	97	post-harv:	450	post-harv:	257	post-harv:	42

In graph 3 the total number of juveniles for each treatment (sum of three replications) is depicted.

With the figures the following statistical analysis were done:

-Average reduction in juveniles after treatment, in percentage of the number before treatment.
Formula used: *100% - (after treatment / before treatment x 100%)*

-Average ratio of juveniles after harvest to the levels before treatment.
Formula used: *(after harvest / before treatment) x 100%*

Results are given in Table 2 and 3.

Graph 3: TOTAL NUMBER OF JUVENILES FOR EACH TREATMENT.

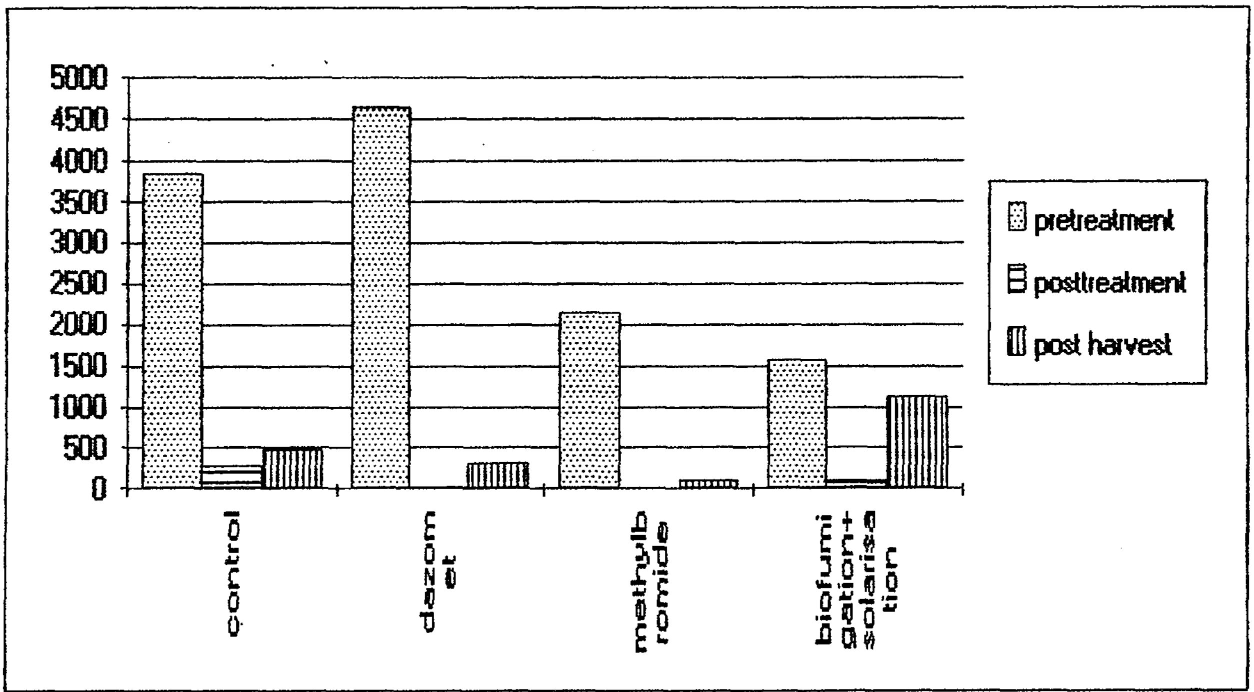


Table 2: AVERAGE REDUCTION IN ROOT KNOT JUVENILES AFTER TREATMENT.

treatment no.	reduction in %	Duncan grouping * 5%	1%
3	100.00	a	a
2	99.60	a	a
4	88.00	a	a
1	85.50	a	a

legend: 1: control 2:dazomet 3:methylbromide 4: biofumigation+ solarisation

* Treatments followed by the same letter are not significantly different.

Table 3: AVERAGE RATIO OF JUVENILES AFTER HARVEST TO THE LEVELS BEFORE TREATMENT

treatment no.	ratio in %	Duncan grouping * 5%	1%
4	82.00	a	a
1	21.30	b	a
2	15.50	b	a
3	5.00	b	a

legend: 1: control 2:dazomet 3:methylbromide 4: biofumigation+ solarisation

* Treatments followed by the same letter are not significantly different.

2.1.1. Discussion:

All calculations were done on the counts as received from Mrs B. Matilo at Agricultural Research . Copies of the reports in annex 1.

As can be seen in table 2 no significant differences exist between the different treatments. Methylbromide is however the only treatment that gives a 100 % reduction!

In trying to understand these figures one should not forget the raised groundwater level which could have had a negative impact on the nematodes due to a lack of oxygen in the soil during that time. This could explain the reduction in the control treatments.

The most striking result in table 3 is the high re infestation in the biofumigation treatment.

2.2. Crop statistics:

Since the normal practice at Hortulus is to have two crops following a methylbromide treatment, the same was done for this experiment (crop 1 & crop 2).

The variety used in all treatments is the standard variety for the farm: 2641 from De Ruiter Seeds CV. A multicell beeftomato with the following resistance pattern: Tm- C5-V-F2-Fr-N-Wi.
The resistance against nematodes has been broken due to continuous mono cropping.

The experiments were conducted in a greenhouse with climate control (heating and cooling facilities). Irrigation was done by drips. Fertigation was done with A&B drums from a central pumproom. The soilless treatment had separate fertiliser injection facilities to adjust the feeding.

2.2.1. Crop 1:

Date of sowing: 18/1/00
Date of planting: 4/3/00
Planting density: 2.7 plants/sqm
Date of first harvest: 19/4/00
Date of last harvest: 4/8/00

Basedressing: All treatments received the same base dressing based on he amount of fertiliser supplied by the horse manure. Analysis of the manure gave a 1% content for N, P and K respectively.
Hence 3 Kg N, 3 Kg P and 3 Kg K which was given as 15 kg '5-1-5' (20.5%N-4%P-20,5%K) and 24 kg Superphosphate (10%P) to the methylbromide, dazomet and control treatments

Disease and Pestcontrol:

Following pests were present in the crop to such an extend that chemical control was necessary:
White fly: *Bemisia tabaci*
Plusia looper: *Chrysodeixis acuta*

Following disease was present in the crop to such an extend that chemical control was necessary:

Early blight: *Alternaria dauci*

Results:

Tables 4 - 6 show the statistics resulting from the first crop.

2.2.1.1. Discussion

Soilless had the highest production, highest average fruitweight and lowest percentage of second grade fruits.
However only the latter parameter showed a significant difference with the other treatments.

2.2.2. Crop 2:

Date of sowing: 06/07/00
Date of planting: 21/08/00
Planting density: 2.7 plants/sqm
Date of first harvest: 17/10/00
Date of last harvest: 05/028/01

Basedressing: All treatments received the same base dressing.

Table 4: CROP 1 TOTAL PRODUCTION PER PLANT

treatment no.	production in Kg/plant	Duncan grouping * 5%	Duncan grouping * 1%
5	4.77	a	a
1	4.59	a	a
3	4.51	a	a
2	4.29	a	a
4	4.27	a	a

legend: 1: control
2:dazomet
3:methylbromide
4: biofumigation+ solarisation
5:soilless

* Treatments followed by the same letter are not significantly different.

Table 5: CROP 1 AVERAGE FRUITWEIGHT (AFW)

treatment no.	AFW in grams	Duncan grouping * 5%	Duncan grouping * 1%
5	177.67	a	a
3	169.00	a	a
4	167.00	b	a
1	165.67	b	a
2	162.67	b	a

legend: 1: control
2:dazomet
3:methylbromide
4: biofumigation+ solarisation
5:soilless

* Treatments followed by the same letter are not significantly different.

Table 6: CROP 1 AVERAGE PERCENTAGE (IN WEIGHT) OF SECOND GRADE FRUIT

treatment no.	2nd grade in %	Duncan grouping * 5%	Duncan grouping * 1%
2	27.13	a	a
4	27.00	a	a
3	26.23	a	a
1	26.24	a	a
5	21.47	b	b

legend: 1: control
2:dazomet
3:methylbromide
4: biofumigation+ solarisation
5:soilless

* Treatments followed by the same letter are not significantly different.

Disease and Pestcontrol:

Following pests were present in the crop to such an extend that chemical control was necessary:
White fly: *Bemisia tabaci*
Leafminer: *Liriomyza trifolii*

Following disease was present in the crop to such an extend that chemical control was necessary:

Early blight: *Alternaria dauci*

Results:

Tables 7 - 9 show the statistics resulting from the second crop.

2.2.2.1. Discussion:

In this second crop, significant differences between treatments were found in the production per plant . Once again soilless and methylbromide have the highest production.

Average fruitweight did not show significant differences between the treatments.
A significant difference between soilless and all other treatments was found in terms of percentage of second grade fruit.

In graph 3 The total production per plant for phase 1 (crop 1 &2) is shown for each treatment.

The combined results from crop 1 and 2 tells us that the Dazomet and Biofumigation/Solarisation treatments will have to be repeated after every crop in order to achieve comparable production to methylbromide.

The combined performance of the control treatment is also remarkable. It should be noted that prior to the crop preceding the experiments a methylbromide treatment had been done on the whole area. As a result crop 1 for the control treatment was actually the second crop after a methylbromide treatment. This is actually a confirmation of our standard treatment schedule, whereby we disinfect the soil every second crop.

Table 7: CROP 2 TOTAL PRODUCTION PER PLANT

treatment no.	production in Kg/plant	Duncan grouping * 5%	1%
5	6.63	a	a
3	6.59	a	a
1	5.52	b	b
4	4.82	c	c
2	4.46	c	c

legend: 1: control
2:dazomet
3:methylbromide
4: biofumigation+ solarisation
5:soilless

* Treatments followed by the same letter are not significantly different.

Table 8: CROP 2 AVERAGE FRUITWEIGHT (AFW)

treatment no.	AFW in grams	Duncan grouping * 5%	1%
3	147.60	a	a
5	144.70	a	a
1	139.80	a	a
4	139.30	a	a
2	135.10	a	a

legend: 1: control
2:dazomet
3:methylbromide
4: biofumigation+ solarisation
5:soilless

* Treatments followed by the same letter are not significantly different.

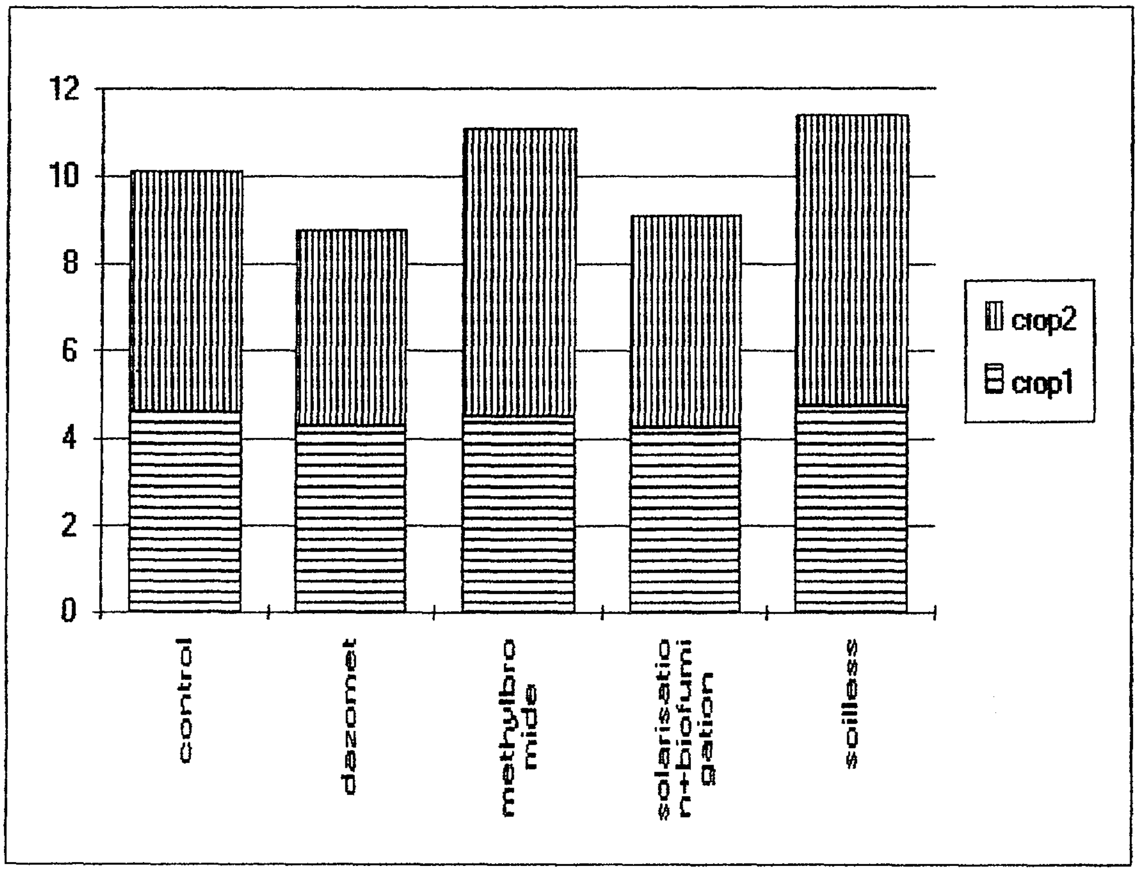
Table 9: CROP 2 AVERAGE PERCENTAGE (IN WEIGHT) OF SECOND GRADE FRUIT

treatment no.	2nd grade in %	Duncan grouping * 5%	1%
2	28.20	a	a
4	26.50	a	a
1	26.00	a	a
3	25.80	a	a
5	21.00	b	b

legend: 1: control
2:dazomet
3:methylbromide
4: biofumigation+ solarisation
5:soilless

* Treatments followed by the same letter are not significantly different.

Graph 3:TOTAL PRODUCTION PER PLANT FOR PHASE 1(CROP1 +CROP2).



2.2.3. Costs and financial results of the different treatments:

Following are the financial aspects of the different treatments as recorded during phase 1. However in the discussion of these results we will take the conclusions and recommendations from the cropstatistics into account.

To correctly analyse the costs for the different treatments we looked at three aspects:
1. Application costs
2. Costs during the growth and production period.
3 The time needed for the application of each treatment.

2.2.3.1. Application costs:

These are the expenses to apply the different treatments in terms of : products, equipment, consumables and labour.

In table 10.1 a summary of these costs per treatment are given .

'Products' are for the dazomet and methylbromide treatments the actual chemicals used as for the biofumigation treatment this reflects the cost of the horse manure (95 % of the cost for horse manure is transport).

'Consumables' are the plastic sheeting to cover the plots and the distribution ducts for methylbromide .

'Equipment' applies only to the soilless treatment and includes things like the containers, the fertigation units and other durable goods used to install the soilless treatment. Costs are calculated based on a assumed 5 year life span (10 crops) and an interest rate of 20%.

2.2.3.2. Costs during the growth and production period of the crops:

Only the costs specific to the treatment are considered here.
In table 10.2 the figures are given.
There were only differences between the treatments on three cost-items:

'fertiliser basedressing': All soiltreatments received a basedressing based on the fertiliser content of the horse manure. So only for the control, dazomet and methylbromide treatments was this an extra cost. Please note that this applies only to the first crop as in the second crop all treatments received the same chemical basedressing.

'fertiliser continuous': This is the cost related to the fertigation of the crop. Since all soiltreatments were given the same fertigation no costs are registered there, the soilless treatment however received additional fertiliser through the irrigation system hence the cost reflected in table 10.2

2.2.3.3. The time needed for the application of each treatment:

In table 10.3 the time cost for each treatment has been recorded.

These figures are based on the following:

-In 1 year we do two crops.
-In between crops we need 1 week to do the "change-over" meaning clearing of old crop and soilpreparation for the next.
-Based on a 52-week year we are then left with 50 weeks of cropping. On average 8 weeks per crop or 16 weeks per year are unproductive meaning the time between planting and first harvest. As a result we have 50 - 16 = 34 weeks of potential production (=turnover).
- The additional time needed for each treatment has to be deducted from this figure of 34, resulting in a reduced turnover period and is therefore considered as a cost.

In phase 1 of our experiments we have done the treatments once.
All treatments have been planted at the same time and harvested over an identical period.

For dazomet and biofumigation the treatment (time the plots are covered) takes two weeks.
After opening the plastics a waiting period of two weeks is necessary for the dazomet.
Methylbromide treatment (placing of ducts, plastics , fumigating, etc..) takes one week.
Therefore the additional time needed after removing the crop and landpreparation for the next crop is:
control: 0 weeks
dazomet: 2+2 weeks
biofumigation: 2 weeks
methylbromide: 1 week
soilless: 0 weeks

To translate this time into costs we multiplied these figures with the turnover per week achieved for each treatment over crop 1 and 2.
The weekly turnover was calculated based on : production per treatment over crop 1 and 2, average amount of second grade for each treatment, a price of 0.6 US$ /Kg for first and 0.4 US$/Kg for second grade and a total harvest period of 32 (2x16) weeks.

The time cost is the result of multiplying the treatment time (in weeks) with the weekly turnover.

In table 10. 4 the total costs per treatment and per year and the netto results are shown.

Applications costs for soilless have to duplicated as this is a cost each time a new crop is planted. Costs during, gives a figure for biofumigation, this is the basedressing for the second crop.

2.3. Conclusion phase 1:

Based on the cropstatistics and economics of the three alternatives tested, it is fair to conclude that soilless cultivation is the most promising one for our conditions.

Table 10.1: APPLICATION COSTS FOR THE DIFFERENT TREATMENTS (US$/100SQM/TREATMENT)

	control	dazomet	methylbr.	biofum.	soilless
products	0	41	35	55	0
consumables	0	8	10	8	0
labour	0	1	1	2	3
equipment*	0	0	0	0	58
total	0	50	46	65	61

*calcullation based on a five year life span and an intrest rate of 20%

Table 10.2: COSTS PER CROP DURING GROWING AND PRODUCTION PERIOD (US$/100SQM)

	control	dazomet	methylbr.	biofum.	soilless
fertiliser basedressing	24	24	24	0	0
fertiliser continuous	0	0	0	0	100
substrate	0	0	0	0	11
total	24	24	24	0	111

Table 10.3: TIME COSTS PER YEAR FOR THE DIFFERENT TREATMENTS (US$/100SQM)

	control	dazomet	methylbr.	biofum.	soilless
treatment in weeks	0	4	1	2	0
turnover per week	47	40	51	42	54
cost	0	161	51	84	0

Table 10.4: TOTAL COST AND NETTO RESULT PER YEAR FOR THE DIFFERENT TREATMENTS (US$/100SQM)

	control	dazomet	methylbr.	biofum.	soilless
APPLICATION COST	0	50	46	65	122
COSTS DURING ...	48	48	48	24	222
TIME COST	0	160	51	84	0
TOTAL COST	48	258	145	173	344
turnover per year	1496	1285	1642	1343	1718
NETTO RESULT	1448	1027	1497	1170	1374

3. Phase 2:

In the second phase the alternative chosen from phase 1 , soilless culture, was applied on a bigger scale.

It was suggested by the international expert to use this second phase to evaluate different containers and substrates .
The following treatments were proposed:

1: Methylbromide as control. (150 sqm)
2: soilless culture (750 sqm):

treat no	container	substrate	no of plants
2.1	PVC pipe, diameter 160mm,600mm long	crusherdust & coir	2 plants/bag
2.2	White polyethylene bags 12 litre volume	crusherdust	1plant/bag
2.3	White polyethylene bags 12 litre volume	crusherdust	2plant/bag
2.4	White polyethylene bags 12 litre volume	crusherdust & coir	1plant/bag
2.5	White polyethylene bags 12 litre volume	crusherdust & coir	2plant/bag

3.1. Crop details:

Variety: 2641 De RUITER Seeds, Tm-C5-V-F2-Fr-N-Wi
Date of sowing: 19/01/01
Date of planting: 03/03/01
Date of first harvest: 23/04/01
Date of last harvest: 16/08/01
Planting density: 2.7 plants/sqm
Fertigation: fertiliser injection with a "Dosatron". All treatments were given the same fertigation , including the methylbromide one.
Irrigation: drip irrigation, every plant was provided with a dripper (2plants/bag = 2 drippers/bag), hence every plant received the same amount of water.

Disease and pestcontrol:

Following pests have been present in the crop to such an extend that chemical was necessary:
Plusia looper: *Chrysodeixis acuta*
Aphids: No colonies were present but winged adults flew in and transmitted Potato Y virus.
Infection was serious but equally spread over the treatments.

3.2. Cropstatistics:

Table 11, 12 and 13 show the results for the different treatments.

Table11: PHASE 2 TOTAL PRODUCTION PER PLANT

treatment no.	production in Kg/plant	Duncan grouping * 5%	1%
1	3.73	a	a
3	3.70	a	a
6	3.68	a	a
5	3.50	a	a
4	3.45	a	a
2	3.25	b	a

* Treatments followed by the same letter are not significantly different.

legend: 1: methylbromide
2:coir+dust:2pl/pipe
3:dust: 1pl/bag
4:dust: 2pl/bag
5:coir+dust:1pl/bag
6:coir +dust:2pl/bag

Table12: PHASE 2 AVERAGE FRUITWEIGHT (AFW)

treatment no.	AFW in grams	Duncan grouping * 5%	1%
1	149	a	a
5	147	a	a
3	145	a	a
4	142	ab	a
6	140	ab	a
2	138	b	a

* Treatments followed by the same letter are not significantly different.

legend: 1: methylbromide
2:coir+dust:2pl/pipe
3:dust: 1pl/bag
4:dust: 2pl/bag
5:coir+dust:1pl/bag
6:coir +dust:2pl/bag

Table 13: PHASE 2 AVERAGE PERCENTAGE (IN WEIGHT) OF SECOND GRADE FRUIT

treatment no.	2nd grade in %	Duncan grouping * 5%	1%
3	30.00	a	a
5	29.70	a	a
6	26.90	a	a
1	26.10	a	a
4	25.60	a	a
2	23.60	b	b

* Treatments followed by the same letter are not significantly different.

legend: 1: methylbromide
2:coir+dust:2pl/pipe
3:dust: 1pl/bag
4:dust: 2pl/bag
5:coir+dust:1pl/bag
6:coir +dust:2pl/bag

3.2.1. Discussion:

Overall production figures are lower than last year over the same period (phase 1, crop 1). This is due to the virus infestation. For the same reason, fruitsize is smaller and % second grade higher.

As far as the different treatments are concerned at the end of the crop there are little or no differences. Soilless proves again to be a suitable alternative.
In terms of containers and substrate, the bags are performing better than the pipes.
Treatments with two plants a bag were initially (after one month production) lower in production, this difference has been recovered by the end of the crop, suggesting that competition for light, rather than rootvolume is to blame.

4. Conclusion:

As a final conclusion of the whole project, it is fair to say that we have found a suitable alternative under our conditions for methylbromide: SOILLESS CULTURE.

PRE-TREATMENT

Numbers of Root - knot nematode (*Meloidogyne*) larvae in 80 cm^3 of soil.

SAMPLE	NUMBER OF LARVAE	100 cm^3
I 1	402	502.5
I 2	2936	3670
I 3	344	430
I 4	248	310
II 1	2008	2510
II 2	384	480
II 3	360	450
II 4	616	770
III 1	664	830
III 2	400	500
III 3	1009	1261
III 4	400	500

NB: Most of the samples were ~80 cm^3 therefore this was taken as the standard sample size. For samples that were more, the excess (which was little) soil was discarded.

POST - TREATMENT

Numbers of root knot nematode larvae in 100 cm^3 of soil

SAMPLE	NUMBER OF ~~LARVAE~~ Juveniles
I-1	140
I-2	12
I-3	0
I-4	76
II-1	120
II-2	16
II-3	0
II-4	12
III-1	17
III-2	0
III-3	0
III-4	16

Post Harvest Nematode counts – Hortulus

Sample	*Root knot larvae	100cm³
I 1	1285	257
I 2	484	96.8
I 3	212	42.4
I 4	2252	450.4
II 1	808	161.6
II 2	868	173.6
II 3	24	4.8
II 4	2352	470.4
III 1	268	53.6
III 2	196	39.2
III 3	264	52.8
III 4	1000	200

*Number of root-knot larvae per 500 cm^3 of soil.