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Demonstration Project on Alternatives to the Use of Methyl Bromide

UNIDO PROJECT MP/ZIM/97/182

Final Report

(June 2000)

by

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UNIDO PROJECT MP/ZIM/97/182

FINAL Report - June 2000

Introduction

Project Details

Country:	Zimbabwe
Counterpart institution:	Tobacco Research Board
Location:	Harare, Zimbabwe
Sector covered:	Tobacco
Estimated ODS use by sector:	500 tonnes/annum
Project duration:	May 1998 to June 2000
Project Objectives:	To develop and demonstrate the use of alternatives to methyl bromide in the production of tobacco seedbeds in the project area.

The aim of the project was to demonstrate the technical and economic feasibility of two alternative methods to the use of methyl bromide as a fumigant in tobacco seedbeds under experimental conditions. The two approaches studied were:

- the application of various mixtures of other chemicals in low doses; and
- the use of non-soil techniques.

The alternative methods were used in combination with an integrated pest management (IPM) programme wherever possible. The results of this study will be disseminated among qualified specialists and farmers.

All experiments outlined in the Terms of Reference (Project MP/ZIM/97/182, Annex B) have been completed and these are: 1) Use of other fumigants and burn techniques in seedbeds - 99 NM02S (page 5), 2) Alternatives against cutworm damage - 98 EN10S (page 22), 3) Combinations of dazomet/plastic sheeting - 98 AG01S (page 18), 4) Alternatives for hardening seedlings - 98 PH07S/K (page 73) and 5) Substrate alternatives in different seedbed systems - 98 PH08S (page 39). A number of additional experiments were carried out where necessary in order to obtain more information and develop practical recommendations.

The results of the completed experiments as well as an overview of the work and an economic comparison of these alternatives with traditional seedbed production with methyl bromide are presented. This report has three main sections:

1. **Alternative fumigants in traditional seedbeds;**
2. **Alternative seedling production systems; and**
3. **An economic comparison of alternatives to methyl bromide.**

1. Alternative Fumigants in Traditional Seedbeds

Two separate topics are discussed in this section. The first deals with alternative fumigants, such as dazomet, metham sodium, EDB (ethylene dibromide) and 1,3-D (dichloropropene), and the second discusses methods to improve insect control in traditional seedbeds.

1.1. ALTERNATIVE FUMIGANTS

INTRODUCTION

When the use of methyl bromide is stopped it is expected that most tobacco growers will change to the float system using soilless media. However, some growers may not be able, or want, to change so work on different fumigants is being done to provide another alternative for tobacco growers which would not require major changes to their current method of production.

Methyl bromide is a very effective fumigant which controls diseases, nematodes and weeds and it is a difficult task to find alternative chemicals that will match its efficacy. EDB and 1,3-dichloropropene (1,3-D) are being tested as nematicides, and the incorporation of chloropicrin with 1,3-D should improve the control of diseases. The other major problem is weed control and the chemicals dazomet and metham sodium are considered to have both weed and nematicidal properties. Consequently, the research effort is mainly aimed at testing various combinations of these chemicals.

Five trials were done to test alternative chemicals in traditional seedbeds, three using metham-sodium in comparison with a burn and ethylene dibromide (EDB) treatment, one comparing EDB, 1,3-dichloropropene (1,3-D) and a mixture of 65% 1,3-D and 35% chloropicrin (1,3-D/C-35) and one testing combinations of dazomet and plastic covers for weed control. All trials had a control and a standard treatment, an untreated and methyl bromide at the current recommended rate. Results were frequently transformed to obtain treatment comparisons.

RESULTS

<u>Use of other fumigants and burn technique in seedbeds (99 NM02S)</u>
(See Terms of Reference (Project MP/ZIM/97/182))

The aim was to compare the nematode and weed control of methyl bromide with EDB and burn and with EDB and metham-sodium. A treatment using metham-sodium alone was included in the latter two trials, but not in the first trial.

<u>Materials and Methods</u>

Design: 4 randomized complete blocks of 6 treatments each

Treatments:
0 untreated
1 methyl bromide 98% + 2% chloropicrin at 50 g/m^2
2 burn and EDB 41%, 5 ml at 38 x 38 cm spacing (35 ml/m^2)
3 EDB, 5 ml at 38 x 38 cm spacing + metham-sodium 510 g/litre at 15 ml/m^2
4 EDB, 5 ml at 38 x 38 cm spacing + metham-sodium at 25 ml/m^2

5 EDB, 5 ml at 38 x 38 cm spacing + metham-sodium at 35 ml/m^2

Half of each bed was sown with weed seeds (site 2) and the other half inoculated with *Meloidogyne javanica* (site 1) before treatment, to increase the weed and nematode pressure. Brushwood was burned on the appropriate beds and the ash removed before the EDB was applied. Metham-sodium applied as a drench and EDB by injection, were applied on the same day and the beds covered with plastic. Methyl bromide was applied, under cover, two weeks later and all covers were removed after a further two days. The beds were dug over twice. Soil samples were taken for germination tests using radish seed and the beds were made up, fertilized and sown when these indicated that the chemicals were no longer present in the soil. Plots were mulched with grass and perforated plastic and maintained as recommended by the Tobacco Research Board.

Germination counts of tobacco, broad leafed weeds and grasses were made a month after sowing, on two 0,2 m^2 areas of each 2 m x 1 m bed, one each in the half sown with weed seeds and the half inoculated with rootknot nematode. Unfortunately soon after these counts were made, the trial was mistakenly destroyed by herbicide and no further results were obtained.

Results and Discussion

The results are given in Tables 1 to 4.

Table 1. Mean germination count/m^2 (site 1)

Treatment	Tobacco	Weeds	Grasses	Total weeds (i.e. grasses + weeds)
Untreated	1.281	58.1	40	98.1
Methyl bromide, 50 g/m^2	184.4	1.9	0.6	2.5
Burn and EDB	167.5	1.3	0.6	1.9
EDB + me Na 15 ml/m^2	178.1	1.3	66.9	68.1
EDB + me Na 25 ml/m^2	187.5	22.5	40	62.5
EDB + me Na 35 ml/m^2	181.3	5.6	5	10.6
MEAN	171.1	15.1	25.5	40.6

Table 2. Mean germination count/m^2 - log transformed (site 1)

Treatment	Tobacco	Weeds	Grasses	Total weeds (i.e. grasses + weeds)
Untreated	2.11	1.6	1.51	1.86
Methyl bromide, 50 g/m^2	2.26	0.33	0.14	0.37
Burn and EDB	2.22	0.27	0.14	0.33
EDB + me Na 15 ml/m^2	2.24	0.27	1.79	1.8
EDB + me Na 25 ml/m^2	2.21	0.76	1.4	1.52
EDB + me Na 35 ml/m^2	2.24	0.71	0.73	0.98
MEAN	2.21	0.66	0.95	1.14
SED $t(0.05,15)=2.131$	0.13	-	0.233*	0.307*
CV%	8.2	-	34.6	38

Table 3. Mean germination count/m² (site 2)

Treatment	Tobacco	Weeds	Grasses	Total weeds (i.e. grasses + weeds)
Untreated	111.9	115.0	81.3	196.3
Methyl bromide, 50 g/m²	196.9	0.6	1.9	2.5
Burn and EDB	176.0	1.9	0.6	2.5
EDB + me Na 15 ml/m²	163.1	24.4	51.9	76.3
EDB + me Na 25 ml/m²	195.6	2.5	50.0	52.5
EDB + me Na 35 ml/m²	209.4	3.1	28.1	31.3
MEAN	175.5	24.6	35.6	60.2

Table 4. Mean germination count/m²- log transformed (site 2)

Treatment	Tobacco	Weeds	Grasses	Total weeds (i.e grasses + weeds)
Untreated	1.97	2.06	1.9	2.29
Methyl bromide, 50 g/m²	2.29	0.14	0.33	0.39
Burn and EDB	2.25	0.41	0.14	0.47
EDB + me Na 15 ml/m²	2.21	1.09	1.38	1.87
EDB + me Na 25 ml/m²	2.28	0.47	1.69	1.72
EDB + me Na 35 ml/m²	2.31	0.53	1.31	1.39
MEAN	2.22	0.78	1.13	1.35
SED $t(0.05,15)=2.131$	0.12	0.205*	-	0.216*
CV%	7.5	37.1	-	22.6

None of the treatments adversely affected the germination of tobacco seedlings. There appeared to be sufficient weed pressure without artificially inoculating the plots. Both the methyl bromide and burn and EDB treatments gave excellent control of broadleaf weeds and grasses. Neither EDB + metham sodium at 15 ml/m² or at 25 ml/m² controlled weeds satisfactorily. Only the high rate of 35 ml/m² metham sodium gave reasonable control, although it was not as good as the burn and EDB or methyl bromide plots.

For lack of phytotoxicity to tobacco seedlings and good weed control, both the burn and EDB and EDB + metham sodium at 35 ml/m² treatments have potential as alternatives to methyl bromide.

<u>**Use of other fumigants and burn technique in seedbeds (99 NM20S)**</u>

<u>Materials and Methods</u>

Design: 4 randomized complete blocks of 7 treatments each

Treatments:
0 Untreated
1 methyl bromide 50 g/m²
2 burn and EDB 41% 5 ml at 38 x 38 cm spacing, 35 ml/m²
3 metham-sodium 510 g/litre 50 ml/m²
4 EDB 5 ml at 38 x 38 cm spacing + metham-sodium 15 ml/m²

5 EDB 5 ml at 38 x 38 cm spacing + metham-sodium 25 ml/m^2
6 EDB 5 ml at 38 x 38 cm spacing + metham-sodium 35 ml/m^2

All beds were inoculated with *M. javanica* before treatment, to increase the low nematode population in the soil. Brushwood was burned on the appropriate beds and the ash removed before the EDB was applied. Metham-sodium and EDB were applied on the same day, by drench and by injection, respectively, and the beds covered with plastic. Methyl bromide was applied, under cover, two weeks later and all covers were removed after a further two days. The beds were dug over twice. Soil samples were taken for germination tests using radish seed and the beds were made up, fertilized and sown when these indicated that the chemicals were no longer present in the soil. Plots were mulched with grass and perforated plastic and maintained as recommended.

Germination counts of tobacco, broad leafed weeds and grasses were made 24 and 33 days after sowing and pulling at 60 days after sowing, on a 0.2 m^2 area of each 1 m x 1 m bed. Seedlings were sorted into 5 cm intervals of size category from < 5 cm to > 25 cm. Forty plants from each sample area were rated for rootknot nematode galling on a scale of 0 - 8.

Table 5. Mean germination count/m^2 - 11 Jan

Treatment	Tobacco	Weeds	Grasses	Total weeds (i.e grasses + weeds)
Untreated	460.0	25.0	63.8	88.8
Methyl bromide, 50 g/m^2	406.3	1.3	0.0	1.3
Burn and EDB	273.8	1.3	0.0	1.3
Metham sodium	331.3	5.0	2.5	7.5
EDB + me Na 15 ml/m^2	517.5	0.0	5.0	5.0
EDB + me Na 25 ml/m^2	430.0	2.5	1.3	3.8
EDB + me Na 35 ml/m^2	297.5	2.5	0.0	2.5
MEAN	388.0	5.4	10.4	15.7
SED $t_{(0.05,18)}=2.101$	103.6	-	-	-
CV%	37.8	-	-	-

Table 6. Mean germination count/m^2 - 20 Jan

Treatment	Tobacco	Weeds	Grasses	Total weeds (i.e grasses + weeds)
Untreated	455.0	27.5	16.3	43.8
Methyl bromide, 50 g/m^2	392.5	0.0	0.0	0.0
Burn and EDB	322.5	0.0	0.0	0.0
Metham sodium	332.5	0.0	0.0	0.0
EDB + me Na 15 ml/m^2	452.5	0.0	0.0	0.0
EDB + me Na 25 ml/m^2	431.3	1.3	0.0	1.3
EDB + me Na 35 ml/m^2	341.3	1.3	1.3	2.5
MEAN	389.6	4.3	2.5	6.8
SED $t_{(0.05,18)}=2.101$	100.6	-	-	-
CV%	36.5	-	-	-

Table 7. Number remaining at pulling/m^2

Treatment	Weeds	Grasses	Total weeds (i.e grasses + weeds)
Untreated	5.0	5.0	10.0
Methyl bromide, 50 g/m^2	1.3	1.3	2.5
Burn and EDB	1.3	0.0	1.3
Metham sodium	2.5	3.8	6.3
EDB + me Na 15 ml/m^2	6.3	2.5	8.8
EDB + me Na 25 ml/m^2	6.3	0.0	6.3
EDB + me Na 35 ml/m^2	2.5	7.5	10.0
MEAN	3.6	2.9	6.4

Table 8. Number of seedlings in each size group/m^2

Treatment	Length (cm)					
	0-5	5-10	10-15	15-20	20-25	>25
Untreated	103.8	86.3	55.0	38.8	43.8	32.5
Methyl bromide, 50 g/m^2	55.0	53.8	43.8	28.8	20.0	47.5
Burn and EDB	126.3	57.5	47.5	23.8	18.8	7.5
Metham sodium	63.8	41.3	67.5	40.0	27.5	28.8
EDB + me Na 15 ml/m^2	77.5	80.0	42.5	52.5	40.0	50.0
EDB + me Na 25 ml/m^2	83.8	65.0	46.3	46.3	40.0	33.8
EDB + me Na 35 ml/m^2	70.0	51.3	52.5	43.8	26.3	25.0
MEAN	82.9	62.1	50.7	39.1	30.9	32.1

Table 9. Number of seedlings in each size group/m^2- log transformed

Treatment	Length (cm)					
	0-5	5-10	10-15	15-20	20-25	>25
Untreated	2.0	1.9	1.7	1.6	1.6	1.2
Methyl bromide, 50 g/m^2	1.7	1.7	1.6	1.4	1.3	1.4
Burn and EDB	2.0	1.7	1.6	1.2	1.0	0.6
Metham sodium	1.7	1.6	1.7	1.5	1.4	1.5
EDB + me Na 15 ml/m^2	1.9	1.9	1.6	1.7	1.6	1.6
EDB + me Na 25 ml/m^2	1.9	1.7	1.6	1.6	1.6	1.4
EDB + me Na 35 ml/m^2	1.7	1.7	1.7	1.6	1.4	1.2
MEAN	1.8	1.8	1.7	1.5	1.4	1.3
SED $t(0.05,18)=2.101$	0.2	0.1	0.2	0.2	0.2	-
CV%	16.5	11.7	14.9	18.8	22.4	-

Table 10. Rootknot nematode gall rating

Treatment	Length (cm)	
	Mean score MRK (Scale 0-8)	Plants with score zero (%)
Untreated	0.05	95.0
Methyl bromide, 50 g/m²	0.01	99.2
Burn and EDB	0.00	100.0
Metham sodium	0.01	99.4
EDB + me Na 15 ml/m²	0.01	98.8
EDB + me Na 25 ml/m²	0.03	97.3
EDB + me Na 35 ml/m²	0.01	99.4
MEAN	0.02	98.4
SED $t_{(0.05,18)}=2.101$	-	1.5
CV%	-	2.2

Results and discussion

Results are given in Tables 5 to 10.

Variation was high between replicates for all treatments and there were no significant differences between any of the treatments on either date for tobacco germination (Tables 5 & 6). Weeds and grasses were controlled by all treatments when compared with the untreated plots, with methyl bromide and burn + EDB giving the least number of total weeds at the first count. Weeds and grasses at the second count were very few in all treated plots. At pulling, numbers of weeds and grasses in untreated and the EDB + 35 ml metham-sodium were the highest, least in the burn + EDB plots (Table 7).

At pulling, although there were more seedlings per square metre in the untreated than in any of the treated beds, they were small compared to seedlings from treated plots although no significant differences were recorded (Tables 8 & 9). The rootknot nematode population was low but a small number of infected plants was found in all treatments except the EDB and burn (Table 10).

The trial was done late in the season for seedbed work and rain interfered with the progress of both setting up the trial and with seedling growth which was very uneven.

Use of other fumigants and burn technique in seedbeds (00 NM03S)

Materials and Methods

Design: 4 randomized blocks of 7 treatments each

Treatments:
0 Untreated
1 methyl bromide 50 g/m²
2 burn and EDB 41% 5 ml at 38 x 38 cm spacing, 35 ml/m²
3 metham-sodium 510 g/litre 50 ml/m²
4 EDB 5 ml at 38 x 38 cm spacing + metham-sodium 15 ml/m²
5 EDB 5 ml at 38 x 38 cm spacing + metham-sodium 25 ml/m²
6 EDB 5 ml at 38 x 38 cm spacing + metham-sodium 35 ml/m²

All beds were inoculated with *M. javanica* before treatment to increase the low nematode population. Brushwood and logs were burned on the appropriate beds and the ash removed. Metham-sodium and EDB were applied on the same day, by drench and by injection, respectively, and the beds covered with plastic. Methyl bromide was applied under sealed cover two weeks later and all covers were removed after a further two days. The beds were dug over twice. Soil samples were taken for germination tests using radish seed and the beds were made up, fertilized and sown when these indicated that the chemicals were no longer present in the soil. Beds were mulched with grass, covered with perforated plastic and maintained as recommended.

Germination counts of tobacco, broad leafed weeds and grasses were made 30 days after sowing, on a 0.2 m^2 area of each 1 m x 1 m bed. Final counts, on the same area of bed, were made 84 days after sowing. Seedlings were sorted into 5 cm intervals of size category from < 5 cm to > 25 cm. Forty plants from each sample area were rated for rootknot nematode galling on a scale of 0 - 8.

Results and discussion

Results are given in Tables 11 to 15

Table 11. Germination count of plants/0.2m^2 17 Sept

Treatment	Tobacco	Weeds	Grasses
Untreated	78.0	84.0	130.8
Methyl bromide, 50 g/m^2	121.5	35.5	6.3
Burn and EDB	107.0	4.0	1.0
Metham sodium	120.5	7.5	0.5
EDB + me Na 15 ml/m^2	103.8	2.3	54.5
EDB + me Na 25 ml/m^2	125.8	3.0	17.0
EDB + me Na 35 ml/m^2	138.0	5.3	1.0
MEAN	113.5	20.2	30.1

Table 12. Germination count of plants/0.2m^2 (square root) 17 Sept

Treatment	Tobacco	Weeds	Grasses
Untreated	8.8	9.1	11.4
Methyl bromide, 50 g/m^2	11.0	5.6	2.1
Burn and EDB	10.3	2.0	0.7
Metham sodium	11.0	2.5	0.5
EDB + me Na 15 ml/m^2	10.2	1.2	6.7
EDB + me Na 25 ml/m^2	11.2	1.5	3.6
EDB + me Na 35 ml/m^2	11.7	2.3	0.9
MEAN	10.6	3.5	3.7
SED $t(0.05,18)=2.101$	0.64*	0.88*	1.21*

Table 13. Number of seedlings in each size group/0.2 m^2 at pulling

Treatment	Length (cm)					
	0-5	5-10	10-15	15-20	20-25	>25
Untreated	13.3	10.0	3.0	3.0	0.5	0.3
Methyl bromide, 50 g/m^2	31.8	17.5	9.8	9.3	7.0	29.5
Burn and EDB	19.8	22.0	10.0	7.5	5.3	27.3
Metham sodium	29.5	17.8	13.5	12.3	8.0	13.0
EDB + me Na 15 ml/m^2	20.0	12.5	9.5	10.5	5.8	17.8
EDB + me Na 25 ml/m^2	20.3	14.5	10.5	7.8	8.8	29.3
EDB + me Na 35 ml/m^2	32.8	17.5	12.8	15.3	10.0	34.0
MEAN	23.9	16.0	9.9	9.4	6.5	21.6

Table 14. Percent of seedlings in each size group/0.2 m^2 at pulling

Treatment	Length (cm)						RKN scale 0-8
	0-5	5-10	10-15	15-20	20-25	>25	
Untreated	50.5	38.1	5.1	5.1	0.8	0.4	1.5
Methyl bromide, 50 g/m^2	30.5	16.7	9.3	8.9	6.9	27.7	0.0
Burn and EDB	22.8	22.9	10.5	8.2	5.9	29.6	0.0
Metham sodium	31.2	18.9	14.5	13.3	8.4	13.7	1.9
EDB + me Na 15 ml/m^2	26.8	16.3	13.3	13.9	7.3	22.4	0.0
EDB + me Na 25 ml/m^2	22.9	15.6	11.3	8.0	9.4	32.7	0.0
EDB + me Na 35 ml/m^2	26.1	14.4	10.7	12.5	8.9	27.3	0.0
MEAN	30.1	20.4	10.7	10.0	6.8	22.0	0.5
SED $t_{(0.05,18)}=2.101$	8.26*	6.69*	4.4	4.5	2.47*	4.03*	-

Table 15. Plant count/0.2m^2 at pulling

Treatment	Weeds	Grasses
Untreated	27.3	19.0
Methyl bromide, 50 g/m^2	1.3	0.3
Burn and EDB	0.3	0.0
Metham sodium	0.5	0.5
EDB + me Na 15 ml/m^2	0.3	4.5
EDB + me Na 25 ml/m^2	0.0	0.5
EDB + me Na 35 ml/m^2	0.3	0.3
MEAN	4.3	3.6

Tobacco germination 30 days after sowing was significantly greater in all treated plots than in the untreated plots (Tables 11 & 12), while broad-leafed weed and grass control was significantly better in all treated plots than in the untreated, although methyl bromide control of weeds and grasses was not as good as usual. Burn and EDB and the metham sodium alone gave the best control, while the EDB/metham sodium combinations were variable.

At pulling, the total number of tobacco seedlings was least in the untreated plots and a large percentage were small compared with the treated plots (Tables 13 & 14). Numbers of broad-leafed weeds and grasses were low in all treated plots (Table 15).

The rootknot nematode population was small and galling was found on only a few plants, in the untreated and metham-sodium treated plots (Table 14).

Comparison of fumigants in seedbeds (00 NM04S)

The aim was to compare the use of EDB, 1,3-D and 1,3-D/C-35 with the recommended rate of methyl bromide for the control of nematodes and weeds in seedbeds.

Materials and Methods

Design: 4 randomized complete blocks of 18 treatments each

Treatments:

	Application	Rate
0 untreated control		
1 methyl bromide		50 g/m^2
2 methyl bromide		25 g/m^2
3 methyl bromide		12.5 g/m^2
4 EDB 41%	5 ml at 38 x 38 cm spacing	35 ml/m^2
5 EDB 41%	4 ml at 35 x 35 cm spacing	33 ml/m^2
6 EDB 41%	3 ml at 30 x 30 cm spacing	33 ml/m^2
7 EDB 41%	4 ml at 38 x 38 cm spacing	28 ml/m^2
8 EDB 41%	3 ml at 35 x 35 cm spacing	25 ml/m^2
9 1,3-D	5 ml at 38 x 38 cm spacing	35 ml/m^2
10 1,3-D	4 ml at 35 x 35 cm spacing	33 ml/m^2
11 1,3-D	3 ml at 30 x 30 cm spacing	33 ml/m^2
12 1,3-D	4 ml at 38 x 38 cm spacing	28 ml/m^2
13 1,3-D	3 ml at 35 x 35 cm spacing	25 ml/m^2
14 1,3-D/C-35	6.5 ml at 35 x 35 cm spacing	35 ml/m^2 1,3-D (53,3 ml product)
15 1,3-D/C-35	4.5 ml at 35 x 35 cm spacing	24 ml/m^2 1,3-D (36.9 ml product)
16 1,3-D/C-35	4.5 ml at 38 x 38 cm spacing	20 ml/m^2 1,3-D (31.0 ml product)
17 1,3-D/C-35	2.0 ml at 30 x 30 cm spacing	14 ml/m^2 1,3-D (22.2 ml product)

Beds were inoculated with rootknot nematode before treatment. EDB, 1,3-D and 1,3-D/C-35 were applied by injection to a depth of 25 cm and plots covered with plastic for seven days. Methyl bromide was applied under sealed cover, sheets removed after four days. Soil samples were taken for germination tests using radish seed to check for phytotoxicity before sowing. Plots were fertilized, watered and prepared two days before sowing. Plots were mulched with grass and maintained as recommended.

Germination counts were made 26 days after sowing and pulling was done 67 days after sowing on a 0.2 m^2 area of a 1 m x 1 m bed. Seedlings were sorted into 5 cm intervals of size category from < 5 cm to > 25 cm. Forty plants from each sampling area were rated for rootknot nematode galling on a scale of 0 to 8.

Results and Discussion

Results are given in Tables 16 to 19.

the study. Based on the findings of the first two phases the study was reconfigured to focus on three techniques:

- 200 cell float;
- 128 cell float;
- traditional seedbed technique.

In addition, each of these techniques has been studied to show the difference between the cheap and expensive approaches to seedbed establishment. The results show that the 200 cell float (cheap) technique gives the best return over a ten-year period followed by the 200 cell float (dear). Both the 128 cell float (dear) and 128 cell float (cheap) methods have a lower crop value than the traditional seedbeds. The overall values of the crops compared to the base case (traditional-cheap) are:

- 0,91% lower for the traditional (dear);
- 9,38% lower for the 128 cell float (cheap);
- 12,21% lower for the 128 cell float (dear);
- 5,96% cent higher for the 200 cell float (cheap); and
- 3,51% cent higher for the 200 cell float (dear).

The overall results of this study show that the use of alternative techniques is a viable option. In fact, the results achieved over the past two seasons with the 200 cell trays illustrate that the value of the enterprise could actually be higher than those produced with the traditional seedbed techniques. The 128 cell float method has a lower net present value than the traditional seedbeds. These results show that the 200 cell float method is the best option from both the practical and economic aspects.

A word of caution has to be expressed in interpreting the results of this economic analysis. Throughout the study period, and especially in the past five to six months, the macro-economic environment prevailing in the country has been very turbulent. The high rates of inflation have contributed to a rapid increase in the cost of production. On the other hand, the authorities have insisted on maintaining a fixed exchange rate (against the US dollar) resulting in an overall cost price squeeze in the tobacco production sector.

Table 18. Grass germination counts/m² - 3 Nov 1999

Treatment	Grass	Log (grass + 10)
Untreated	170.0	2.24
Methyl bromide, 50 g/m²	21.3	1.43
Methyl bromide, 25 g/m²	23.8	1.44
Methyl bromide, 12.5 g/m²	30.0	1.50
EDB: 5 ml at 38 x 38 cm	151.3	2.18
EDB: 4 ml at 35 x 35 cm	222.5	2.05
EDB: 3 ml at 30 x 30 cm	245.0	2.16
EDB: 4 ml at 38 x 38 cm	140.0	2.02
EDB: 3 ml at 35 x 35 cm	150.0	2.11
1,3-D: 5 ml at 38 x 38 cm	8.8	1.24
1,3-D: 4 ml at 35 x 35 cm	8.8	1.24
1,3-D: 3 ml at 30 x 30 cm	8.8	1.25
1,3-D: 4 ml at 38 x 38 cm	5.0	1.16
1,3-D: 3 ml at 35 x 35 cm	17.5	1.30
1,3-D/C-35: 6.5 ml at 35 x 35 cm	17.5	1.34
1,3-D/C-35: 4,5 ml at 35 x 35 cm	3.8	1.12
1,3-D/C-35: 4,5 ml at 38 x 38 cm	37.5	1.44
1,3-D/C-35: 2,0 ml at 30 x 30 cm	132.5	1.77
MEAN	77.4	1.61
SED $t_{(0.05,51)}$ 2.009	-	0.255*
CV%	-	22.3

NOTE: Contrast for control vs treated is **significant**.

Table 19a. Percent seedlings at pulling <5 cm in length

Treatment	0-5 cm	Square root (0-5 cm)
Untreated	70.1	8.3
Methyl bromide, 50 g/m²	28.3	5.3
Methyl bromide, 25 g/m²	34.7	5.9
Methyl bromide, 12.5 g/m²	34.8	5.8
EDB: 5 ml at 38 x 38 cm	52.6	7.2
EDB: 4 ml at 35 x 35 cm	41.9	6.5
EDB: 3 ml at 30 x 30 cm	32.1	5.6
EDB: 4 ml at 38 x 38 cm	42.4	6.5
EDB: 3 ml at 35 x 35 cm	47.2	6.9
1,3-D: 5 ml at 38 x 38 cm	36.5	6.0
1,3-D: 4 ml at 35 x 35 cm	31.8	5.5
1,3-D: 3 ml at 30 x 30 cm	31.9	5.6
1,3-D: 4 ml at 38 x 38 cm	33.1	5.7
1,3-D: 3 ml at 35 x 35 cm	50.3	7.1
1,3-D/C-35: 6,5 ml at 35 x 35 cm	38.1	6.2
1,3-D/C-35: 4,5 ml at 35 x 35 cm	35.8	5.9
1,3-D/C-35: 4,5 ml at 38 x 38 cm	39.7	6.2
1,3-D/C-35: 2,0 ml at 30 x 30 cm	28.1	5.3
MEAN	39.4	6.2
SED $t_{(0.05,51)}$ 2.009	-	0.57*
CV%	-	13.0

NOTE: Contrast for all treatments vs untreated is **significant**.

Table 19b. Percent seedlings at pulling 5-10 cm in length

Treatment	5-10 cm	Square root (5-10 cm)
Untreated	27.5	5.0
Methyl bromide, 50 g/m^2	20.5	4.5
Methyl bromide, 25 g/m^2	19.0	4.3
Methyl bromide, 12.5 g/m^2	17.6	4.1
EDB: 5 ml at 38 x 38 cm	21.0	4.5
EDB: 4 ml at 35 x 35 cm	27.3	5.2
EDB: 3 ml at 30 x 30 cm	29.3	5.3
EDB: 4 ml at 38 x 38 cm	20.0	4.4
EDB: 3 ml at 35 x 35 cm	27.3	5.2
1,3-D: 5 ml at 38 x 38 cm	14.4	3.8
1,3-D: 4 ml at 35 x 35 cm	20.2	4.3
1,3-D: 3 ml at 30 x 30 cm	19.7	4.3
1,3-D: 4 ml at 38 x 38 cm	17.6	4.2
1,3-D: 3 ml at 35 x 35 cm	16.0	4.0
1,3-D/C-35: 6.5 ml at 35 x 35 cm	22.0	4.7
1,3-D/C-35: 4.5 ml at 35 x 35 cm	19.3	4.3
1,3-D/C-35: 4.5 ml at 38 x 38 cm	15.9	4.0
1,3-D/C-35: 2.0 ml at 30 x 30 cm	16.2	4.0
MEAN	20.6	4.40
SED $t_{(0.05,51)}$ 2.009	-	0.69
CV%	-	22.1

NOTE: Contrast for all treatments vs untreated is <u>not significant</u>.

Table 19c. Percent seedlings at pulling 10-15 cm in length

Treatment	10-15 cm	Square root (10-15 cm)
Untreated	2.3	0.8
Methyl bromide, 50 g/m^2	11.3	3.3
Methyl bromide, 25 g/m^2	8.3	2.8
Methyl bromide, 12.5 g/m^2	10.0	3.1
EDB: 5 ml at 38 x 38 cm	9.1	2.9
EDB: 4 ml at 35 x 35 cm	24.4	4.8
EDB: 3 ml at 30 x 30 cm	10.4	3.1
EDB: 4 ml at 38 x 38 cm	20.7	4.5
EDB: 3 ml at 35 x 35 cm	14.2	3.7
1,3-D: 5 ml at 38 x 38 cm	13.1	3.6
1,3-D: 4 ml at 35 x 35 cm	10.2	3.1
1,3-D: 3 ml at 30 x 30 cm	11.4	3.3
1,3-D: 4 ml at 38 x 38 cm	18.5	4.3
1,3-D: 3 ml at 35 x 35 cm	9.5	3.1
1,3-D/C-35: 6,5 ml at 35 x 35 cm	12.5	3.4
1,3-D/C-35: 4,5 ml at 35 x 35 cm	14.2	3.7
1,3-D/C-35: 4,5 ml at 38 x 38 cm	13.1	3.5
1,3-D/C-35: 2,0 ml at 30 x 30 cm	15.4	3.8
MEAN	12.7	3.40
SED $t_{(0.05,51)}$ 2.009	-	0.60*
CV%	-	25.0

NOTE: Contrast for all treatments vs untreated is **<u>significant</u>**.

Table 19d. Percent seedlings at pulling 15-20 cm in length

Treatment	15-20 cm	Square root (15-20 cm)
Untreated	0.0	0.0
Methyl bromide, 50 g/m^2	14.8	3.6
Methyl bromide, 25 g/m^2	10.4	3.1
Methyl bromide, 12.5 g/m^2	10.8	3.2
EDB: 5 ml at 38 x 38 cm	9.7	2.7
EDB: 4 ml at 35 x 35 cm	5.1	1.9
EDB: 3 ml at 30 x 30 cm	15.8	3.4
EDB: 4 ml at 38 x 38 cm	11.2	2.9
EDB: 3 ml at 35 x 35 cm	5.7	2.1
1,3-D: 5 ml at 38 x 38 cm	12.3	3.4
1,3-D: 4 ml at 35 x 35 cm	9.8	3.1
1,3-D: 3 ml at 30 x 30 cm	14.1	3.7
1,3-D: 4 ml at 38 x 38 cm	17.0	4.1
1,3-D: 3 ml at 35 x 35 cm	11.3	3.3
1,3-D/C-35: 6.5 ml at 35 x 35 cm	13.2	3.6
1,3-D/C-35: 4,5 ml at 35 x 35 cm	12.4	3.5
1,3-D/C-35: 4.5 ml at 38 x 38 cm	17.5	4.2
1,3-D/C-35: 2.0 ml at 30 x 30 cm	13.7	3.4
MEAN	11.4	3.10
SED $t_{(0.05,51)}$ 2.009	-	0.89*
CV%	-	40.9

NOTE: Contrast for all treatments vs untreated is **significant**.

Table 19e. Percent seedlings at pulling 20-25 cm in length

Treatment	20-25 cm	Square root (20-25 cm)
Untreated	0.0	0.0
Methyl bromide, 50 g/m^2	9.7	3.0
Methyl bromide, 25 g/m^2	9.2	3.0
Methyl bromide, 12.5 g/m^2	8.0	2.8
EDB: 5 ml at 38 x 38 cm	3.9	1.7
EDB: 4 ml at 35 x 35 cm	0.8	0.6
EDB: 3 ml at 30 x 30 cm	7.4	2.3
EDB: 4 ml at 38 x 38 cm	2.8	1.1
EDB: 3 ml at 35 x 35 cm	3.6	1.3
1,3-D: 5 ml at 38 x 38 cm	9.9	3.1
1,3-D: 4 ml at 35 x 35 cm	6.1	2.5
1,3-D: 3 ml at 30 x 30 cm	9.3	3.0
1,3-D: 4 ml at 38 x 38 cm	10.9	3.3
1,3-D: 3 ml at 35 x 35 cm	8.8	2.9
1,3-D/C-35: 6,5 ml at 35 x 35 cm	8.6	2.8
1,3-D/C-35: 4,5 ml at 35 x 35 cm	10.0	2.6
1,3-D/C-35: 4,5 ml at 38 x 38 cm	9.3	3.0
1,3-D/C-35: 2,0 ml at 30 x 30 cm	16.4	4.0
MEAN	7.5	2.40
SED $t_{(0.05,51)}$ 2.009	-	0.70*
CV%	-	41.5

NOTE: Contrast for all treatments vs untreated is **significant**.

Table 19f. Percent seedlings at pulling >25 cm in length

Treatment	>25 cm	Square root (>25 cm)
Untreated	0.0	0.0
Methyl bromide, 50 g/m²	15.4	3.4
Methyl bromide, 25 g/m²	18.4	4.2
Methyl bromide, 12.5 g/m²	18.8	3.7
EDB: 5 ml at 38 x 38 cm	3.7	1.3
EDB: 4 ml at 35 x 35 cm	0.4	0.3
EDB: 3 ml at 30 x 30 cm	5.0	1.6
EDB: 4 ml at 38 x 38 cm	2.9	0.8
EDB: 3 ml at 35 x 35 cm	2.0	0.7
1,3-D: 5 ml at 38 x 38 cm	13.7	3.1
1,3-D: 4 ml at 35 x 35 cm	21.8	4.0
1,3-D: 3 ml at 30 x 30 cm	13.7	2.9
1,3-D: 4 ml at 38 x 38 cm	2.9	1.5
1,3-D: 3 ml at 35 x 35 cm	4.2	1.7
1,3-D/C-35: 6,5 ml at 35 x 35 cm	5.5	1.7
1,3-D/C-35: 4,5 ml at 35 x 35 cm	8.3	2.5
1,3-D/C-35: 4,5 ml at 38 x 38 cm	4.5	1.7
1,3-D/C-35: 2,0 ml at 30 x 30 cm	10.2	2.2
MEAN	8.4	2.10
SED $t_{(0.05,51)}$ 2.009	-	1.11*
CV%	-	75.6

NOTE: Contrast for all treatments vs untreated is **significant**.

At 26 days after sowing, untreated plots had significantly fewer seedlings than most of the treated plots and there were no differences between treatments for tobacco germination (Table 16). There were no differences in broad-leafed weed numbers for all plots and numbers were high (Table 17). Numbers of grasses showed clearly that EDB has no herbicide effect, but that 1,3-D, as well as the 1,3-D/C-35 mixture, have some control of grasses (Table 18).

At pulling, seedling number and size were badly affected by weed pressure due to re-infection of the plots from weed growth outside the trial area. Untreated plots had the greatest number of small seedlings and least for the other size categories (Table 19, a to f).

The rootknot nematode infection was low in the trial area. Infected plants occurred only in untreated plots (mean rating 1,06 on scale 0 - 8) and in plots treated with less than the full rate of methyl bromide (mean rating 0,02 for both half and quarter rates).

Combinations of dazomet and plastic sheeting (98 AG01S)

(See Terms of Reference (Project MP/ZIM/97/182))

The aim was to determine the phytotoxicity and weed control efficacy of various combinations of dazomet and plastic sheeting.

Materials and Methods

Design: 4 randomized complete blocks of 5 main plots and 2 subplots per main plot.

Treatments:
<u>Fumigation</u> (Main plots)
1. plastic only (75µm)
2. dazomet + plastic
3. dazomet + watered only
4. methyl bromide only
5. no treatment

<u>Weeds</u> (Sub-plots)
0. None
1. Weeds

Plots 1.5 m. No pre-fumigation with methyl bromide. Weeds (1 g/plot of *Dactyoctenium aegyptium, Rotboellia cochinchinensis, Eleusine indica, Richardia scabra, Cleome monophylla, Galinsoga parviflora*) sown and watered for about a week before fumigation. Dazomet applied at 20 g/m^2 and incorporated to a depth of about 15 cm. Plastic kept on for 2 weeks and then soil aerated and germination tested with cress before sowing. All subplots with no weeds treated with clomazone (Command) at 0.0471 g a.i./m^2 (0.471 kg a.i./ha) to control weed growth.

<u>Results and Discussion</u>

None of the fumigation treatments in the subplots with no weeds significantly reduced the germination of tobacco seedlings, nonetheless, the dazomet treatments and the plastic on its own had fewer seedlings than the untreated control and methyl bromide plots. In the presence of weeds, only the dazomet + water treatment was not significantly different from methyl bromide (Table 20). The decrease in tobacco seedling germination was, therefore, mainly due to poor weed control in the other treatments.

Table 20. Tobacco seedling germination counts (30 days after sowing - number/m^2)

Fumigation	No Weed	Weed	Mean
plastic	113.0	101.2	107.1
dazomet + plastic	112.7	99.1	105.9
dazomet + water	110.2	109.0	109.6
methyl bromide	129.9	117.6	123.7
none	128.2	94.0	111.1
Mean	118.8	104.2	111.5

t (p=0.05, df = 27) 2.052

SED:		
	Fumigation	10.5
	Weeds	6.6*
	Fumigation x weeds	14.9

Although the germination of seedlings was not seriously affected by the dazomet and plastic treatments, very poor growth occurred in all the weed-free plots, except methyl bromide (Table 21). The data in tables 21 and 22 was not analysed statistically because of the high coefficient of variation (CV's 63% and 78% respectively). The growth of tobacco in the dazomet + plastic treatment was extremely variable and some replicates grew well while others appeared to have severe phytotoxicity.

The dazomet + water treatment had the second highest dry mass of tobacco and this was much greater than the other treatments. In the presence of weeds, only the methyl bromide treatment had a relatively high dry mass of tobacco. The weed dry mass data (Table 22) indicated that the two dazomet treatments and methyl bromide had relatively good control of weeds, particularly as the weed pressure was extremely high. The dazomet + plastic treatment appeared to be more effective in controlling weeds than the dazomet + water.

The poor growth of tobacco in the weed-free subplots of the plastic only, dazomet + water, dazomet + plastic and the no fumigation treatments cannot be explained on the basis of poor weed control or phytotoxicity only. No disease was found on the seedlings and the nematode gall-ratings were very low (Table 23). Hence, there appeared to be an additional fumigation/growth promotion effect from the methyl bromide.

These results indicated that dazomet + plastic was the best alternative tested, however, it appeared to be phytotoxic to tobacco seedlings.

Table 21. Tobacco seedling dry mass (70 days after sowing - g/m²)

Fumigation	No Weed	Weed	Mean
plastic	66.3	0.8	33.5
dazomet + plastic	125.3	38.4	31.9
dazomet + water	56.0	44.9	50.5
methyl bromide	175.9	127.8	151.9
none	71.9	0.2	36.0
Mean	99.1	42.4	70.8
CV%		63.0	

Table 22. Dry mass of weeds (70 days after sowing - g/m²)

Fumigation	Dry mass
plastic	153.9
dazomet + plastic	52.6
dazomet + water	95.2
methyl bromide	42.1
none	215.0
Mean	111.8
CV%	78.0

Table 23. Rootknot nematode (*Melodogyne javanica*) rating of tobacco roots

Fumigation	Rating (0 = none, 8 = dead plants)
plastic	0.4
dazomet + plastic	0.2
dazomet + water	0.0
methyl bromide	0.0
none	0.5
Mean	0.2

DISCUSSION

Both the methyl bromide and burn plus EDB treatments gave excellent control of broadleaf weeds, grasses, nematodes and good growth of tobacco seedlings, and these were the best treatments. However, the burn and EDB is unlikely to be recommended as an alternative because of the environmental implications of burning. EDB on its own had no herbicidal effect, however 1,3-D and the 1,3-D/C-35 mixture appeared to have some control of grasses. Neither EDB + metham sodium at 15 ml/m^2 or at 25 ml/m^2 controlled weeds satisfactorily. Only the high rate of 35 ml/m^2 metham sodium gave reasonable control in some experiments, although it was not satisfactory in others. Metham sodium at 50 ml/m^2 and dazomet gave good control of weeds. However, the latter fumigant appears to be too unpredictably phytotoxic to be used in tobacco seedbeds.

Further work is necessary to finalise suitable treatments for recommendation. However, EDB + metham sodium and 1,3-D or 1,3-D/C-35 are the most promising alternatives. For the metham-sodium/EDB treatments, a rate should be finalised this season and for the possible use of 1,3-D or 1,3-D/C-35, a trial similar to last year's will be done, omitting EDB.

1.2. IMPROVING THE CONTROL OF INSECT PESTS IN CONVENTIONAL TOBACCO SEEDBEDS

INTRODUCTION

Current Tobacco Research Board recommendations for nematode, disease and weed control in conventional seedbeds rely very much on an initial methyl bromide fumigation. This is not the case for the recommendations on insect pest control. Although methyl bromide is an excellent insecticide, it has no residual effects. Termites and true ants are commonly observed to move back into a seedbed area within days of the completion of a fumigation. The time that elapses before the seed germinates and the seedlings have begun to increase in size is ample to allow the arrival, from outside the fumigated area, of other seedbed pests such as cutworms and aphids. Since current insect pest control practices are designed to correct such immigration, the lack of an initial methyl bromide fumigation will have little or no *direct* effect on their efficacy.

The disappearance of methyl bromide could, however, conceivably bring about changes in current insect control practices in an indirect manner through the widespread adoption of new methods of seedling production. For instance, methods that involve the use of float systems in low or high tunnel-like structures would result in environments closer to those found in greenhouses than to those of conventional seedbeds.. This might, in time, bring about some shifts in the arthropod pest spectrum. It is conceivable that whiteflies and dipterous leaf-miners, which are not currently a problem in conventional seedbeds, could become more important. Whiteflies are notorious for their ability rapidly to become resistant to new pesticides. The long-term control of these insects thus requires resistance management strategies that incorporate planned switches between materials having different modes of insecticidal action.

Until it has become clear which of the new techniques of seedling production will become widely used in Zimbabwe and what, if any, new pest challenges will arise as a result, it is difficult to predict what changes in pest control practices may be needed. However, our ability to react quickly to any new situation will certainly be enhanced if a wide selection of effective, non-phytotoxic pesticides of low mammalian toxicity and belonging to different chemical groups, is available to choose from. Unfortunately, the recent changes in pesticide regulations in many developed countries increasingly threaten the availability of many proven chemicals of the older groups (organophosphates, carbamates and pyrethroids). Thus the entomological research connected with UNIDO project MP/ZIM/97/182 has concentrated on testing the efficacy of a range of new "green" chemicals, used in a variety of strategies in conventional seedbeds.

As the result of the work of other contributors to the project, it now seems very probable that seedling production techniques based on floating seedling trays, with their cells filled with artificial media, will dominate new production methods in Zimbabwe. Such systems have, up to now, proved remarkably free of arthropod pest problems but the situation could change as they become widespread.

Future entomological research on seedling protection will be directed towards (i) finding the most economical strategies that can be devised using currently available chemicals and (ii) examining to what extent the final stages of the seedling protection strategies can be adapted to provide bridging protection for the period immediately after transplanting the seedlings into the field.

RESULTS

Three experiments are briefly described below.

Alternatives against cutworm damage (98 EN10S)

(See Terms of Reference (Project MP/ZIM/97/182))

The objective was to evaluate the efficacy, as cutworm (*Agrotis segetum*) damage preventatives in tobacco seedbeds, of eight materials, each used according to three different application schedules. The schedules involved the application of the materials either four-times, three-times or twice during an approximately eight-week period of challenge created by successive artificial infestations of 4- to 6-day-old cutworm larvae.

Materials and Methods

Design: Five randomized complete blocks of 25 treatments; 1.2 m × 1.2 m plots

Treatments (tmts), other than the control (coded 0), were arranged in three series (A, B & C). Each of the eight chemicals to be tested appears once in each series.
The A series comprises codes for treatments that involve four applications, separated by two-week intervals, and made at 8, 10, 12 and 14 weeks after sowing (w.a.s.).

The B series comprises codes for treatments that involve three applications, separated by three-week intervals, and made at 8, 11 and 14 w.a.s.

The C series comprises codes for treatments that involve two applications, separated by a four-week interval, at 8 and 12 w.a.s.

Tmt Codes A B C	Material	Rate per application (g a.i./m^2)
0	untreated control	–
1 9 17	acephate 97% pellets	0,73
2 10 18	monocrotophos 40% wsc (standard)	0,72

3 11 19	indoxacarb (MP062) 30% wg	0,12
4 12 20	chlorfenapyr (AC 303;630) 36% sc	0,12
5 13 21	spinosad (DE-105) 48% sc	0,12
6 14 22	fipronil 20% sc	0,12
7 15 23	lufenuron 5% ec	0,12
8 16 24	etofenprox 20% ec	0,12

Prior to sowing, disulfoton 5% granules at 4 g product/m^2 (0,2 g a.i./m^2) were raked into top 2–3 cm of soil. The seedbeds were sown on 25 August 1997. Asbestos-cement seedbed dividers and angle-iron stakes were used to form the walls and corners of plots (1,2 m square = 1,44 m^2), and they were positioned in the seedbeds on 7–9 October 1997 (43–45 days after sowing [d.a.s]). Artificial infestation of cutworm larvae was done using 4-, 5- or 6-day post-hatch larvae from laboratory culture over the period of 9½ weeks extending from 11 October (47 d.a.s.) to 17 December (114 d.a.s.). Over this period, a total of 191 such larvae were placed in each plot on an almost daily, fully recorded, basis. The cutworm preventative treatments were applied by watering-cans at 1,5 litre/m^2, and the treatments were applied on either four occasions (Series A treatments), three occasions (Series B treatments) or two occasions (Series C treatment) using the full per application treatment rate on each occasion as follows:

Tmt Series	Date	w.a.s.
A B C	20 Oct	8
A	3 Nov	10
B	10 Nov	11
A C	17 Nov	12
A B	1 Dec	14

The final assessments were made from 1 January 1998 (140 d.a.s) to 16 January (144 d.a.s.). A Damage Rating Scale was used where: 0 = undamaged stem; 1 = superficial damage to epidermis and cortex that does not reach hard portion of vascular cylinder; 4 = damage reaches hard portion of vascular cylinder; 6 = damage goes through hard portion of vascular cylinder and exposes central pith of stem; 7 = seedling cut off leaving only a stump.

Results and Discussion

An ANOVA of the arcsine-transformed proportions of undamaged seedlings recovered from the plots at the final assessment gave highly significant *F* values for the model (P>0,001) and for treatment effects (P>0,0001). Mean arcsine proportions for the treatments and their de-transformed values (as percentages) are presented in Table 24.

All treatments gave proportions of undamaged seedlings that were significantly higher than the untreated control (Waller-Duncan, 0,05 probability level). Treatments 2, 10 and 18 (monocrotophos ×4, ×3 and ×2) were significantly less effective than all the other treatments at preventing damage and treatments 17 and 24 (acephate ×2 and etofenprox ×2) were not as effective as the remaining treatments which were not statistically separable and gave mean proportions of undamaged seedlings ranging from 99,9% to 92,6%. Indoxacarb, lufenuron and chlorfenapyr, whether used as the ×4, ×3, or ×2 strategies gave proportions of undamaged seedlings of over 99,0%.

Table 24. Mean proportions of seedlings rated as undamaged by cutworms at the final assessment

First value for each entry is mean of arcsine transformed proportion; means followed by the same letter are not significantly different from one another by the Waller-Duncan K-ratio *T* test (0.05 probability level)*; bracketed values are de-transformed mean percentages.

Material applied	Number of applications			
	4	3	2	0
nil (control)	–	–	–	0.39 i (14.38)
acephate	1,44 bcde (98,22)	1,47 abc (99,05)	1,29 f (92,17)	–
monocrotophos	1,11 g (79,97)	0,84 h (55,85)	0,87 h (58,29)	–
indoxacarb	1,56 a (99,98)	1,53 abc (99,74)	1,52 abc (99,81)	–
chlorfenapyr	1,51 abc (99,96)	1,48 abc (99,18)	1,50 abc (99,05)	–
spinosad	1,47 abc (98,94)	1,45 abcd (98,62)	1,31 f (93,21)	–
fipronil	1,50 abc (99,51)	1,45 abcde (98,60)	1,35 def (95,18)	–
lufenuron	1,53 abc (99,81)	1,55 ab (99,94)	1,51 abc (99,60)	–
etofenprox	1,42 cde (97,82)	1,34 ef (94,80)	1,24 f (89,32)	–

* K-ratio = 100 df = 96 MSE = 0,010039 F = 38,13416 Critical Value of t = 1,77245
Minimum Significant Difference = 0,1123

Indoxacarb, lufenuron, chlorfenapyr, spinosad, and probably fipronil and etofenprox, appear likely to be excellent substitutes for the chemicals (monocrotophos, acephate and methamidophos) currently recommended to prevent cutworm damage in seedbeds. The results also suggest that it may be possible to use some of them (particularly indoxacarb, lufenuron and chlorfenapyr) at frequencies of application below those at which acephate and monocrotophos are currently used. For virtually all materials, except perhaps etofenprox, the customary two week interval (represented by series A treatments) can be extended to a three week interval (represented by series B treatments) with no loss of protection against cutworm damage.

Aphid and cutworm: seedbed preventatives (00 EN06S)

The objective was to compare the efficacies of two aphid (*Myzus persicae* complex) pre-sowing preventatives (one granular, the other a drench) and the efficacies of ten cutworm (*Agrotis segetum*) damage preventatives, applied as drenches at three week intervals, either without, or following, one of the pre-sowing aphid preventatives.

Materials and Methods

Design: Five randomized complete blocks of 32 treatments; 1.2 m × 1.2 m plots

Treatments: The two pre-sowing aphicide applications were (i) disulfoton 5% granules at 0,2 g a.i./m^2 and (ii) a solution of imidacloprid 20% sl at 0,1 g a.i./m^2. The ten cutworm preventatives used were applied at 5, 8 and 11 weeks after sowing. They were arranged in three series of eleven treatments (A, B & C), with each of the chemicals to be tested appearing once in each series together with an untreated control. Series A treatments were not preceded by an initial aphid preventative, series B treatments followed disyston and series C treatments followed imidacloprid.

Tmt Codes A B C	Cutworm Preventative Material	Rate per application (g a.i./m²)
0 11 22	untreated control	–
1 12 23	monocrotophos 40% wsc (standard)	0,73
2 13 24	acephate 97% pellets	0,72
3 14 25	methamidophos 58,5%	0,70
4 15 26	indoxacarb (MP062) 30% wg	0,12
5 16 27	chlorfenapyr (AC 303,630) 36% sc	0,12
6 17 28	spinosad (DE-105) 48% sc	0,12
7 18 29	lufenuron 5% sc	0,12
8 19 30	teflubenzuron 15% ec	0,12
9 20 31	novaluron 10% ec	0,12
10 21 32	deltamethrin 2.5% ec	0,12

Prior to sowing, series B treatment plots received disulfoton 5% granules at 4 g product/m^2 (0,2 g a.i./m^2) raked into top 2–3 cm of soil; series C treatment plots received a solution of imidacloprid 20% sl applied onto the soil surface at 1,5 litres/m^2 using watering cans, at a rate of 0.10 g a.i./m^2. The seedbeds were sown on 18 August 1999. Asbestos-cement seedbed dividers and angle-iron stakes were used to form the walls and corners of plots (1,2 m square = 1,44 m^2), and they were positioned in the seedbeds on 14–16 September 1999 (27–29 d.a.s). Artificial infestations of aphids, at which from 5 to 30 (the numbers varied on different occasions but were constant on any given one) apterous individuals from the laboratory culture were introduced to each plot, were made on seven occasions between 27 September and 4 November (40-77 d.a.s.). Artificial infestation of cutworm larvae was done using 4-, 5-, or 6-day post-hatch larvae from laboratory culture over the period extending from 22 September to 17 November (35-58 d.a.s.). Over this period, a total of 58 such larvae were placed in each plot on an almost daily, fully recorded, basis.

Cutworm preventative treatments were applied by watering-cans at 1,5 litre/m^2 on 22 September, 13 October and 3 November (35, 56 & 77 d.a.s).

Assessments of the intensity of aphid infestation in plots were made on four occasions, 12 October, 20 October, 28 October and 26 November (55, 63, 71 & 100 d.a.s.) using a five-level logarithmic scale (a rating of 1 indicated 1-10 aphids on the assessed seedling, 2 indicated 11-100 aphids, 3 indicated 101-1000 aphids and 4 indicated more than a thousand).

Final cutworm damage assessments were made from 27 November to 9 December (101 - 113 d.a.s.). A Damage Rating Scale was used where: 0 = undamaged stem; 1 = superficial damage to epidermis and cortex that does not reach hard portion of vascular cylinder; 4 = damage reaches hard portion of vascular cylinder; 6 = damage goes through hard portion of vascular cylinder and exposes central pith of stem; 7 = seedling cut off leaving only a stump.

Results and Discussion

(a) Aphid

ANOVAs of the mean intensities of infestation at each of the first three assessments (at 55, 63 & 71 days after sowing) all gave highly significant *F* values for the model (P>0,001) and for treatment effects (P>0,0001). Mean aphid infestation ratings at each assessment are presented in Table 25. On treatment 1 plots (untreated control) aphid populations increased until the third assessment. After this time they suffered a precipitous fall, apparently due to a fungal disease that affected the whole experiment and interfered with subsequent attempts to re-establish the populations by artificial infestation. For this reason the results of the fourth assessment (101 days after sowing) are not considered as a reliable indication of any residual aphicidal effects that may have persisted to that time and they are not presented here.

Table 25 clearly shows that imidacloprid is definitely superior to the currently recommended disulfoton as a pre-sowing aphicide for conventional seedbeds. It also shows that the following materials, tabulated in this experiment as "cutworm preventatives", have strong aphicidal activity in their own right: monocrotophos (treatments 1,12,23), acephate (2,13, 24), methamidophos (3, 14, 25) and deltamethrin (10, 21, 32). Any such strong aphicidal activity is not an outstanding feature of the remaining "cutworm preventatives" tested, namely indoxacarb (4,15,26), chlorfenapyr (5, 16, 27), spinosad (6,17,28), lufenuron (8, 19, 30) and novaluron (9,20, 31). The fourth assessment indicated that the effectiveness of the imidacloprid protection did not persist to 100 days after sowing.

(b) Cutworm

An ANOVA of the arcsine-transformed proportions of undamaged seedlings recovered from the plots at the final assessment gave highly significant *F* values for the model (P>0,001) and for treatment effects (P>0,0001). Mean arcsine proportions for the treatments and their de-transformed values (as percentages) are presented in Table 26.

Table 25. Mean aphid infestation ratings of 30 seedlings/plot at three assessments

First, second and third values for each entry refer to aphid ratings at 1st, 2nd & 3rd aphid assessments (55, 63 & 71 days after sowing); means from the same assessment that are followed by the same letter are not significantly different from one another by the Waller-Duncan K-ratio *T* test (0,05 probability level)*. Aphid rating scale is logarithmic with 0 coding for no aphids; 1 for 1-10 aphids; 2 for 11-100 aphids; 3 for 101- 1000 aphids; and 4 for > 1000 aphids.

Cutworm preventative	Aphid preventative		
	nil	disulfoton	imidacloprid
nil	0,209 a 1,109 a 2,753 a	0,020 e 0,127 ef 0,846 cd	0,000 e 0,000 f 0,000 e
monocrotophos	0,000 e 0,000 f 0,000 e	0,000 e 0,000 f 0,000 e	0,000 e 0,000 f 0,000 e
acephate	0,007 e 0,000 f 0,000 e	0,000 e 0,000 f 0,000 e	0,000 e 0,000 f 0,000 e
methamidophos	0,000 e 0,000 f 0,000 e	0,000 e 0,000 f 0,027 e	0,000 e 0,000 f 0,000 e
indoxacarb	0,250 a 1,025 ab 2,700 ab	0,000 e 0,007 f 0,200 e	0,000 e 0,000 f 0,000 e
chlorfenapyr	0,088 bcd 0,859 c 2,426 ab	0,007 e 0,147 def 0,533 d	0,000 e 0,000 f 0,000 e
spinosad	0,400 b 0,833 c 2,533 ab	0,053 cde 0,140 ef 0,827 cd	0,000 e 0,000 f 0,000 e
lufenuron	0,142 b 0,974 abc 2,163 ab	0,020 e 0,187 de 0,820 cd	0,000 e 0,000 f 0,000 e
teflubenzuron	0,108 b 0,878 bc 2,547 ab	0,027 e 0.300 d 0,573 cd	0,000 e 0,000 f 0,000 e
novaluron	0,133 b 1,073 a 2,740 ab	0,027 e 0,300 d 0,573 cd	0,000 e 0,000 f 0,000 e
deltamethrin	0,033 de 0,000 f 0,042 e	0,000 e 0,000 f 0,014 e	0,000 e 0,000 f 0,000 e

* 1st assessment: K-ratio = 100 df = 128 MSE = 0,002494 *F* = 8,82607 Critical Value of *t* = 1,85339
Minimum Significant Difference = 0,0585

2st assessment: K-ratio = 100 df = 128 MSE = 0,01981 *F* = 38,91253 Critical Value of *t* = 1,76469
Minimum Significant Difference = 0,1571

3nd assessment: K-ratio = 100 df = 128 MSE = 0,081249 *F* = 67,99035 Critical Value of *t* = 1,75449
Minimum Significant Difference = 0,3163

Table 26. Mean proportions of seedlings rated as undamaged by cutworms at the final assessment

First value for each entry is mean of arcsine transformed proportion; means followed by the same letter are not significantly different from one another by the Waller-Duncan K-ratio *T* test (0,05 probability level)*; bracketed values are de-transformed mean percentages.

Cutworm prevent-ative	Aphid preventative		
	nil	disulfoton	imidacloprid
nil	0.68 g (39,41)	0,57 hl (28.85)	0,53 i (25.14)
monocrotophos	1,24 d (89,69)	1,31 d (93.12)	1,42 c (97,87)
acephate	1,48 bc (99,18)	1,50 abc (99,44)	1,49 bc (99,31)
methamidophos	1,53 ab (99,87)	1,55 ab (99,96)	1,52 b (99,75)
indoxacarb	1,57 a (100.00)	1,56 ab (99.99)	1,57 a (100,00)
chlorfenapyr	1,56 ab (99.99)	1,55 ab (99.96)	1,56 ab (99,99)
spinosad	1,53 ab (99.81)	1,50 abc (99,44)	1,52 ab (69,74)
lufenuron	1,54 ab (99,88)	1,55 ab (99.95)	1,57 a (100.00)
teflubenzuron	0,99 e (69,62)	0,86 f (57,34)	0,64 gh (35,45)
novaluron	1,54 ab (99.93)	1.53 ab (99.82)	1.53 ab (99.84)
deltamethrin	1,57 a (100,00)	1.57 a (100,00)	1.56 ab (99,99)

* K-ratio = 100 df = 128 MSE = 0,006322 *F* = 86,76105 Critical Value of *t* = 1,75157
Minimum Significant Difference = 0,0881

The considerable numbers of damaged seedlings obtained from treatments 11 (disulfoton only) and 22 (imidacloprid only) indicate that the pre-sowing aphicidal treatments had no practical effects as cutworm preventatives. All preventative cutworm treatments gave proportions of undamaged seedlings that were significantly higher than the untreated controls (0, 11, 22). The treatments involving teflubenzuron (8, 19, 30) and monocrotophos (1, 12, 23) were less effective than the other treatments but there is little to choose between the remainder. Those giving between 100 and 99.99% undamaged seedlings were deltamethrin, indoxacarb, chlorfenapyr and lufenuron but these proportions are not significantly different from the slightly lower percentages of undamaged seedlings produced by methamidophos, novaluron, spinosad and acephate.

<u>Aphid and cutworm: seedbed preventative strategies (00 EN07S)</u>

The objective was to compare the efficacies of five aphid (*Myzus persicae* complex) pre-sowing preventatives combined with five potential cutworm (*Agrotis segetum*) damage preventatives applied at three week intervals.

<u>Materials and Methods</u>

Design: Five randomized complete blocks of 6 treatments; 1.2 m x 1.2 m plots

Treatments:

Tmt Code	Aphid Preventative	Rate (g a.i./m^2)	Cutworm Preventative	Rate/applic. (g a.i./m^2)
0	nil	–	nil	
1	disulfoton 5% gr	0.20	acephate 97% sg	0.73
2	imidacloprid 20% sl	0.10	triflumeron 48% sc	0.12
3	thiomethoxam 25% wg	0.10	lufenuron 5% ec	0.12
4	triazamate 14% ew	0.10	teflubenzuron 15%	0.12
5	acetamiprid 20% sp	0.10	deltamethrin 2.5% ec	0.12

Prior to sowing, disulfoton 5% granules at 4 g product/m^2 (0,2 g a.i./m^2) were raked into top 2–3 cm of soil; the other preventative aphicides were applied onto the soil surface at 1,5 litres/m^2 using watering cans, at a rate of 0.10 g a.i. The seedbeds were sown on 18 August 1999. Asbestos-cement seedbed dividers and angle-iron stakes were used to form the walls and corners of plots (1,2 m square = 1,44 m^2), and they were positioned in the seedbeds on 14–16 September 1999 (27–9 d.a.s). Artificial infestations of aphids, at which from 5 to 30 (the numbers varied on different occasions but were constant on any given one) apterous individuals from the laboratory culture were introduced to each plot were made on seven occasions between 27 September and 4 November (40-77 d.a.s.). Artificial infestation of cutworm larvae was done using 4-, 5-, or 6-day post-hatch larvae from laboratory culture over the period extending from 22 September to 17 November (35-58 d.a.s.). Over this period, a total of 58 such larvae were placed in each plot on an almost daily, fully recorded, basis.

Cutworm preventative treatments were applied by watering-cans at 1,5 litre/m^2 on 22 September, 13 October and 3 November (35, 56 & 77 d.a.s).

Assessments of the intensity of aphid infestation in plots were made on four occasions, 12 October, 20 October, 28 October and 26 November (55, 63, 71 & 100 d.a.s.) using a five-level logarithmic scale (a rating of 1 indicated 1-10 aphids on the assessed seedling, 2 indicated 11-100 aphids, 3 indicated 101-1000 aphids and 4 indicated more than a thousand).

Final cutworm damage assessments were made from 27 November to 9 December (101-113 d.a.s.). A Damage Rating Scale was used where: 0 = undamaged stem; 1 = superficial damage to epidermis and cortex that does not reach hard portion of vascular cylinder; 4 = damage reaches hard portion of vascular cylinder; 6 = damage goes through hard portion of vascular cylinder and exposes central pith of stem; 7 = seedling cut off leaving only a stump.

Results and Discussion

(a) Aphid

ANOVAs of the mean intensities of infestation at each of the first three assessments (at 55, 63 & 71 days after sowing) all gave highly significant *F* values for the model (P>0,001) and for treatment effects (P>0,0001). Mean aphid infestation ratings are presented in Table 27. It is clear that the control strategies represented by treatments 1, 2, 3 and 5 (pre-sowing aphicides disulfoton, imidacloprid, thiamethoxam, and acetamiprid) gave excellent aphid control up to 71 days after sowing. It is not, however, possible to separate the aphicidal effects of the acephate used in treatment 1 and the deltamethrin used in treatment 5 from those of the presowing aphicides (disulfoton and acetamiprid) with which they are paired. Since the previous experiment has shown that lufenuron has no important aphicidal effect it is clear that thiamethoxam is at least as effective as imidacloprid. Triazamate (paired with teflubenzuron which has no practical aphicidal effect) did not prove a satisfactory pre-sowing preventative aphicide.

Table 27. Mean aphid infestation ratings of 30 seedlings/plot at three assessments with mean proportions of seedlings rated as undamaged by cutworms at the final assessment

For aphid data, first, second and third values for each entry refer to aphid ratings at 1st, 2nd & 3rd aphid assessments (55, 63 & 71 days after sowing); means from the same assessment that are followed by the same letter are not significantly different from one another by the Waller-Duncan K-ratio *T* test (0,05 probability level)*. Aphid rating scale is logarithmic with 0 coding for no aphids; 1 for 1-10 aphids; 2 for 11-100 aphids; 3 for 101- 1000 aphids; and 4 for > 1000 aphids. For cutworm damage data, first entry is mean of arcsine-transformed proportion; means followed by the same letter are not significantly different from one another by the Waller-Duncan K-ratio *T* test (0,05 probability level)*; bracketed values are de-transformed mean percentages.

Aphid preventative	Cutworm preventative	Aphid infestation levels	Proportion undamaged seedlings
nil	nil	0,211 b 1,081 a 2,628 a	0,776 c (49,05)
disulfoton	acephate	0,000 c 0,000 b 0,000 b	1,536 a (99,88)
imidacloprid	triflumeron	0,000 c 0,007 b 0,000 b	1,449 a (98,53)
thiamethoxam	lufenuron	0,000 e 0,000 b 0,667 b	1,571 a (100,00)
triazamate	teflubenzuron	0,313 a 1,012 a 2,268 a	1,071 b (77,06)
acetamiprid	deltamethrin	0,027 c 0,000 b 0,007 b	1,571 e (100,00)

*Aphid:

1st assessment: K-ratio = 100 df = 20 MSE = 0,00309 *F* = 29,81 Critical Value of *t* = 1,90147
Minimum Significant Difference = 0,0669

2st assessment: K-ratio = 100 df = 20 MSE = 0,027309 *F* = 53,356 Critical Value of *t* = 1,88372
Minimum Significant Difference = 0,1969

3nd assessment: K-ratio = 100 df = 20 MSE = 0,033994 *F* = 275,871 Critical Value of *t* = 1,6606
Minimum Significant Difference = 0,2176

Cutworm: K-ratio = 100 df = 20 MSE = 0,016728 *F* = 32,659 Critical Value of *t* = 1,890807
Minimum Significant Difference = 0,1553

(b) Cutworm

An ANOVA of the arcsine-transformed proportions of undamaged seedlings recovered from the plots at the final assessment gave highly significant *F* values for the model (P>0,001) and for treatment effects (P>0,0001). Mean arcsine proportions for the treatments and their de-transformed values (as percentages) are presented, together with the aphid results, in Table 27.

It is clear that the strategies represented by treatments 3 and 4 gave excellent control of cutworm with those of treatments 1 and 2 not statistically separable. Teflubenzuron (treatment 2) did not give satisfactory protection against cutworm damage.

DISCUSSION

The research on control strategies for insect pests of tobacco seedlings in conventional seedbeds conducted under UNIDO project MP/ZIM/97/182 concerned both preventative aphicides that can be applied before sowing and cutworm preventatives that are applied at intervals after germination.

Pre-sowing Aphicides

Imidacloprid, a chloronicotinyl insecticide, has been shown to provide better protection against aphid infestations than the currently registered disulfoton (an organo-phosphate). This protection will last for at least ten weeks (experiments 00 EN06S & 00 EN07S). Thiamethoxam (another chloronicotinyl), is as effective as imidacloprid (00 EN07S) while a third member of the same group may prove to be similarly effective when its effects are disentangled from the aphicidal effects of the cutworm preventative (the synthetic pyrethroid, deltamethrin) with which it was combined (in 00 EN07S). These chloronicotinyls are likely to prove equally effective in seedling production systems that involve floating trays and they are also likely to be effective against whiteflies should problems from these insects arise as the result of changes in seedling production practices. However, cases of whitefly populations becoming resistant to chloronicotinyls are already known.

Cutworm Preventatives

The efficacies of the currently registered organophosphate cutworm preventatives, monocrotophos, acephate and methamidophos were re-tested (98 EN10S, 00 EN06S and 00 EN07S). All three have important aphicidal effects in addition to their actions against cutworms, but their future availabilities (especially those of monocrotophos and methamidophos) are under threat from regulatory reviews that are currently underway. As a cutworm preventative, monocrotophos is definitely inferior to the other two and it should be de-registered for this usage. Methamidophos is undesirable on account of its high mammalian toxicity. Deltamethrin (a synthetic pyrethroid) has been shown to be an excellent cutworm preventative (00 EN06S, 00 EN07S) but is not currently registered for this purpose. This omission is for reasons associated with the Zimbabwean insecticide resistance management strategy that is aimed primarily at budworm, *Helicoverpa armigera*. This insect is not, however, a tobacco seedbed pest, so that the use of pyrethroids in this situation could be tolerated, since it would not increase this insect's exposure to this group.

The experiments cited have identified some promising substitute cutworm preventatives.
Of these, indoxacarb (a sodium channel inhibitor), chlorfenapyr (an uncoupler of oxidative phosphorylation), and lufenuron (a benzoylphenyl urea growth regulator) seem most promising, though spinosad (a biological produced from an Actinomycete) and fipronil (a phenyl pyrozole) may approach them in efficacy. None of these materials has any practical aphicidal effects. The recommended intervals between applications to seedbeds can certainly be extended from the current two weeks to three weeks without reducing cutworm control (98 EN10S) but, since several are slow acting, they must be present continuously in seedbeds if cutworm larvae are to be killed when young, before they are capable of causing damage to the seedling stems.

Future seedbed insect control strategies

In terms of insecticide resistance strategies, it will clearly be unwise to rely too heavily on the chloronicotinyls for aphid control and it will therefore be necessary to search for alternative aphicides belonging to other groups.

In contrast, the wide variety of cutworm preventatives now appearing, promises considerable flexibility in the design of strategies for this application.

2. Alternative Seedling Production Systems

Six main topics are discussed in this section. The first deals with experiments on different systems of soilless seedling production. The next four topics describe testing various media, use of *Trichoderma* in the float seedbed system, methods of improving germination and hardening techniques. The last subject describes the various workshops/conferences attended and demonstrations to disseminate the information to farmers.

2.1. ALTERNATIVE SYSTEMS OF SEEDLING PRODUCTION IN SOILLESS MEDIA

INTRODUCTION

Methyl bromide is not required when tobacco seedlings are produced with non-soil techniques. Many systems have been developed and these include soilless media seedbeds (developed in South Africa) and Speedling® trays (expanded polystyrene seedling trays, in this report, called "speedling" trays, being locally made but similar to Speedling® trays) with soilless media watered either by an overhead irrigation system or floated on water (developed in the USA). This part describes the experiments done to identify the most appropriate methods of seedling production using soilless media. The studies included pine bark seedbeds, microjet watering of suspended locally made "speedling" trays and floating "speedling" trays on water (float system). The media consisted of either pine bark alone for the pine bark seedbed and overhead watered (microjet) system, or pine bark mixed with river sand for "speedling" trays in the float system.

RESULTS

<u>UNIDO demonstrations of alternative seedbed systems (99 PH04S)</u>

This is similar to 99 PH02S (Further Investigation of Alternative Seedbed Systems) except on a large scale in order to demonstrate the methods to farmers.

<u>Materials and Methods</u>

Design: A series of beds in demonstration plots to show alternative tobacco seedling production methods which do not utilise methyl bromide: non-soil cultivation.

Treatments:
1. "Speedling" tray floats - (128 cells/tray, 34 cm^3/cell) with 50:50 pine bark and sand
2. "Speedling" tray floats - (200 cells/tray, 21 cm^3/cell) with 50:50 pine bark and sand
3. Open pine bark beds on permanent concrete base (overhead watered) - direct seeded uncoated seed
4. Open pine bark beds on permanent concrete base (overhead watered) - precision sower using pelleted seed
5. Seedling trays on suspended wire strand base (overhead watered) - polystyrene tray (128 cells/tray, 34 cm^3/cell) with 50:50 pine bark and sand
6. Seedling trays on suspended wire strand base (overhead watered) - black plastic tray (153 cells/tray, 19 cm^3/cell) with 50:50 pine bark and sand

Results and Discussion

The primary purpose of these seedbeds was to demonstrate the use of soilless media to produce tobacco seedlings. Research staff at the Tobacco Research Board and The Ozone Officer from the Ministry of Mines Environment and Tourism visited the site. In the coming season, the seedbed demonstrations will be aimed at educating the farmers.

Further investigation of alternative seedbed systems (99 PH02S)

To further investigate alternative (non-fumigant treatment) seedbed systems.

Materials and Methods

Design: Large non-randomised blocks of 6 treatments set aside in the UNIDO demonstration beds

Treatments:
1. "Speedling" tray floats - (128 cells/tray, 34 cm^3/cell) with 50:50 pine bark and sand
2. "Speedling" tray floats - (200 cells/tray, 21 cm^3/cell) with 50:50 pine bark and sand
3. Open pine bark beds on permanent concrete base (overhead watered) - direct seeded uncoated seed
4. Open pine bark beds on permanent concrete base (overhead watered) - precision sower using pelleted seed
5. Seedling trays on suspended wire strand base (overhead watered) - polystyrene tray (128 cells/tray, 34 cm^3/cell) with 50:50 pine bark and sand
6. Seedling trays on suspended wire strand base (overhead watered) - black plastic tray (153 cells/tray, 19 cm^3/cell) with 50:50 pine bark and sand

The seedbeds were sown towards the end of July. Seedlings in open permanent pine bark beds were grown from pelleted and uncoated seed, the latter being sown using the standard watering can method. The cultivar used in all cases was Kutsaga RK 6 and the pelleted seed was the "Oxymelt" type from Germains (UK). The medium was 50% pine bark and 50% sand for all trays and 100% pine bark (sifted) for permanent open beds. The sand was sifted to a particle size of between 0.5 and 2.0 mm. A lightweight polyester seedbed cover and a thin grass mulch was applied to all treatments to try and improve the rate of germination. This was to increase temperature and moderate diurnal temperature variations, while the grass mulch also gave some protection, especially to the newly emerging seedlings in the suspended overhead watered treatments.

The overhead watering was carried out four times per day and each irrigation was continued until water began to drain out of the suspended trays. The lightweight seedbed cover was removed for watering.

The float seedlings received all nutrient through the float water and concentrations were monitored and adjusted at three stages during the trial (Appendix Table A.1.1). The overhead watered seedlings received fertilization through prepared solutions applied by hand with a watering can (Appendix Tables A1.2 and A1.3).

Germination counts were done at 34 and 60 days after sowing (d.a.s.) The count and seedling cotyledon diameter was measured at 60 d.a.s and was not done on the two permanent pine bark beds, treatments 3 and 4, because there was no indication of delayed germination and plants were too big. A final stand count and seedling measurements were done 98 d.a.s, which was transplanting (pulling) time.

Seedlings produced in this trial were used in the experiment to test the hardness and growth in the field (99 PH03S/K).

Results and Discussion

Despite getting good pre-season results in laboratory germination tests with the pelleted seed (+ 97%), there was considerable variance in germination in the seedbed site. Poor germination occurred in both the 128 and 200 cell floats (treatments 1 and 2). The germination was much better in the overhead watered system with both uncoated and pelleted seed (treatments 3, 4, 5, 6) (Table 28). It appears that the type of pelleted seed, dibbling depth, type and packing density of the medium all influence germination in the float system, but are not so crucial in the overhead system. Further work is planned to investigate these factors in order to improve germination in the float system.

Although germination in the suspended "speedling" trays with overhead watering was good, especially in the black 153 cell trays (treatments 5 and 6), droplet impact and uneven watering from the microjets decreased the stand count. A grass mulch and lightweight polyester cover were put onto the seedbeds to reduce this problem. Measurements done 60 d.a.s and 98 d.a.s (at pulling time) showed that the growth of seedlings in the suspended trays was much slower than those in the float trays and pine bark seedbeds (treatments 1, 2, 3 and 4) (Table 29). This was possibly due to a cooling effect from frequent irrigations, combined with the small volume of media.

The pine bark seedbed which was "precision sown" with pelleted seed (treatment 4) had fewer plants/m^2 than that where uncoated seed was used (treatment 3), because it was sown at a lower density. There were no signs of delayed or staggered germination in the two pine bark seedbeds (treatments 3 and 4), as was the case in the float speedlings and to a lesser extent in the suspended tray seedlings with overhead watering.

Table 28. Percent germination or stand count

	Days after sowing (d.a.s.)					
	34 d.a.s		60 d.a.s.		At pulling 98 d.a.s.	
Treatment	%	SE Mean	%	SE Mean	%	SE Mean
128 cell floats	37	2.4	47	4.1	55	3.7
200 cell floats	16	2.1	38	5.5	49	4.6
Pine bark bed - uncoated seed	219†	20.3†	-	-	196/m^2	8.9
Pine bark bed - pelleted seed	181†	17.5†	-	-	153/m^2	8.6
128 cell microjet	57	2.5	73	3.2	70	3.8
153 cell microjet	62	2.4	69	3.4	71	3.8

† Number/m^2 (not %)

At pulling, the largest seedlings were obtained from the pine bark bed sown with pelleted seed (treatment 4) (Tables 29 and 30). This seedbed had a considerably lower plant population and this contributed to the greater size. The germination and growth of seedlings in the pine bark bed sown with uncoated seed (treatment 3) was very similar to that sown with pelleted seed (treatment 4); the major difference was slightly smaller seedlings at pulling, which was attributed to an increased sowing density. The dry mass of seedlings grown in pine bark from uncoated seed was lower than expected, particularly as the stem length and diameter were relatively large. It is difficult to explain this result.

The suspended trays with overhead watering (treatments 5 and 6) were the smallest. However, towards the end of the experiment they were catching up in size. Plants in treatment 6, with 153 cells/tray, were taller, but thinner with a lower dry mass than those in treatment 5, with 128 cells/tray (Tables 29 and 30). The black plastic, therefore, appeared to speed up the growth of seedlings in the trays with 153 cells, but the higher population caused a decrease stem diameter.

The float trays with 200 cells (treatment 2) had larger seedlings at transplanting than those with 128 cells (treatment 1) (Table 29), although, early in the season the situation was the reverse. It was difficult to explain this difference at transplanting, as it was contrary to previous results with polystyrene trays, which had shown that larger cell volumes produced bigger seedlings.

Generally, the pine bark seedbeds had good germination and produced well grown seedlings. The largest plants came from the beds where pelleted seed was used and this was because of a lower seeding rate. The float seedbeds had an extended and poor germination and this was thought to be related to the type of pelleted seed, dibbling depth, type and packing density of the medium. Further work is required to establish the optimum conditions for germination and growth using pelleted seed in the float system. However, seedlings that germinated early grew well and produced reasonable plants by transplanting time, especially in the trays with 200 cells.

The overhead watered suspended "speedling" trays had better germination than the float trays, but the seedlings grew much slower and were the smallest at transplanting. This was thought to be as a result of lower temperatures, and consequently the black plastic trays performed better than the polystyrene trays. Nonetheless, the seedlings produced in this manner, were a vast improvement on the previous year's attempt (see 98 PH08S). This was because leaching was controlled and the fertilizer was applied as several topdressings, rather than as a basal fertilizer put into the medium, as in the previous year.

Table 29. Seedling cotyledon diameter and stem diameter and length

Treatment	Days after sowing (d.a.s.)					
	Seedling leaf diameter (60 d.a.s.)		Seedling stem diameter (98 d.a.s.)		Seedling stem length (98 d.a.s.)	
	(mm)	SE Mean	(mm)	SE Mean	(cm)	SE Mean
128 cell floats	7.2	0.45	6.4	0.15	7.3	0.56
200 cell floats	6.3	0.36	6.9	0.12	13.0	0.45
Pine bark bed - uncoated seed	-	-	8.1	0.24	13.5	0.2
Pine bark bed - pelleted seed	-	-	9.3	0.26	14.3	0.3
128 cell microjet	5.4	0.18	6.4	0.09	9.9	0.49
153 cell microjet	4.8	0.24	5.7	0.08	11.8	0.47

Table 30. Dry mass of seedlings at transplanting time (98 days after sowing)

Treatment	Dry mass shoots		Dry mass roots		Total dry mass	
	(g/plant)	SE Mean	(g/plant)	SE Mean	(g/plant)	SE Mean
128 cell floats	1.1	0.04	0.5	0.03	1.7	0.05
200 cell floats	1.7	0.08	0.6	0.04	2.3	0.11
Pine bark bed - uncoated seed †	1.1	-	0.5	-	1.6	-
Pine bark bed - pelleted seed †	2.2	-	0.5	-	2.7	-
128 cell microjet	1	0.03	0.5	0.03	1.6	0.05
153 cell microjet	0.9	0.03	0.7	0.05	1.5	0.07

† No replication for dry mass

DISCUSSION

Overall, the seedlings grown in "speedling" trays with the overhead watering system were much smaller than those grown in a pine bark seedbed with the same watering system, and those in the float system. The slow growth was because the fertilizer was incorporated as a basal in the medium and, consequently, leaching of nutrient occurred. Better results were obtained when the fertilizer was applied as a drench relatively frequently. The rate of growth of seedlings in the float and pine bark seedbed systems was comparable, if not better, than that in the traditional seedbeds.

The open pine bark bed works well and is used very effectively in South Africa but the main drawback in Zimbabwe is that it is considerably more expensive than the float or overhead (microjet) systems (Table 72). This is primarily because more pine bark is required to produce a similar sized seedbed to the float system and considerably more area of seedbed is required per hectare. A further problem with this system is that if the entire Zimbabwean tobacco industry converted to it, there may not be sufficient composted pine bark to meet the needs of all growers.

The overhead watered microjet system works and is economic. It is already used very successfully by nurserymen in Zimbabwe on other crops but the level of management required is considerably higher than float management especially for the watering and fertigation regimes. It has been shown that the leaching of nutrient (overwatering) and the rapid drying out of the suspended cells (underwatering) can easily occur if attention to these details lapses for a short period.

Taking all aspects of these different systems into consideration and being well aware of the variation in management styles existent in the Zimbabwean tobacco growing sector it soon became apparent that the floating tray system would be most appropriate. It has been shown to work extremely well in trials and even in large demonstration projects. It is cost effective and does well in low management input situations. For these reasons we concentrated our efforts on improving the float system.

2.2. TESTING DIFFERENT MEDIA FOR THE FLOAT SYSTEM

INTRODUCTION

Composted pine bark has been used to produce seedlings in trays by nurseries in Zimbabwe, South Africa and Australia. However, little work has been done on the use of pine bark in the float system. The depth at which the trays float depends on the type of tray used (amount and density of the polystyrene) and the density of the media. It was therefore necessary to establish whether pine bark could be used on its own or whether it had to be mixed with other media such as river sand. This section describes the work done to identify the best pine bark/sand mix and experiments to test other locally available media which could be used in addition to pine bark. The first two experiments studied various combinations of pine bark, river sand and vermiculite. The next two tested whether dibbling and mulching (covering the seed) were necessary. Maize, groundnuts and bagasse (fibrous pressings from sugar cane) were screened as alternative media to pine bark in the last three experiments.

Properties of the pine bark medium
Before starting the experiments, the pH and microbial composition of the pine bark was assessed. The pH was 4.9 and 2 g lime/kg pine bark was added. The pine bark was free of any pathogens and generally had few bacteria growing in it.

Visit of Mr F. Lemaire - Substrate and Composting Specialist
Between January 7 and 20 1999, we had the services of Mr Francis Lemaire, sponsored by UNIDO, to examine our progress and to advise on our efforts in using pine bark as a soilless media. He also examined our proposed seedbed alternatives and examined the suitability of other more accessible local substrates as soilless media. Composting, sterilization and re-utilization of various substrates was also addressed.

Mr Lemaire studied our Half-Yearly Report 1, December 1998 and commented in detail on our results and offered analyses or techniques to improve on our approach. He explained optimum substrate characteristics, methods of analysis and substrate formulation. After examining our physical layout and facilities, Mr Lemaire commented as follows:

- That we concentrate initially only on pine bark mixtures in our experiments until all other aspects of soilless cultivation have been clarified

- That only then should we diversify into the suitability of other locally available substrates.
- He proposed new combinations of available substrates and these are currently under evaluation in a greenhouse environment during this off-season in preparation for the new season.
- He examined our composting techniques and the problems of organic material composting using local resources and media combinations and offered assistance accordingly.
- He suggested several reasons as to why the maize stover may have failed as a substrate, and these will be investigated when we resume work with alternative substrate media.
- He suggested ways of improving the germination of pelleted seed in the float system.
- He made suggestions about the layout and comparisons of some treatments within experiments.

The professional advice and assistance given by Mr Lemaire proved invaluable to all involved and the complementary literature, techniques and conclusions offered by him will be of great benefit in our efforts to establish new alternative seedbed techniques.

RESULTS

<u>Substrate alternatives in different seedbed systems (98 PH08S)</u>
(See Terms of Reference (Project MP/ZIM/97/182))

The aim was to compare various "speedling" tray mulches, such as pine bark and vermiculite plus sand mixtures, grown with different watering methods.

Materials and Methods

Design: 4 randomized blocks 2 main plots and 4 sub-plots per main plot

Treatments:
Factor 1: Watering regime
1. Float system
2. Overhead microjet (G-Jet) system

Factor 2: Medium
1. 50:50 - pine bark:sand
2. 100% pine bark
3. 50:50 - vermiculite:sand
4. 100% vermiculite

All speedlings produced with pelleted seed in 128 cell trays.

Results and Discussion

The germination of tobacco seedlings was not particularly good, however, it was better in the overhead-watered treatment than in the float system (Table 31). The pelleted seed in the float system did not appear to dissolve as easily as in the overhead watered system. The germination in vermiculite was significantly higher than in pine bark and there appeared to be little difference between 100% medium and 50% sand + 50% medium.

Table 31. Percent germination of tobacco seedlings

Media	Watering Method		
	Float	Overhead Microjet	Mean
50:50 - pine bark:sand	54.6	74.3	64.5
100% pine bark	51.9	68.0	59.9
50:50 - vermiculite:sand	72.7	78.5	75.6
100% vermiculite	69.5	75.7	72.6
Mean	62.2	74.1	68.2

t (p=0.05, df = 3) 3.182

t (p=0.05, df = 18) 2.101

t (p=0.05, calc) 2.494

CV%		5.5
SED:	Watering Method	3.1*
	Media	3.3*
	Watering Method x Media	5.0

There was an interaction between the watering system and media for seedling diameter measured 11 weeks after sowing (Table 32). This was because there was no difference in growth between the media in the float system, however, seedlings in the pine bark treatments in the overhead watered system were significantly smaller than the vermiculite treatments. Overall, the seedlings in the overhead watered system were much smaller than those in the float system and this was because of leaching of nutrients. The poor growth in the overhead watered, pine bark treatment was possibly because of greater leaching compared with the overhead watered, vermiculite treatments. Seedling length was not measured in the overhead watered system because the seedlings were too small. In the float system, the 100% pine bark seedlings were significantly shorter than the other media and there was little difference between these (Table 33).

The poor germination of pelleted seed might have been caused by many factors such as the packing density of the medium, depth of dibbling, type of medium or the type of pelleted seed. Further work needs to be done to test these factors in order to try and improve the germination with pelleted seed in the float system.

Table 32. Seedling diameter measured 11 weeks after sowing (mm)

Media	Watering Method		
	Float	Overhead Microjet	Mean
50:50 - pine bark:sand	5.5	3.5	4.5
100% pine bark	5.7	3.4	4.5
50:50 - vermiculite:sand	5.0	4.9	4.9
100% vermiculite	5.3	4.6	5.0
Mean	5.4	4.1	4.7

t (p=0.05, df = 3) 3.182

t (p=0.05, df = 18) 2.101

t (p=0.05, calc) 2.494

CV%		6.4
SED:	Watering Method	0.27*
	Media	0.21
	Watering Method x Media	0.37*

Table 33. Seedling length in the float system measured 11 weeks after sowing

Media	Length (cm)
50:50 - pine bark:sand	11.4
100% pine bark	9.0
50:50 - vermiculite:sand	11.3
100% vermiculite	11.1
Mean	10.7
SED $t_{(p=0.05,\ df=9)}$ 2.262	0.75*
CV%	6.2

Further investigation of alternative seedbed growing media combinations (00 PH06S)

To determine the effect on germination and subsequent growth of variations (by volume) in media combinations.

Materials and Methods

Design: 6 randomized complete blocks of 6 treatments (36 trays).

Treatments:
Media variations by volume

	Pine bark	River sand	Gde 3 Vermiculite
1.	100%	nil	nil
2.	75%	15%	10%
3.	50%	40%	10%
4.	70%	nil	30%
5.	50%	nil	50%
6.	nil	nil	100%

The above treatments were produced in the irrigated permanent seedbeds (UNIDO Demonstration) in 128 cell "speedling" trays, 1 tray per plot, and all aspects of germination and growth was monitored. All Speedlings were produced with pelleted seed in (new or pre-sterilized) "speedling" trays. All beds were covered with a standard grass mulch and floating row cover (lightweight polyester cover). The cultivar was K RK6 (pelleted, Rickards).

Results and Discussion

Although we are producing very satisfactory results with our standard medium mix of 50% composted pine bark, 40% washed river sand and 10% vermiculite, it was felt that we should evaluate other variations of these constituents. An arcsine transformation was used to normalise the data where necessary.

As can be seen from Table 34 there were no significant differences between the various mixes over the first month of germination. None of the percentages at 28 d.a.s. reached the 85% minimum germination level (109 seedlings/128 cell tray), but at the end of the trial [12 weeks after sowing (w.a.s.)] all treatments had reached this level (Table 35). There was no significant difference in number or dry mass of seedlings measured at this time. This data indicates that vermiculite and pine bark can be substituted for each other. Although the 100% pine bark treatment was similar to the other treatments in this experiment, previous results at the Tobacco Research Board (96 PH01S) showed that seedlings grew slower with this treatment compared with pine bark:sand mixtures.

Table 34. Percent germination at 7 and 28 days after sowing

Media	%		Arcsine %	
	7	28	7	28
100% pine bark	11.7	77.3	0.33	1.08
75% pine bark, 15% sand, 10% vermiculite	12.2	74.2	0.34	1.05
50% pine bark, 40% sand, 10% vermiculite	17.6	80.5	0.42	1.12
70% pine bark, 30% vermiculite	16.5	78.6	0.39	1.10
50% pine bark, 50% vermiculite	20.6	73.0	0.44	1.03
100% vermiculite	11.1	76.6	0.31	1.08
Mean	15.0	76.7	0.37	1.08
SED $t_{(p=0.05,\ df=25)}$ 2.060	-	-	0.104	0.076
CV%	-	-	48.5	12.1

Table 35. Number of seedlings per tray (128 cell), dry mass of roots and shoots and seedling length 12 weeks after sowing

Media	Number	Dry mass (g/plant)			Length (cm)
		Shoots	Roots	Total	
100% pine bark	116	1.43	0.21	1.65	17.4
75% pine bark, 15% sand, 10% vermiculite	120	1.50	0.26	1.76	18.2
50% pine bark, 40% sand, 10% vermiculite	115	1.67	0.30	1.97	16.5
70% pine bark, 30% vermiculite	117	1.45	0.21	1.66	17.5
50% pine bark, 50% vermiculite	115	1.55	0.24	1.79	18.8
100% vermiculite	109	1.54	0.26	1.80	15.5
Mean	115	1.52	0.25	1.77	17.3
SED $t_{(p=0.05,\ df=25)}$ 2.060	6.56	0.148	0.038	0.180	1.88
CV%	9.8	16.8	26.6	17.6	18.8

Table 36. Percent of transplantable seedlings per tray (128 cell)

Media	%	Arcsine %
100% pine bark	74.10	1.04
75% pine bark, 15% sand, 10% vermiculite	65.00	0.94
50% pine bark, 40% sand, 10% vermiculite	72.70	1.04
70% pine bark, 30% vermiculite	70.00	1.00
50% pine bark, 50% vermiculite	72.10	1.03
100% vermiculite	75.10	1.07
Mean	71.50	1.02
SED $t_{(p=0.05, df=25)}$ 2.060	-	0.100
CV%	-	16.9

It is a matter of concern that the number of pullable seedlings was less than the required 85% usable (Table 36), despite a satisfactory final stand count. It is thought that the slow rate of germination contributed to the decrease in transplantable seedlings; the rate was only about 76% after 28 days.

Soilless media (density) and mulching combinations in float seedling production (99 PH15S)

To evaluate various substrate and mulch combinations in float "speedling" trays in order to improve the rate and uniformity of germination using pelleted seed.

Materials and Methods

Design: Four randomized complete blocks with 4 treatments (2 x 2), one tray per plot (total 16 x 128 cell trays) + 2 trays with uncoated seed applied using ash and shaker as indication of raw seed germination.

Treatments:
Factor 1 - Media combination
1. - 50% pine bark, 40% river sand, 10% vermiculite grade 3
2. - 70% pine bark, 30% vermiculite grade 3

Factor 2 - Mulch or none
1. - no mulch
2. - light, vermiculite grade 3 mulch

In greenhouse budget float seedbeds, all seedlings were produced in 128 cell "speedling" trays containing the medium mixture indicated above with the river sand washed and sieved to between 0.5 and 2.0 mm particle size, and using grade 3 vermiculite. Nine trays of each of the 2 medium mixes indicated above were prepared and filled using the new hopper. All trays (except two) were dibbled with the dibble board and K RK6 (blue) pelleted seed was added to 16 trays. Raw seed, also K RK6, was added to the other 2 undibbled trays using ash and shaker. A vermiculite mulch was applied to half the trays as indicated above. The 18 trays were floated in a budget float bed in the greenhouse. Over the next 4 weeks, growth was monitored carefully to determine germination rate and stand count.

Results and Discussion

The ambient and float water temperature and ambient relative humidity are shown in Table 44, and these environmental factors are discussed with the next experiment (99 PH14S). There were some spiral roots in the two no-mulch treatments and none in those with a cover mulch (Table 37), and this observation was consistent with the next experiment (99 PH14S). This data was not analysed because most of the plots had no spiral roots. The uncovered (no mulch) treatments germinated faster than those covered with a vermiculite mulch (Table 38), but 28 days after sowing there was no significant difference in germination between treatments (Table 39). Media fall-outs were negligible with a mean of 0.6% for the experiment and the data is not presented.

Table 37. Percent spiral roots 28 days after sowing

Media	Mulch		
	None	**Mulch**	**Mean**
50% pine bark, 40% sand, 10% vermiculite	0.8	0.0	0.4
70% pine bark, 30% vermiculite	2.0	0.0	1.0
Mean	1.4	0.0	0.7

Table 38. Percent germination 14 days after sowing

Media	Mulch		
	None	**Mulch**	**Mean**
50% pine bark, 40% sand, 10% vermiculite	56.1	42.6	49.3
70% pine bark, 30% vermiculite	62.9	50.8	56.8
Mean	59.5	46.7	53.1

t (p=0.05, df = 12) 2.179

CV% 20.7

SED: Media 5.50

Mulch 5.50*

Media x Mulch 7.77

Table 39. Percent germination 28 days after sowing

Media	Mulch		
	None	**Mulch**	**Mean**
50% pine bark, 40% sand, 10% vermiculite	74.4	69.1	71.8
70% pine bark, 30% vermiculite	79.1	71.9	75.5
Mean	76.8	70.5	73.6

t (p=0.05, df = 12) 2.179

CV% 14.1

SED: Media 5.20

Mulch 5.20

Media x Mulch 7.35

Dibbling and seed covering (mulching) in soilless media for float seedling production (99 PH14S)

To evaluate various treatments and procedures in float "speedling" trays to obtain optimum rate and uniformity of germination using pelleted seed and a substrate mix of 50% pine bark, 40% river sand and 10% grade 3 vermiculite.

Materials and Methods

Design: Four randomized complete blocks with 4 treatments (2 x 2)

Treatments:
Factor 1 - Dibbling or none
1. no dibble (only slight indentation)
2. standard depth dibble using dibble board
Factor 2 - Mulch covering or none
1. no mulch
2. light, finely sieved pine bark mulch

In greenhouse float seedbeds, all seedlings produced in 128 cell "speedling" trays containing medium mixture indicated above with the river sand washed and sieved to between 0.5 and 2.0 mm particle size. 16 trays were prepared by filling with the medium mix using the media charging hopper. A single pelleted (Germains Filcoat) K RK6 seed was sown into each cell.

Results and Discussion

These off-season trials had to be done in greenhouses because the seasonal rainfall would disrupt any work carried out in the open. It was, however, a good opportunity to establish whether increased ambient and float water temperature, and increased ambient humidity, as found in the greenhouse, had any beneficial effects on rate and uniformity of germination. In contrast to the germination counts in Experiment 99 PH02S conducted during the official seedbed season (Winter 1998) where the float bed mean was 55% at transplanting time (98 days after sowing), the mean in this experiment was 36% after 8 days (Table 40) and 81% after 21 days (Table 41).

Media fall-outs from the different treatments were rare and inconsistent and the mean number for the experiment was 1.5%, therefore the data is not presented.

Some spiral roots also occurred and at 14 days after sowing (d.a.s.) reached a level of 3.4% with the two no mulch treatments being marginally higher than the two mulch treatments (Table 42). This was curiously reduced at 21 d.a.s. to an overall mean of 1.51% with the no dibble and no mulch treatment being producing significantly more spiral roots (Table 43). Therefore, it appeared that covering the seed with a mulch decreased the number of spiral roots, while dibbling had no effect in this greenhouse experiment.

Table 40. Percent germination 8 days after sowing

	Mulch		
Dibble	**None**	**Mulch**	**Mean**
None	34.8	42.2	38.5
Dibble	38.1	30.7	34.4
Mean	36.4	36.4	36.4

$t_{(p=0.05,\ df=12)}$ 2.179

CV%		17.7
SED:	Dibble	3.21
	Mulch	3.21
	Dibble x Mulch	4.55*

Table 41. Percent germination 21 days after sowing

Dibble	Mulch		
	None	Mulch	Mean
None	77.9	82.2	80.1
Dibble	84.8	78.3	81.5
Mean	81.3	80.3	80.8

t (p=0.05, df = 12) 2.179

CV%		14.4
SED:	Dibble	5.73
	Mulch	5.73
	Dibble x Mulch	8.10

Table 42. Percent spiral roots 14 days after sowing

Dibble	Mulch					
	%			Arcsine %		
	None	Mulch	Mean	None	Mulch	Mean
None	8.4	0	4.2	0.28	0	0.14
Dibble	4.9	0.2	2.5	0.21	0.02	0.12
Mean	6.6	0.1	3.4	0.25	0.01	0.13

t (p=0.05, df = 12) 2.179

CV%		52.6
SED (for arcsine %):	Dibble	0.034
	Mulch	0.034*
	Dibble x Mulch	0.048

Table 43. Percent spiral roots 21 days after sowing

Dibble	Mulch					
	(%)			Arcsine %		
	None	Mulch	Mean	None	Mulch	Mean
None	5.3	0.2	2.7	0.23	0.02	0.13
Dibble	0.4	0	0.3	0.04	0.02	0.03
Mean	2.8	0.2	1.5	0.14	0.02	0.08

t (p=0.05, df = 12) 2.179

CV%		58.3
SED (for arcsine %):	Dibble	0.021*
	Mulch	0.021*
	Dibble x Mulch	0.030*

Table 44. Variations in seedbed environments

Means	Ambient Temperatures °C			Ambient Relative Humidities			Float water Temperatures °C		
	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min
Expt 99 PH02S outdoor	25.5	16.2	7.5	81.4	51.2	22.9	22.1	20.3	18.5
Expt 99 PH14S greenhouse	34.1	24.7	18.2	77.9	58.5	31.1	27.6	25.3	23.4
Expt 99 PH15S greenhouse	31.4	24.1	17.2	57.9	39.5	21.4	25.0	23.3	22.0

Dibbling had no significant effect on the number of media fall-outs and there appeared to be no benefit from covering the seed. The ambient and float water temperatures were higher in the greenhouse experiments than those conducted outdoors and this probably contributed to the greater germination measured in the greenhouse (Table 44).

Maize stover as soilless media in float seedling production (99 PH01S)

This experiment evaluated maize stover, a plentiful, locally available medium, in the float system compared with pine bark.

Materials and Methods

Design: Fully randomized 6 replications of 7 treatments, one tray per plot (total 42 x 128 cell trays)

Treatments:
1. composted pine bark : sand (50 : 50)
2. composted & shredded maize stover alone
3. composted & shredded maize stover/sand (75 : 25)
4. composted & shredded maize stover/sand (50 : 50)
5. composted & shredded maize stover/sand (25: 75)
6. composted & shredded maize stover/pine bark (50 : 50)
7. composted & shredded maize stover/vermiculite (50 : 50)

The experiment was sown with pelleted seed and floated on 2 July, 1998.

Results and Discussion

The pH of the maize stover was 6.5 and no lime was added. Some *Rhizoctonia* spp. was found in the maize stover, however, there was no *Pythium* or *Phytophthora* spp. This medium was heavily colonised by Gram+ bacteria, none of which fitted the descriptions of plant pathogenic bacteria, most of which are Gram-.

Production of seedlings from the 7 alternative media combinations seemed to start well with the first signs of germination being at 13 days after sowing (d.a.s.), but it soon became apparent that seedlings were not growing well in the maize stover medium treatments. The only treatment doing well was the standard, treatment 1, consisting of 50% composted pine bark:50% river sand (Table 45).

The first germination count was done 30 d.a.s. and although the standard treatment had about 10% better germination at this stage, there were still indications that with more time other treatments might improve. The germination ranged between 55% (Tmt. 1) and 24% (Tmt. 6).

The seedlings were pale green to yellow in colour, which is typical of nitrogen or sulphur deficiency. A chemical analysis of the float water did not indicate any significant nutrient deficiencies, so we attempted to stimulate growth by adding a top-dressing drench of calcium nitrate (2.5 g/m^2) in solution at 33 d.a.s. However, growth was still poor and there was very little evidence of further (late) germination, except in the standard treatment and a small increase in treatment 6 at 67 d.a.s. From 30 d.a.s. onwards, most of the seedlings in treatments 2 - 7 remained very small and yellow and started to die back.

The stand count at 92 d.a.s. indicated that in all treatments, except 1, there was a decrease in the stand count as seedlings began to die (Table 45). Figure 1 clearly shows that the stand count decreased with increasing maize content. As no further meaningful measurements could be obtained, the experiment was terminated at 92 d.a.s. At this stage length and diameter of stem measurements could only be obtained from Treatment 1 as all other treatments were unacceptable and did not produce pullable seedlings for transplanting.

Table 45. Percent germination or stand count of tobacco seedlings

Treatment	% (days after sowing)		
	30	67	92
composted pine bark/sand (50:50)	55	75	85
composted & shredded maize stover alone	24	7	3
composted & shredded maize stover/sand (75:25)	33	11	4
composted & shredded maize stover/sand (50:50)	42	17	9
composted & shredded maize stover/sand (25:75)	44	38	39
composted & shredded maize stover/pine bark (50:50)	36	38	35
composted & shredded maize stover/vermiculite (50:50)	45	15	8

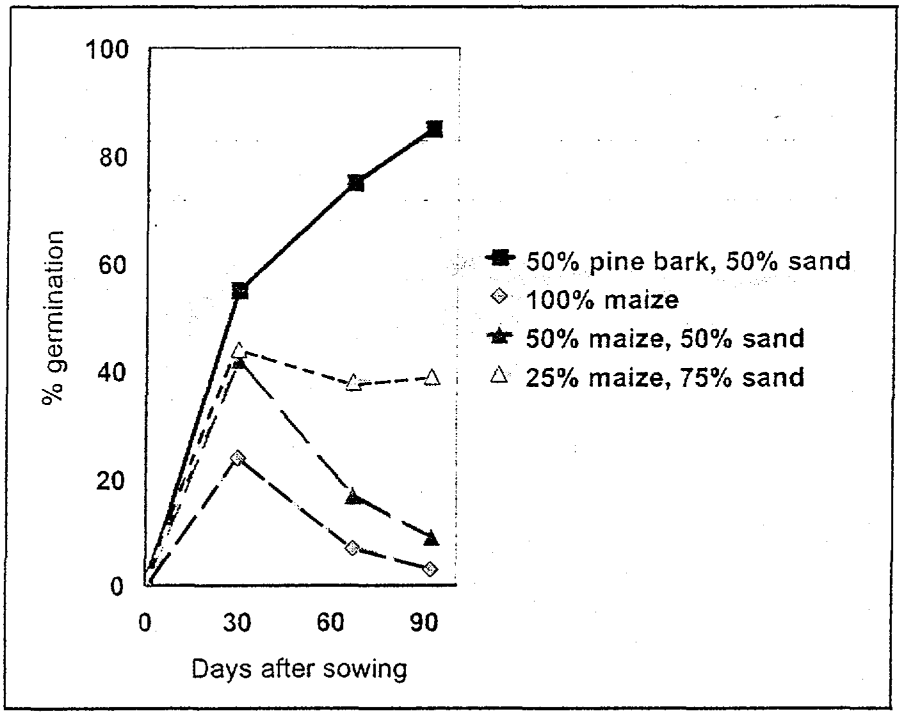


Figure 1. Percent germination of tobacco seedlings grown in maize stover

It was clear that the more maize stover used in the mix, the worse the growth. The standard, of composted pine bark : sand (50:50), grew well and produced transplantable seedlings. It was thought that the problem with the maize stover was related to insufficient composting, as the medium was heavily colonised by Gram+ bacteria, and they were probably utilizing (immobilizing) the nitrogen from the float water. The carbon:nitrogen ratio of the composted maize stover is still to be determined, and this would give an indication of the degree of composting.

Further work on this is needed as maize stover is the most plentiful and easily available potential medium in the country and, if it could be used successfully, it would greatly simplify any necessary shift to soilless production of tobacco seedlings in Zimbabwe.

Evaluation of new growing media for float seedbeds - groundnut and maize (00 PH15S)

To evaluate the effect of groundnut, pine bark and river sand combinations on germination and subsequent growth of tobacco seedlings in the float system. Two 10% maize stover treatments were included as *Trichoderma* does not grow very well on pine park and the maize stover could be used to improve the colonisation of the media.

Materials and Methods

Design: Four randomized complete blocks of 8 treatments.

Treatments: The following media combinations (by volume) were evaluated.

Tmt	Pine bark	River sand	Gde 3 Vermic.	Maize Stover	G/nut shells
1	50%	40%	10%	nil	nil
2	50%	50%	nil	nil	nil
3	50%	40%	nil	10%	nil
4	40%	50%	nil	10%	nil
5	50%	40%	nil	nil	10%
6	40%	50%	nil	nil	10%
7	nil	50%	nil	nil	50%
8	nil	nil	nil	nil	100%

Various combinations of pine bark, river sand, vermiculite, maize stover and shredded groundnut shells (by volume) were evaluated. The media mixes were prepared as above, with river sand sieved to between 0.5 and 2.0 mm particle size, and using vermiculite grade 3. The 128 cell trays were filled with the above moistened media combinations using the hopper and dibble board. With the medium in the trays well moistened, all 32 trays were sown with Rickards pelleted K RK6 non-primed seed (yellow 2). All trays were then wrapped with black plastic and left in the greenhouse for 5 days. Spiral roots and germination were measured every 7 days for a month and seedling leaf diameter at 28 days after sowing.

Results and Discussion:
The treatment with 100% groundnuts shells was excluded from the ANOVA for number of spiral roots and percent germination because it had too many dry cells and, therefore, missing seedlings. Shredded groundnut shells have a poor capillary action and are too light to be used on their own in the float system.

Our results indicated that groundnut shells at up to 50% (by volume) may be a very good substitute for pine bark. The 50% sand, 50% groundnut treatment had significantly fewer spiral roots ($p<0.05$) than the other treatments 7 days after sowing, possibly because these trays were floating about 10 mm higher than the others. There was no difference in the number of spiral roots 28 days after sowing (Table 46). The germination in the 100% groundnut was poor because of the number of dry cells, however, germination and seedling diameter in the other groundnut treatments were similar to the standard pine bark, sand and vermiculite media (Table 47). This experiment showed that 10% maize stover by volume resulted in good germination but very poor growth thereafter with the seedling diameter being significantly smaller than the other non-maize treatments ($p<0.01$) (Table 47). This result is similar to a previous experiment (99 PH01S), therefore confirming that maize stover is not a suitable medium for the float system.

The germination and seedling diameter of the media combinations with groundnut were not significantly different from the standard media, except for the 100% groundnut treatment. Groundnut is locally available and therefore has great potential as a second "organic" media with pine bark.

Table 46. Percent spiral roots

Treatment	Days after sowing	
	14	28
50% pine bark, 40% sand, 10% vermiculite	34.4	12.3
50% pine bark, 50% sand	31.8	10.0
50% pine bark, 40% sand, 10% maize stover	34.9	22.3
40% pine bark, 50% sand, 10% maize stover	31.1	13.7
50% pine bark, 40% sand, 10% groundnut	36.7	16.8
40% pine bark, 50% sand, 10% groundnut	31.4	7.4
50% sand 50% groundnut	17.9	11.7
100% groundnut†	0.4†	0.0†
Mean	31.2	13.5
SED t (p=0.05, df = 18) 2.101	4.31*	4.53
CV%	19.6	47.5

† The 100% groundnut treatment is excluded from the ANOVA (excluded from Mean, SED and CV%) because of too many zeros

Table 47. Percent germination and seedling diameter

Treatment	Germination (%)		Seedling Diameter (mm)
	Days after sowing		
	7	28	28
50% pine bark, 40% sand, 10% vermiculite	65.0	94.9	20.6
50% pine bark, 50% sand	80.3	94.7	24.6
50% pine bark, 40% sand, 10% maize stover	64.4	91.6	8.6
40% pine bark, 50% sand, 10% maize stover	60.4	96.5	13.3
50% pine bark, 40% sand, 10% groundnut	84.0	95.7	18.9
40% pine bark, 50% sand, 10% groundnut	68.0	93.6	24.8
50% sand 50% groundnut	82.4	96.5	25.7
100% groundnut	1.0†	15.2†	18.9
Mean	72.1	94.8	19.4
SED (germination t(p=0.05, df = 18) 2.101) (diameter t(p=0.05, df = 21)2.080)	8.81	2.18	4.38*
CV%	17.3	3.3	31.9

† The 100% groundnut treatment is excluded from the ANOVA (excluded from Mean, SED and CV%) because of too many zeros

Evaluation of new growing media for float seedbeds - bagasse (00 PH14S)

To evaluate the effect of bagasse, pine bark and river sand combinations on germination and subsequent growth of tobacco seedlings in the float system.

Materials and Methods

Design: Four randomized complete blocks of 4 treatments.

Treatments: The following media combinations (by volume) were evaluated as a greenhouse experiment to test the media combination outlined below.

	Pine bark	River sand	Gde 3 Vermic.	Shredded Bagasse
0	50%	40%	10%	nil
1	50%	40%	nil	10%
2	50%	nil	nil	50%
3	nil	nil	nil	100%

Results and Discussion:

No fall-outs at 7 days after sowing were evident, but the 100% bagasse treatment had 17% dry cells. This medium is very coarse and these trays were floating higher than the others, thereby preventing sufficient capillary movement of the water. There were virtually no dry cells in the other treatments. This treatment was excluded from the analysis because there were so many dry cells. Again there was a great number of spiral roots as shown in Table 48 below. There were fewer spiral roots in the 50% pine bark, 40% sand, 10% bagasse treatment compared with the others at 14 days after sowing ($p<0.05$), although the CV% was very high and the data should be viewed with caution (Table 48)

Table 48. Percent spiral roots

Treatment	Days after sowing	
	14	28
50% pine bark, 40% sand, 10% vermiculite	20.9	11.9
50% pine bark, 40% sand, 10% bagasse	7.8	6.8
50% pine bark, 50% bagasse	25.0	12.7
100% bagasse†	1.6†	0.7†
Mean	17.9	10.5
SED t (p=0.05, df = 6) 2.447	5.49*	4.61
CV%	43.4	62.2

† The 100% bagasse treatment is excluded from the ANOVA (excluded from Mean, SED and CV%) because of too many zeros

Table 49. Percent germination and seedling diameter

Treatment	Germination (%)		Seedling Diameter (mm)
	Days after sowing		
	14	28	28
50% pine bark, 40% sand, 10% vermiculite	84.1	90.0	50.3
50% pine bark, 40% sand, 10% bagasse	89.6	93.5	50.3
50% pine bark, 50% bagasse	87.7	93.1	25.0
100% bagasse†	18.7†	39.6†	1.7†
Mean	87.1	92.2	41.9
SED t (p=0.05, df = 6) 2.447	4.76	3.27	5.13*
CV%	7.7	5.0	17.3

† The 100% bagasse treatment is excluded from the ANOVA (excluded from Mean, SED and CV%) because of too many zeros and a lack of normality

The 100% bagasse treatment was obviously unsatisfactory. The germination of seedlings was similar with the other 3 treatments, however, seedling diameter (growth) decreased when more than 10% bagasse was added ($p<0.01$) (Table 49). The 50% pine bark, 40% sand, 10% bagasse treatment was similar to the standard media (50% pine bark, 40% sand, 10% vermiculite) and this proportion of bagasse could be used in the float media.

DISCUSSION

The comparison of germination in the greenhouse and outdoors shows the importance of higher temperature in achieving good germination in the float system. Although dibbling showed no effect on germination or fall-outs, the practice will be continued as work elsewhere (Flue-Cured Tobacco Information, 1999) has shown that it is beneficial. These trials also demonstrated that covering the seed in the float system was not necessary and this will be discontinued.

Pine bark is a good medium and will be adopted as the prime organic medium for use in floating trays. Sand is also an important constituent of the mix but it cannot form more than 50% of the mix as fallouts tend to occur. Best media combinations determined so far are 50:50 (pine bark:sand) and 50:40:10 (pine bark:sand:grade 3 vermiculite). Both of these are used as our "standard" media.

Despite its ready availability, especially in the small grower areas, maize stover or any extract of maize has no potential as a medium as the growth of seedlings is decreased. Bagasse could be incorporated up to a level of 10% but, because of its inaccessibility and transport problems, plus the fact that it would have to be sold at a burning fuel equivalent price, it is unlikely to be used.

Groundnut shells are more readily available so prices and supplies should make this a worthwhile medium. It has only recently been tested but it is showing great promise and may well be a substitute for composted pine bark, although will probably not be as readily.

There were fewer spiral roots on seedlings in outdoor floatbeds compared with inside the greenhouse. In the greenhouse, seedlings grown in lighter media, such as bagasse or groundnut, appeared to have fewer spiral roots initially, possibly because the trays float higher and have better aeration; this does not appear to be the case outdoors.

2.3. THE ROLE OF THE BIOCONTROL AGENT, *TRICHODERMA HARZIANUM* (AGRICURA T77) IN THE PRODUCTION OF HEALTHY TOBACCO SEEDLINGS IN A FLOATBED SYSTEM.

INTRODUCTION

A local strain of *Trichoderma harzianum* isolated by research staff at Kutsaga Research Station, has been extensively tested against soil-borne pathogens, especially *Thanatephorus cucumeris* against which it is particularly effective. It is produced commercially under the name Agricura T77. New blends of organic substrate for production of the commercial product are presently being evaluated. In the interim we have used both the pure fungus and two new formulations in our trials.

In a series of experiments in which the fungus, *Trichoderma harzianum* was incorporated either as pure, dried fungus or grown on a blended organic base, into various combinations of soilless media, the effect of *Trichoderma* on seedling growth, root colonisation and pathogen control was monitored.

RESULTS

Five experiments were done to investigate the use of *Trichoderma* in the float system.

Effect of *Trichoderma harzianum* on pathogens in a 50:50 medium of maize stover:sand for growing tobacco seedlings in a floatbed system (99 PP20S)

Materials and Methods.

Treatments were:

Trichoderma

Site 1	none
Site 2	added at a rate of 2.5g cfu/tray

Pathogen

1 *Thanatephorus cucumeris (AG3)* cause of sore shin

2 none

arranged in 4 randomized blocks of 2 treatments in each site.

Trichoderma harzianum spores and mycelium (colony forming units, cfu) produced in Czapeks liquid medium, was dried and crushed and incorporated into the soilless medium (maize stover:sand 50:50) at the above rate. Dried, crushed *Thanatephorus cucumeris* mycelium produced in Czapeks liquid medium was also incorporated into the media of appropriate treatments (7.5g cfu/tray)

Trays (128-cell expanded polystyrene) were filled with the appropriate mixture and sown with pelleted seed (cv. K M10). The trays were placed in outdoor float beds, and covered with polypropylene cloth to retain heat because night air temperatures were below 10 ^{0}C. Fertilization was done according to a schedule similar to that in Appendix Table A1.1.

Germination counts were done 4 weeks after sowing (w.a.s) and seedling diameter was measured 6 w.a.s. Seedlings from *Thanatephorus cucumeris*-treated medium were pulled up 11 w.a.s and assessed for root damage by plating roots onto *Rhizoctonia* selective medium (SMR) and observing fungal growth after 24h. Root colonisation by *Trichoderma* was assessed after 6 days on the above medium.

Samples of float bed water were taken from both *Trichoderma* and non-*Trichoderma* sites and plated onto SMR. Water from the *Trichoderma* site was pipetted onto PDA amended with chloramphenicol and streptomycin to check for viable *Trichoderma* cfu in the water.

Results and discussion

There was no difference in germination between seedlings growing in *Thanatephorus* (pathogen-infected medium) and no-*Thanatephorus* (uninoculated medium). Germination at the two sites was different so the comparison between the *Trichoderma/Thanatephorus* and *Trichoderma*-only treatments was achieved by using the diameter of the uninoculated seedlings in each site as a standard. Based on this, 6 w.a.s, the diameter of infected seedlings was 18.72 % of the uninoculated in the no-*Trichoderma* site and 87.1% of the uninoculated in the *Trichoderma* site. *Thanatephorus* was only detected in two roots 11 w.a.s because most of the infected plants had died. The fungus had not apparently moved into or possibly survived in the water because no *Thanatephorus* was detected in float water.

Seventy-six percent of roots of seedlings from the *Trichoderma*-only treated medium were colonised by the fungus compared with none from the no-*Trichoderma* no-*Thanatephorus* medium. However, if the no-*Trichoderma* medium was inoculated with *Thanatephorus, Trichoderma* was isolated from 41% of roots, indicating a positive attraction for *Thanatephorus* from, presumably, airborne *Trichoderma*.

Table 50. Diameter of *Thanatephorus*-inoculated and uninoculated seedlings in the presence or absence of *Trichoderma*

Trichoderma	***Thanate-phorus***	**Mean diameter (mm)**	**inoculated / uninoculated (%)**	**Fungus in float water (16 samples)**	***Trichoderma* on roots (%)**
No	No	24	17.82	*Thanatephorus* 0	0
No	Yes	4.3		1	41
Sed (3df)		1.05 (P<0.05)			
Yes	No	4.42	87.1	*Trichoderma* 16	not done
Yes	Yes	3.85		16	76
t-test		P<0.002*			

* *Trichoderma* vs. No *Trichoderma* in presence of pathogen

Role of *Trichoderma harzianum* (T77) in producing healthy tobacco seedlings in soilless media (99 PP21S)

Materials and Methods

Treatments:
Trichoderma:
Site 1 none
Site 2 added at 0.5g cfu/kg to sand or 2.2 mg cfu/g to maize stover
Medium:
1 maize stover
2 maize stover + sand 50:50

Both media at each site, replicated 4 times (8 plots/site).

Soilless media were inoculated with *Trichoderma harzianum* as previously described (99 PP20S). Trays (128 cell) were filled and sown with pelleted seed (cv. K M10). The trays were placed in float beds and covered with polyester covers. Germination counts were done 4 w.a.s. and seedling diameter was measured 8 w.a.s. Seedlings were pulled up 12 w.a.s, the roots were surface sterilised in sodium hypochlorite (1%) for I minute, rinsed in sterile distilled water and plated onto PDA amended with chloramphenicol and streptomycin to check for *Trichoderma* colonisation. Water samples were collected from the float beds at both sites and plated onto PDA amended as above to check for *Trichoderma.*

Results and discussion

Germination varied between 56% in the maize stover to 98% in the 50:50 mixture. Site differences made it impossible to compare the *Trichoderma* with no-*Trichoderma* treatments. Overall germination in Site 2 (edge) was 86% and in Site 1 (inner) 68%. Seedling diameter at 8 weeks after sowing was greater in Site 2 than Site 1. This could not be attributed to *Trichoderma* because in a related experiment, the inner site, which in this case was plus *Trichoderma*, also had a poorer germination than the edge site.

The float water in which *Trichoderma*-treated medium had been floating was almost entirely colonised by *Trichoderma* (97% of the water samples contained *Trichoderma* as the most prolific component) compared to 6% of the water in which untreated media had been floating. *Trichoderma* obviously survives well in water and the possibility of a water treatment of *Trichoderma* should be considered to protect plants against water-borne pathogens. The source of the *Trichoderma* in the non treated float bed is not known, but 28% of the roots in this bed were colonised although very little *Trichoderma* was present in the water.

Table 51. Germination, diameter and colonisation of seedlings grown in two media in the absence or presence of *Trichoderma*

Treatment	Germination (%)	Mean diam. of seedlings (mm)	*Trichoderma* on roots (%)	*Trichoderma* in float water (%)*
No *Trichoderma* Maize stover	37	0	-	6.25
No *Trichoderma* 50:50 maize:sand	69	2.7	28	
Sed (3df)		0.2		
Trichoderma Maize stover	50	3.2	-	96.88
Trichoderma 50:50 maize:sand	84	9.9	98.6	
t-test		P<0.035#	P<0.05	P<0.001

* % of water samples containing *Trichoderma* Total: 32.

\# maize v maize-sand medium

Effect of *Trichoderma harzianum*, T77, on germination, root colonisation and pathogens in a soilless medium used to produce tobacco seedlings in a floatbed system (00 PP13S & 00 PP12S)

Materials and Methods.

Treatments:

Trichoderma (Main plot) (common to both experiments)

1 none

2 added at a rate of 2.5g cfu/tray

In 00 PP13S only:

Pathogen (sub-plot)

1 None

2 *Thanatephorus cucumeris*(AG3)=sore shin

Design: 4 randomized blocks of 2 main plots each, (main plot:6 trays of 128 plants each) 2 subplots (subplot :1 tray x 128 plants) per main plot, replicated 3 times within a main plot. In 00 PP12S, the six subplots were replicates of one treatment

Two weeks prior to sowing, the outdoor float beds were filled with water and covered with black polythene to increase the water temperature.

A mixture of dried, crushed *Trichoderma* mycelium and spores were incorporated into pine bark/sand/vermiculite 50:40:10 mixture for relevant trays on the day of filling.

In 00 PP13S, dried, crushed *Thanatephorus cucumeris* mycelium was incorporated into the medium of relevant treatments (7.5g cfu/tray). In both experiments, the trays were filled with

the appropriate mixture and sown with pelleted seed (cv. K RK6 Germains 00 PP13S and K M10 Rickards 00 PP12S). The floatbeds were covered by plastic tents to retain heat. Germination counts were done 17 d.a.s. (Table 52) and seedling diameter measured 5 w. a. s. in 00 PP12S. Root colonisation by *Trichoderma* was measured at 5 and 8 weeks (00 PP13S) and at 5,10,15 and 20 weeks (00 PP12S) respectively. Roots of seedlings (28/tray) from treated plots, were surface sterilised with 1% sodium hypochlorite for 1 minute, plated onto amended PDA and assessed for *Trichoderma* growth after 6d.
In 00 PP13S *Thanatephorus* treatments: 28 seedlings/tray were pulled up 8 weeks after germination and assessed for root damage visually and/or by plating onto PDA amended with chloramphenicol and streptomycin.

Results and discussion

The two experiments ran from July to December with an overlap of two weeks from mid-to late August. Water temperature during the overlap period was very similar in the float beds monitored (Figures 3,4 and 5). Water temperature fluctuated with external conditions throughout the experiments, unlike water temperatures in greenhouses where once the polystyrene trays were placed in the water, the insulating effect kept water temperatures constant (Fortnum, et al, 2000). In the earlier experiment (00 PP13S) which ended late August, water temperature varied between a minimum of 14^{0}C and a maximum of 24^{0}C, the second experiment (00 PP12S) was monitored until the beginning of January, 2000, and the range was 18-27 ^{0}C.

Germination of the pelleted tobacco seed in both experiments (Tables 52 and 53) was good.

Table 52. Germination of seedlings (cv. K RK6 Germains) 17 days after sowing (00 PP13S)

	Trichoderma		
Th. cucumeris	None	Added (2.5 g/tray)	Mean (SED 1.387,df 38)
None	93.68	90.76	92.22
Added(7.5g/tray)	96.09	95.96	96.03
Mean (SED 2.960,df 3)	94.89	93.36	94.12

Table 53. Germination of pelleted seed (cv. KM 10) 17 d.a.s. in "speedling" trays filled with pine bark/soil/vermiculite mixture and floated on water (00 PP12S)

Trichoderma	Germination (%)
None	91.6
2.5 g/ tray added	90.8

Seedling diameter was measured 5 weeks after sowing (av. 40 mm) and did not differ whether the cells contained *Trichoderma harzianum* or not and dry mass of seedlings from *Trichoderma* or no-*Trichoderma* trays was similar (Table 54).
Trichoderma did not reduce the number of seedlings that died or the severity of damping off (*Thanatephorus cucumeris)* in inoculated cells (Table 55). The reason for the lack of response to *Trichoderma* was probably associated with the very low percentage of *Trichoderma* attached to roots (10 %) at the time of assessment (8 w.a.s.) in the pinebark/sand/vermiculite

mixture. In a related experiment (00 PP 12S) where initial root attachment was of a similar order, root attachment eventually rose to 53.1% 12 w.a.s (Figure 2). Last season in a maize stover/sand (50:50) medium, root attachment was 98.6% at a similar stage (99 PP 21S).

Table 54. Mean seedling diameter and dry mass of seedlings growing in medium inoculated with *Trichoderma harzianum* and/or *Thanatephorus cucumeris*, and root colonisation by *T.harzianum* (00 PP13S)

Treatment	Dry Mass (g)	Seedling diam (mm)	% roots with *Trichoderma*
Th. cucumeris			
None	0.92	40.3	7
Added	0.89	39.6	3.4
SED, 38df	0.04	0.58	
Trichoderma			
None	0.93	40.7	0
Added	0.88	39.2	10.4
SED, 3df	0.03	1.86	

Table 55. Effect of *Trichoderma* on damping off of seedlings by *Thanatephorus cucumeris*

Th. cucumeris	*Trichoderma* None	*Trichoderma* Added	Mean (SED 0.085, df 38)
	Damage scale 1-3		
None	1.13	1.17	1.15
Added	1.33	1.42	1.38
Mean (SED 0.050,df 3)	1.23	1.29	1.26
	% Dead Plants		
None	0	0.89	0.45
Added	12.5	19.35	15.92
Mean	6.25	10.12	8.18

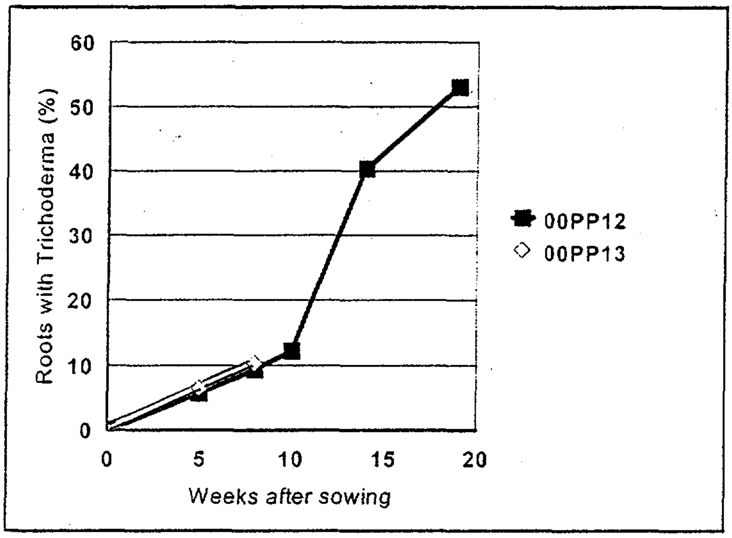


Figure 2. ***Trichoderma*** **attachment to roots of tobacco seedlings growing in a pine bark/sand/vermiculite mixture in floating trays**

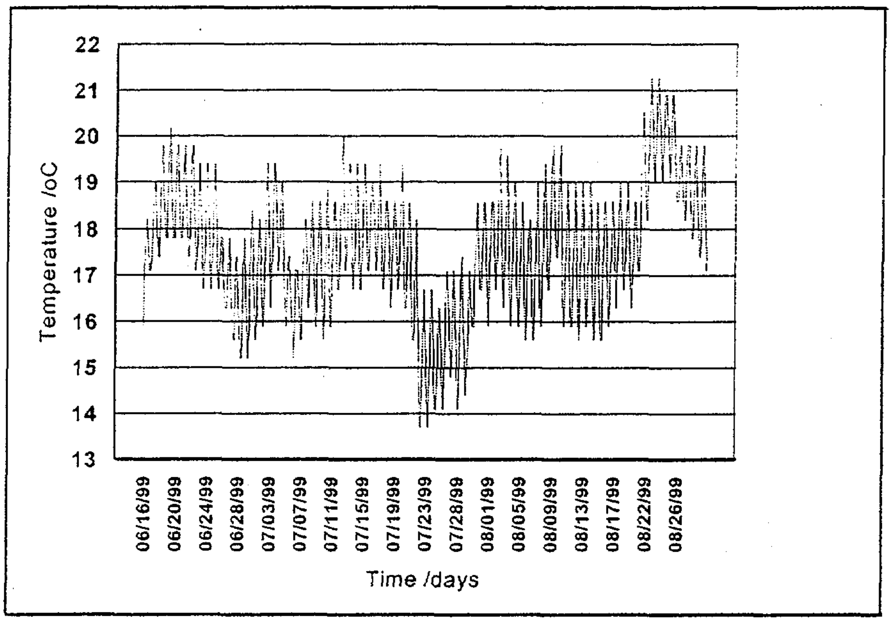
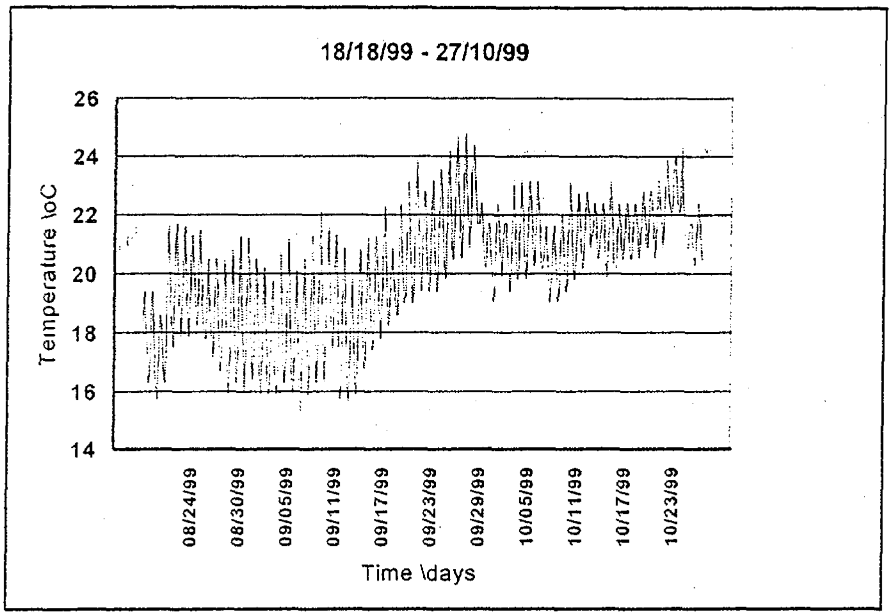
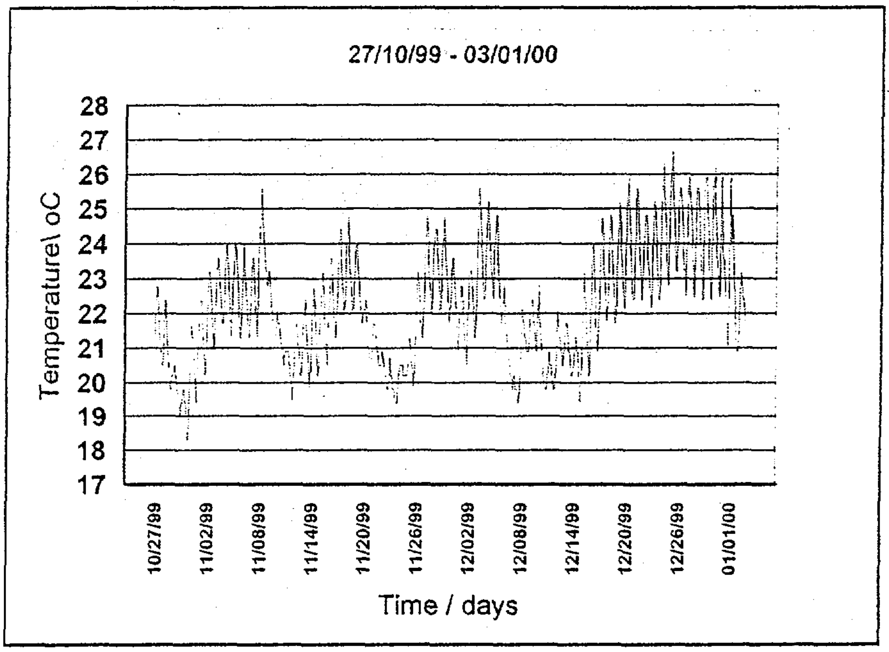


Figure 3. Water temperature fluctuations in outdoor floatbed covered with polystyrene trays





Figures 4 & 5. Water temperature fluctuations in outdoor floatbed covered with polystyrene trays containing seedlings (00 PP12S)

New blends of *Trichoderma harzianum* T77 in soilless medium (00 PP25G)

Agricura, the agrochemical company that produces a commercial biocontrol agent, *Trichoderma harzianum*, T77, are experimenting with new organic media for more efficient production of the fungus. We are testing the biological efficacy of two such blends. One is a mixture of maize residue (70%) and spent grain (30%) , the other is a 50:50 mixture of sawdust and spent grain with various additives on which the biocontrol fungus is cultured.
In this experiment we evaluated the efficacy of T77 produced on new blends of media in colonising tobacco roots in the floatbed system.

Materials and Methods.

Treatments:
Trichoderma medium (4.67 g/kg soilless medium)

1 70% maize residue meal: 30% spent grain
2 50% sawdust: 50% spent grain

arranged in 5 randomized complete blocks of 2 treatments each.

The formulations of *Trichoderma* T77 were added to a 50:40:10 pine bark:sand:vermiculite soilless medium at a rate of 4.7 g/kg of soilless medium and the mixtures were used to fill 128-cell expanded polystyrene trays. The trays were watered and sown with pelleted seed (cv. K RK 6), incubated in stacks under black polythene for 5 days in the greenhouse to promote seed germination, after which they were floated on water in the greenhouse.

Results and discussion

Germination was slower in trays treated with the maize/spent grain biocontrol mix (Table 56). Root colonisation by the biocontrol fungus, *Trichoderma harzianum*, was measured at 5, 9 and 13 weeks after sowing, the duration of the normal growing period for seedlings in trays before transplanting. There was a marked difference in the root colonisation of tobacco seedlings by *Trichoderma* T77 produced by the two methods (Table 57). T77 produced on the maize/spent grain formulation colonised roots more successfully with upwards of 75% of roots colonised 9 w.a.s. (Figure 6) As seedlings aged, colonisation decreased slightly in both treatments. In a related experiment incorporating the two blends into standard sandy soil, as used in conventional seedbeds, the pattern was similar, 71% of roots were colonised by the maize/spent grain formulation and 50% of those in soil treated with the sawdust/grain combination.

Table 56. Germination of tobacco seed in media treated with two blends of the biocontrol agent, T77

Treatment	Germination %(days after sowing)		
	14	21	28
Maize(70):Spent grain(30)	68.93	87.12	89.64
Sawdust(50):Spent grain(50)	85	93.22	93.57

Table 57. Root colonisation of tobacco seedlings by *Trichoderma harzianum*

Treatment	Root colonisation (%)		
	Weeks after sowing		
	5	9	13
Maize(70):Spent grain(30)	33.5	75	61
Sawdust(50):Spent grain(50)	14.5	28	22

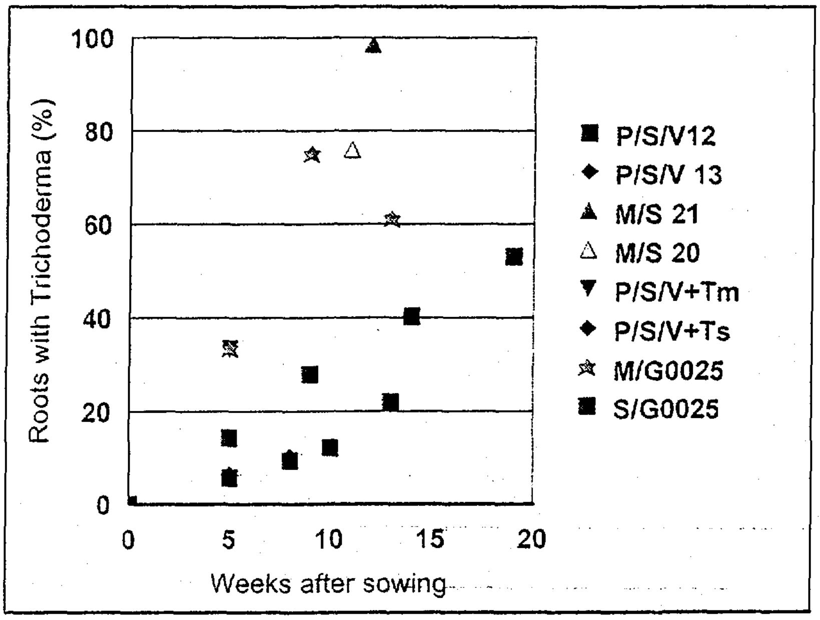


Figure 6. Root colonisation of seedlings by *Trichoderma* over time

DISCUSSION

Outdoor floatbed water temperatures which fluctuated between 14 and 27°C and diurnally by several degrees during seedling production (Figs. 3,4 and 5), did not appear to affect root colonisation of seedlings by *Trichoderma harzianum*.

In our experiments, both the media on which the *Trichoderma* was originally produced and the medium into which it was subsequently incorporated, affected the efficiency of root colonisation. The most successful root colonisations were either from *Trichoderma* produced in a medium containing maize residue as an organic base, or when *Trichoderma* was added without an organic base, if the soilless medium contained maize residue. The enhancement of *Trichoderma* root colonisation in the presence of maize residue is being studied on the T 77 production side, because maize residue as a component of soilless media is unsuitable for growing tobacco seedlings.

Because of the variability of seedling germination and growth in the outdoor experimental float beds, data on the efficacy of *Trichoderma* as a biocontrol agent was inconclusive. It had no adverse effect on seedling germination and growth, but because of the low root attachment in the experiment where dry mass was measured, there was no evidence that it enhanced seedling growth. Root attachment appeared to peak between 9 and 13 weeks after sowing (Figure 6) which corresponds with transplanting and is ideal for the protection of transplants against field pathogens.

2.4. STUDIES TO IMPROVE GERMINATION AND INITIAL GROWTH IN THE FLOAT SYSTEM

INTRODUCTION

In order to make the float system viable there should be more than 85% pullable seedlings. To date, germination in this system has been variable and many factors, such as type of media, source of pellets and air and water temperatures, have been proposed as possible sources of variation.

Some tobacco producing countries, such as Spain, have had problems with erratic germination using locally pelleted seed. The germination improved dramatically once they used a company recognised internationally for good quality pellets. Therefore, an experiment was done to investigate the effect of source of pelleting of locally produced seed on germination and seedling growth. The stand count of seedlings can be decreased due to dry cells and media falling out of the trays (fall-out). Different trays were compared in an experiment to identify those which were unsuitable.

Countries such as the USA produce the majority of their float seedlings in greenhouses. This could make the cost of replacing methyl bromide prohibitive in Zimbabwe and we have decided to try and grow our float seedlings under small plastic tents or with no tents under warmer conditions. The main problems in not using a greenhouse are very low temperatures and delayed germination. Considerable effort is being made to find ways of speeding up the germination process under these relatively cold conditions. A commercial producer of flower and vegetable seedlings suggested pre-germinating (incubating) the seed after sowing, but before floating the trays. This was done by watering and then stacking the "speedling" trays in the greenhouse immediately after sowing for a period of 5 days. The stack was covered with black plastic. If left too long (7 to 8 days), the germinating seed etiolated and then died when placed into the float bath; probably as a result of the rapid and excessive changes in light, humidity and temperature. However, considerable success was achieved when the trays were floated after 5 days, as the seed had only just begun to germinate and was not susceptible to the above mentioned changes in conditions. Stand counts exceeding 95% were recorded and this method is tested in two trials.

Disease in the float system is a potential hazard and tray sterilisation can be a major problem. Research is being done in the USA on the use of PVA paint mixed with copper to coat the trays in order to decrease disease incidence and extend the life of the trays. A preliminary experiment was done to test the phytotoxicity of various "homemade" copper/coloured paint mixes and a commercial product. Dark coloured paints such as black and red were used as it was noticed in the overhead watered system that seedlings in black trays grew faster than those in the white polystyrene trays.

RESULTS

Germination and emergence of various commercial pelleted seed (00 PH03S)

To evaluate the germination of seedlings from various commercially prepared Kutsaga K RK6 and K 35 pelleted seed.

Materials and Methods

Design: Six randomized complete blocks of 6 treatments - irrigated crop seedbeds.

Treatments: Pelleted seed

1. Germains, UK - K RK6 Filcoat (blue)
2. Germains, UK - K RK6 Oxymelt (yellow)
3. Rickards, USA - K RK6 primed (green)
4. Rickards, USA - K RK6 non-primed (yellow)
5. Incotec, Holland - K 35 primed (ex National Tested Seeds)
6. Germains, UK - K 35 Filcoat (pink)

In the irrigated permanent seedbeds (UNIDO Demonstration), we produced the treatments in 128 cell "speedling" trays and monitored all aspects of their germination and emergence. All speedlings were produced with pelleted seed in (new or pre-sterilized) seedling trays.

Media for all trays was 50% pine bark, 40% sieved river sand and 10% grade 3 vermiculite. The trays were limed at the standard rate of 2g lime/kg pine bark, and then floated on the water bed in the randomized layout. The tray surfaces were covered with a thin grass mulch and then with a plastic tunnel. We did not stack the trays before floating them as a way of improving the germination but rather floated them directly on the waterbeds in order to detect more easily differences in germination rates.

Results and Discussion

The number of fall-outs and spiral roots were negligible (average of 0.9 cells per tray) and the data is not shown. One should be cautious when making comparisons between the different seed companies as the cultivars are not the same and the Germains seed used in this trial was pelleted and received in May 1998 whereas the Rickards and Incotec seed was pelleted and received a year later. The arcsine transformation was used with the percent data because of a lack of normality and both the means and transformed data are presented. At 7 and 28 days after sowing the germination was 5.8 and 83.4%, respectively (Table 58). The two primed treatments, K 35 from Incotec and RK 6 from Rickards, germinated faster than the unprimed ($P<0.05$). There appeared to be little difference between the Germains Filcoat and Oxymelt seed coats.

The final evaluation of seedlings was done 12 weeks after sowing and included the total number of seedlings per tray and dry mass of roots and shoots (Table 59). The final stand count was 81% (104 per 128 cell tray), which is below the required level of 85% (109 per 128 cell tray). The primed RK 6 from Rickards had a significantly heavier root system ($P<0.05$) than the other treatments. The total seedling dry mass was also greater, but this was not significant. The reason for this larger root system is not clear.

Table 58. Percent germination at 7 and 28 days after sowing

Pelleted seed	%		Arcsine %	
	7	28	7	28
Germains - RK 6 Filcoat	3.4	80.1	0.18	1.12
Germains - RK 6 Oxymelt	3.9	84.1	0.19	1.18
Rickards - RK 6 primed	8.5	73.4	0.29	1.04
Rickards - RK 6 non-primed	3.1	91.4	0.16	1.28
Incotec - K 35 primed	13.7	83.5	0.36	1.17
Germains - K 35 Filcoat	2.0	88.0	0.12	1.23
Mean	5.8	83.4	0.22	1.17
SED t (p=0.05, df = 25) 2.060	-	-	0.041*	0.068*
CV%	-	-	33.0	10.1

Table 59. Number of seedling per tray (128 cell) and dry mass of roots and shoots 12 weeks after sowing

Pelleted seed	Number	Dry mass (g/plant)		
		Shoots	Roots	Total
Germains - RK 6 Filcoat	110	1.42	0.30	1.72
Germains - RK 6 Oxymelt	108	1.34	0.31	1.66
Rickards - RK 6 primed	98	1.68	0.43	2.11
Rickards - RK 6 non-primed	109	1.44	0.33	1.77
Incotec - K 35 primed	91	1.33	0.26	1.58
Germains - K 35 Filcoat	109	1.42	0.28	1.70
Mean	104	1.44	0.32	1.76
SED t (p=0.05, df = 25) 2.060	8.3	1.680	0.042*	0.176
CV%	13.8	17.0	22.7	17.3

There seem to be few differences between the various commercial pelleted seed. This experiment showed no evidence that one year old pelleted seed was less viable than the newly coated seed. However, more research is needed on this aspect as work in other countries, such as Australia, has demonstrated the problem of poor germination with pelleted seed that is kept from one season to the next.

The microbiological analysis of the float water sample showed that there were no bacterial pathogens in the water, and that the only bacteria present were small, gram negative cocci. There was a small amount of *Pythium* present, but when we tried to re-isolate this for purification, it was annihilated by *Trichoderma*, of which there was plenty. We may therefore have a natural biological check on *Pythium*, as *Trichoderma* appears to thrive in the warmer water.

Cell size in relation to the incidence of medium fall-out (00 PH11S)

To establish whether the size of tray cells and their base apertures have a bearing on the incidence of medium fall-outs (and dry cells) in float "speedling" trays. This may be largely due to the size of cell base openings which is dictated by tray size and the manufacturer's design.

Materials and Methods

Design: 4 randomized blocks of 4 treatments each.

Treatments: Cell number per tray and manufacturer's design. Three local and one imported tray designs as follows:

0 - 72 cell Rau tray (locally manufactured)
1 - 128 cell Rau tray (locally manufactured)
2 - 200 cell Rau tray (locally manufactured)
3 - 200 cell Hygrotech tray (manufactured in South Africa)

The standard medium mix of 50% pine bark, 40% washed, river sand sieved to between 0.5 and 2.0 mm particle size, 10% vermiculite grade 3 was used. Filling was kept as uniform as possible with one person doing the same task throughout and as the tests were only for fall-out and dry cell incidence no seed sowing was necessary. The trays were left for 1 week before counting number of fall-outs or dry cells.

Results and Discussion

At 10 days after sowing there was only 1 fall-out in the 200 cell Hygrotech tray, and 16 dry cells in the 72 cell Rau tray. All trays floated at about the same depth except the 72 cell trays. These are considerably deeper in design (100 mm rather than 60 mm) and have a greater styrofoam content. This higher float level probably contributed to the greater number of dry cells. No further measurements were taken as heavy rain affected the experiment. It is clear from this work that the 72 cell tray with the standard media (50% pine bark, 40% sand and 10% vermiculite) is not suitable for the float system. There appeared to be no problems with the other trays tested.

Pre-germination techniques in the float system (Observation)

In our continued efforts to try and improve germination in the float system various techniques were tested in the 1999 Kutsaga UNIDO Demonstration Float beds. Three simple alternative pre-germination (incubation) procedures were further tested in an attempt to identify the quickest and most reliable germination method:

1. Trays were placed directly into the float bed after sowing, dibbling and covering the surface with a light grass mulch. The beds were then covered with early seedbed plastic tents.
2. Trays were stacked one on top of the other as a solid cube measuring approximately 1.3 x 0.7 x 0.5 metres in a greenhouse with relatively high temperatures and humidities. One layer of unsown trays containing the moist media was placed on the top to act as an insulator. The "stack" was then wrapped in black plastic sheeting to maintain higher temperatures and humidity. The trays were then left in this condition for 5 days, until the first signs of seedling germination, and then placed in the float system and covered with the early seedbed plastic tents.
3. As for treatment 1 (sown and placed directly into the float system), except that the trays were covered with solid clear plastic sheet mulch (Polywrap placed directly onto the tray surface) until the first signs of germination. The plastic was then removed and the trays covered with the same early seedbed plastic tents as in 1. and 2. above.

The results from treatment 2 (stacking the trays before floating, to pre-germinate the seed) were very encouraging and this appears to be the best way so far devised to obtain good germination. However, the trays must not be left too long in the stack as the seedlings etiolate very quickly and then die when exposed to the sun in the float system. It appears that 5 days is the optimum stacking time, although this will vary with the conditions in which the trays are stored. The germination achieved using this method was significantly better than were the trays which were floated immediately (treatment 1). Treatment 3 did not work well as many of the seedlings were killed by excessive temperatures.

Pre-germination techniques in float seedbed trays (00 PH12S)

To investigate the effect of incubation (pre-germination) before floating the trays on the rate and uniformity of germination, and subsequent growth of pelleted seed.

Materials and Methods

Design: Five randomized complete blocks of 3 treatments.

Treatments: Pre-germination variations as follows:

0. none - float directly after sowing
1. cover with black plastic and stack in greenhouse for 5 days, then float
2. cover with white floating row cover (FRC) and stack in greenhouse for 5 days, then float

In the prepared fixed budget greenhouse and using the standard medium mix, we investigated the effect of pre-germination (incubation) techniques on the rate and uniformity of germination, and subsequent growth of pelleted seed. All trays were sown with Rickards pelleted K RK6 non-primed quality seed, and one spare medium-filled tray was placed over each of the two stacks, both completely wrapped, treatment 1 in black plastic and treatment 2 in white floating row cover. These were then both left in the greenhouse for 5 days while treatment 0 was floated immediately. Counts for fall-outs and dry cells were carried out 1 w.a.s., germination and spiral roots every 7 days for a month, and seedling leaf diameter at 4 w.a.s.

Results and Discussion

There were no dry cells or fall-outs but there was an unusually high level of spiral roots (Table 60). This has been the pattern with the greenhouse floating trials but not so apparent in the open air floats. It is also noteworthy that the number of spiral roots decreases over time as the seedlings begin to grow.

A very good germination rate was achieved with all three techniques and there was no significant difference in percent germination or seedling diameter (Table 61). Therefore pre-germinating the seed by stacking did not appear to be necessary in the greenhouse. However, observations done outdoors showed that pre-germination was of great benefit. This difference could be due to the higher temperature and humidity conditions inside the greenhouse compared with outdoors (Figure 7).

Table 60. Percent spiral roots

Treatment	Days after sowing			
	7	14	21	28
none	0	14.4	14.2	9.2
cover with black plastic	0	10.2	13.1	11.1
cover with FRC	0	17.8	18.1	11.7
Mean	0	14.1	15.1	10.7
SED $t_{(p=0.05,\ df=8)}$ 2.306	-	3.37	4.06	2.58
CV%	-	38	43	38

Table 61. Percent germination and seedling diameter 28 days after sowing

Treatment	Percent germination (Days after sowing)			Seedling Diameter (mm)
	7	14	28	
none	7.7	90	95.6	61.6
cover with black plastic	1.6	83.8	95.8	48.6
cover with FRC	0.0	95.2	93.2	58.9
Mean	3.1	89.6	94.0	56.4
SED $t_{(p=0.05,\ df=8)}$ 2.306	-	6.23	4.02	6.6
CV%	-	11	6.7	19

The temperature during the first 4 days after sowing was about 10 °C higher in the greenhouse compared with the outdoor beds (Figure 7). It should be noted that the days after sowing are not on the same calendar day, as the greenhouse experiments were done in January and the outdoor ones in June when it is colder. The drop in maximum temperature in the greenhouse during the 3rd and 4th day after sowing occurred as a result of rain. The differences in humidity were not as noticeable as temperature, although the green house appeared to have a greater minimum value compared with the outdoor beds. The float water temperature was measured from 15 days after sowing because the temperature probes were not ready in time, however, it is clear that the water temperature in the greenhouse was higher and more constant (about 23 to 24 °C) than that outdoors (15 to 19 °C) (Figure 8). The greenhouse temperature is similar to the optimum found in work elsewhere of 21 to 24 °C (Baxter *et. al.*, 1999; Flue-Cured Tobacco Information, 1999). The temperature outdoors appears to be below the optimum.

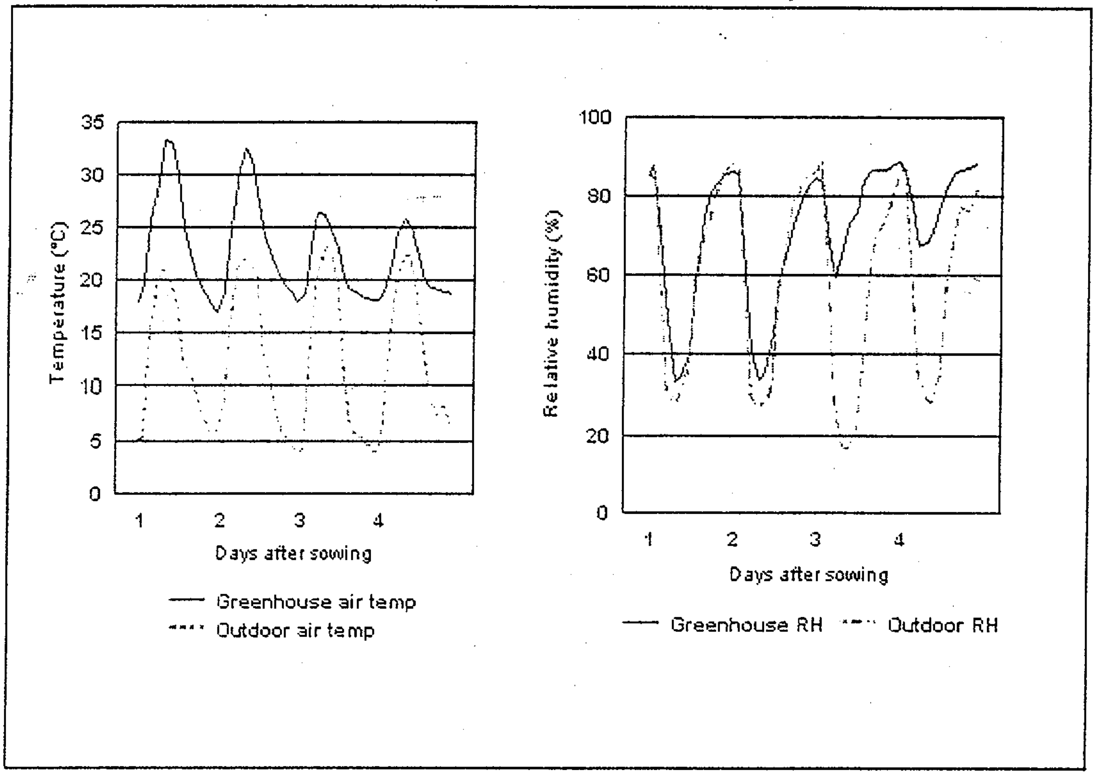


Figure 7. Air temperature and relative humidity for float seedbeds in the greenhouse and outdoors

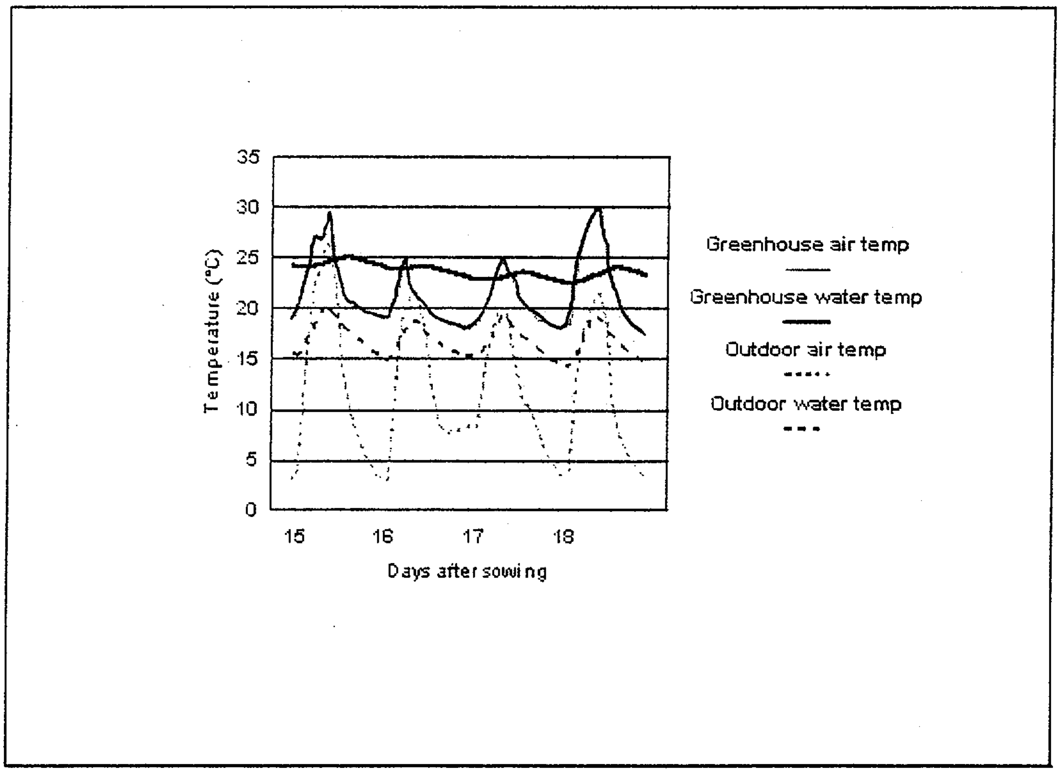


Figure 8. Float water and air temperature in the greenhouse and outdoors

Phytotoxicity of seed-tray paint or sanitizing dip in float seedling production (00 PH13S)

To compare seedlings grown in trays dipped in a commercial sanitizing fluid with those dipped in various home-made (custom) mixtures. Different colours of the PVA paint were tested in order to determine if the darker ones improved the rate of germination as a result of higher temperatures at the level of the seedling.

Materials and Methods

Design: Three randomized complete blocks of 5 treatments

Treatments: Sanitizing method - trays dipped in following mixtures and then used to grow seedlings:

0. - none
1. - custom white dip
2. - custom black dip
3. - custom red dip
4. - Styroseal® (Hygrotech) - commercial dip

The custom dips were made with the following ingredients: 1 litre PVA paint (white, red or black), 300g copper oxychloride (85% WP) or 425 ml copper oxychloride (60% fw), topped up to 15 litres with water - trays were submersed in this 16.3 litre mix. For the commercial preparation, 10 litres of water were added to the 5 litres of Styroseal® and 3 trays submersed in this 15 litre mix. The trays were then dried for 6 hours.

The experiment was done in the greenhouse using the standard medium mix and "speedling" trays in the float system. The upper surface of the trays was also painted with the PVA in order to darken the colour. The treated trays were pre-germinated in stacks for the standard 5-day incubation period. Growth was monitored for 4 weeks to determine germination rate and phytotoxicity.

Results and Discussion

About 27% of the trays had seedlings with spiral roots at 14 days after sowing. The percentage had decreased to 18% by 28 days after sowing, but this was still relatively high (Table 62). The commercial Styroseal® had fewer spiral roots than the other treatments, including the untreated control, although this was not significant. The reason for this is not apparent.

There were no ill-effects on germination from the various paints or sanitizing solutions. The mean germination for the experiment from 14 days after sowing onwards was 96%.
The Styroseal® and custom white dip had a significantly ($p<0.05$) larger leaf diameter than the custom black dip (Table 63). However, the untreated control was not significantly different from the custom black dip. Overall, the Styroseal® appeared to be the best treatment having the fewest spiral roots and largest seedling diameter, however, none of the treatments were worse than the untreated control. Although there were no obvious signs of disease, the trays in this experiment had been used before and the slightly better results with the Styroseal® may have been connected to disease and the ability of the dip to effectively "coat" the tray.

In a previous experiment (99 PH02S), seedlings in black trays germinated faster than those in the normal white polystyrene trays, probably because of a higher temperature. The beneficial effect of the darker coloured trays was not evident in this experiment, possibly because of the higher temperatures in the greenhouse compared with outdoors (see experiment 00 PH12S).

Table 62. Percent spiral roots

Treatment	Days after sowing	
	14	28
none	30.2	18.2
custom white dip	20.5	13.2
custom black dip	21.1	15.4
custom red dip	23.9	15.1
Styroseal	11.9	8.1
Mean	26.9	17.6
SED t (p=0.05, df = 8) 2.306	5.11	4.35
CV%	23.3	30.3

Table 63. Percent germination and seedling diameter

Treatment	Germination (%)		Seedling Diameter (mm)
	Days after sowing		
	14	28	28
none	94.3	95.6	50.3
custom white dip	95.8	95.8	59.4
custom black dip	96.6	93.2	43.8
custom red dip	97.1	98.1	52.3
Styroseal	96.3	97.4	66.8
Mean	96.0	96.0	54.5
SED t (p=0.05, df = 8) 2.306	1.87	1.58	5.67*
CV%	2.4	2.0	12.7

DISCUSSION

Trays with larger and fewer cells than the 128 were not suitable because the larger holes in the base of the cells encouraged higher levels of fall-out and because of the higher costs associated with the larger area of seedbed required per hectare of tobacco planted. After several experiments using pelleted (coated) seed from various major overseas sources it appears that there is very little difference in the source of seed in regard to germination rates and growth performance. There were few differences between primed and unprimed seed. The primed seed germinated faster than the unprimed but there was little difference overall. It appears that the use of primed seed does not reduce the need for warm temperatures for rapid germination. However, we have seen seed pelleted in South Africa that appears to be substandard physically compared to what we have been working with.

In order to decrease the cost and risks associated with sending seed overseas for pelleting, the technology would have to be developed locally. This would require extensive research and capital input in the future. Consequently, we are investigating the possibility of sowing uncoated seed into floating trays, although there may still be a case for a certain percentage of our seed requirements to be pelleted, perhaps for some small growers who will not have easy access to the more sophisticated sowing techniques and machinery. In addition, work has shown that uncoated seed germinates faster and more uniformly than pelleted seed and as we are aiming for a minimum of 85% pullable seedlings per tray, the higher and more reliable our germination figures the easier it will be to maintain this minimum requirement.

Work continues with pre-germination techniques such as the stacking of trays, both in greenhouses and in the open, and it appears that an incubation period of 5 days in a stacked, high humidity and warm environment does stimulate better germination in outdoor float seedbeds. Stacking for longer than this resulted in etiolated seedlings which did not survive possibly due to the sudden and excessive changes in the environment.

Additional work on sterilising used trays and ensuring that they contain no plant pathogens using biocidal paints and steam are being evaluated. Dark coloured paints were chosen to increase the temperature surrounding the seedling so as to stimulate post-germination growth. None of the dips or paints used so far have had any detrimental effects on germination and it is difficult to establish whether the small growth differences observed in the seedlings were due to the effect of the different disease deterrent chemical additives or to the colour of the trays. This is now being further tested in an outdoor environment where the differences may become more apparent.

Experiments planned for this season involve identifying the best environment for pre-germination by stacking and whether simple plastic covered stacks outside in the middle of our winter will produce the desired effect. Studies on further seedling growth enhancement include using black painted trays to increase the surface temperature of the trays and documenting the difference between coated and uncoated seed in the rate of germination and subsequent growth of the seedlings.

2.5. HARDENING FLOAT SEEDLINGS TO WITHSTAND DRY PLANTING CONDITIONS

INTRODUCTION

Zimbabwe normally has dry conditions at the time of transplanting into the field and traditional seedlings are well hardened. Therefore, it was necessary to ensure that plants produced in "speedling" trays could be sufficiently hardened.

The recommended size for traditional seedlings is 15 cm in length and about pencil thickness (6 mm). Traditional seedlings that are smaller than this do not establish well under the hot conditions prevalent at planting time. The seedlings produced in 128 cell trays are similar in size to the traditional ones, however, these are more expensive to produce than those in the 200 cell trays. Therefore, it was necessary to test if the seedlings from the more economic 200 cell trays responded any differently in the field. It had been suggested that monopotassium phosphate (MKP) could be used as a drench in a situation where the hardening of seedlings was disrupted by the addition of water or by rain.

This part describes two experiments which compared the yield and quality of tobacco from traditional seedlings with those produced in "speedling" trays, including the float system with and without MKP

RESULTS

Alternatives for hardening seedlings (98 PH07S/K)

(See Terms of Reference (Project MP/ZIM/97/182))

This experiment compared hardening procedures for float, permanent pine bark seedbeds and standard seedlings. Monopotassium phosphate (MKP) as a potassium source was also tested as a hardening technique.

Materials and Methods

Design: Four randomized complete blocks of 6 (3 x 2) treatments.

Treatments: Planted into the field as follows:
Factor 1:
1. - bare-root (standard) seedlings
2. - intact-root float speedlings
3. - bare-root pine bark (RSA) seedlings

Factor 2:
0. - None
1. - MKP (KH_2PO_4 - monopotassium phosphate)

Seedlings from the above treatments were planted out into the field. No seedlings from the intact-root, overhead watered speedlings (microjet) were used, as the plants were too small for transplanting into the field (Treatment 4 in 98 PH07S/K in the Terms of Reference Project MP/ZIM/97/182).

All speedlings were produced with pelleted seed in 128 cell trays using a 50% pine bark and 50% sand medium. Monopotassium phosphate (MKP) was used as a potassium source instead of potassium sulphate. The MKP (N: P_2O_5: K_2O ratio of 0: 52: 34 or N: K: P ratio of 0: 22.5: 28.4) was applied twice with the first application 1 week before pulling and the second 3 days later. The MKP was used at a rate of 1kg/100 litres water and applied as a drench to encourage both foliar and root uptake.

The float seedlings were hardened by draining all but a small amount of water and the seedlings allowed to gradually use the water and come under increasing water stress. A small amount of water was added to the float bath when plants wilted severely before 10 am. The process was then repeated. To harden the overhead watered treatments, the number of irrigations was initially reduced and then stopped until wilting occurred before 10 am, when a heavy irrigation was applied. A similar process was done for the traditional seedbeds which were watered with an overhead system.

Unseasonal early rain occurred in September, which was about 5 weeks before planting into the field. Consequently, seedlings were transplanted into soil which was almost at field capacity and they established easily.

Results and Discussion

At planting, the float speedlings were longer and thicker than the other seedling types. The pine bark bare-root seedlings were a similar size to the standard bare-root seedlings (Tables 64 and 65). The MKP had little effect on seedling size, which was to be expected as it had only been applied a week before transplanting.

Table 64. Seedling length at planting (cm)

Seedling type	Monopotassium phosphate (MKP)		
	None	MKP	Mean
Standard bare-root	11.5	13.1	12.3
Speedlings (intact-root) float	15.2	17.8	16.3
Pine bark seedbed bare-root	12.5	14.7	13.6
Mean	13.8†	16.0†	

† Mean for comparison of treatments 2 and 3 only

t (p=0.05, df = 8) 2.306

CV%	27.6
SED (comparisons for treatments 2 and 3 only):	
Seedling type	2.15
MKP	2.15
Seedling type x MKP	3.20

Table 65. Seedling stem diameter at planting (mm)

Seedling type	Monopotassium phosphate (MKP)		
	None	MKP	Mean
Standard bare-root	5.0	4.3	4.7
Speedlings (intact-root) float	6.4	5.8	6.2
Pine bark seedbed bare-root	5.0	5.0	5.0
Mean	5.72†	5.35†	

† Mean for comparison of treatments 2 and 3 only

t (p=0.05, df = 8) 2.306

CV%	9.4
SED (comparisons for treatments 2 and 3 only):	
Seedling type	0.27*
MKP	0.27
Seedling type x MKP	0.41

The MKP had no effect on plant height measured 5 weeks after transplanting. The plants grown from float speedlings were significantly larger than those from the standard and pine bark seedbeds (Table 66), possibly because of the larger size of seedlings at transplanting (Tables 64 and 65).

The float speedlings produced a significantly higher yield of tobacco than the standard and pine bark bare-root seedlings. There was little difference in yield between the standard and pine bark seedlings (Table 67). The higher yield of tobacco from seedlings grown in the float system might be associated with the intact-root, compared with the bare-root in the other treatments, or because the seedlings were larger at transplanting. Further research would be needed to confirm this. The float speedlings produced the best quality tobacco (Table 68), however the reason for this is not clear; possibly because the plants were more uniform and, therefore, so was the harvesting.

Table 66. Plant height 5 weeks after planting (cm)

Seedling type	Monopotassium phosphate (MKP)		
	None	MKP	Mean
Standard bare-root	14.9	14.2	14.5
Speedlings (intact-root) float	17.7	18.5	18.1
Pine bark seedbed bare-root	15.3	15.3	15.3
Mean	16.0	16.0	16.0

t (p=0.05, df = 15) 2.131

CV%		14.5
SED	Seedling type	1.16*
	MKP	0.95
	Seedling type x MKP	1.64

Table 67. Saleable yield of tobacco (kg/ha)

Seedling type	Monopotassium phosphate (MKP)		
	None	MKP	Mean
Standard bare-root	2507	2432	2470
Speedlings (intact-root) float	2600	2791	2695
Pine bark seedbed bare-root	2412	2470	2441
Mean	2506	2564	2535

t (p=0.05, df = 15) 2.131

CV%		6.1
SED	Seedling type	77.2*
	MKP	63.0
	Seedling type x MKP	109.2

Table 68. Grade index (quality) of tobacco

Seedling type	Monopotassium phosphate (MKP)		
	None	MKP	Mean
Standard bare-root	60.0	59.7	59.9
Speedlings (intact-root) float	62.2	65.8	64.0
Pine bark seedbed bare-root	60.2	61.6	60.9
Mean	60.8	62.3	61.6

t (p=0.05, df = 15) 2.131

CV%		4.4
SED	Seedling type	1.36*
	MKP	1.11
	Seedling type x MKP	1.92

The conditions for crop establishment were good due to early rainfall, nonetheless, these results indicate that seedlings produced in both the float system and in a pine bark seedbed can be successfully hardened and produce yields that are comparable with standard seedlings. However, further work is necessary to confirm this under dry conditions.

Hardening of float seedlings (99 PH03S/K)

This experiment was a continuation of the research on hardening of seedlings produced with soilless media and was related to 98 PH07S/K.

Materials and Methods

Design: Four randomized complete blocks of 12 (6 x 2) treatments - standard dryland seedbed site. (total 24 "speedling" styrofoam and 8 black plastic seedling trays)

Treatments: Treatments planted into the field as follows

Factor 1 - seedling type/system

1. traditional seedbed seedlings
2. float speedlings 200 cell
3. float speedlings 128 cell
4. overhead watered 128 cell seedlings
5. overhead watered 153 cell black plastic tray seedlings
6. permanent pine bark seedlings - uncoated seed
7. permanent pine bark seedlings - pelleted seed

Factor 2 - potassium

1. none
2. monopotassium phosphate (MKP)

The different seedling types, apart from the traditional seedlings, were produced from the experiment 99 PH02S, which is described above. Also, the hardening procedures are explained in the experiment 98 PH07S/K. Two applications of MKP were applied as a drench, two weeks before pulling and then a week later.

The seedlings were planted with about 5 to 6 litres of water and then they were left to grow. The early part of the season was very hot and dry and this provided ideal conditions for testing seedling survival and growth.

Results and Discussion

There were differences in growth in the seedbed between the alternative systems which made it difficult to plant out the various treatments at the same stage of development (Table 69). Nonetheless, it was still reasonable to compare seedlings that had spent the same time in the seedbeds. This could be avoided in future by sowing the slowest system first in a staggered arrangement.

There were no deaths despite very hot, dry conditions. The differences in plant height measured 5 weeks after planting were related to the size of seedlings at transplanting (Table 69). This confirms previous research done by the Tobacco Research Board that larger seedlings survive and grow better than small ones under dry conditions.

MKP had no effect on seedling growth in the field and this result was similar to the previous experiment (99 PH07S/K). Therefore, the application of potassium as MKP does not have any use for hardening of tobacco seedlings.

Table 69. Seedling dry mass at planting and stalk height five weeks after planting[†]

Seedling type	Dry mass (g/plant)	Plant height (cm)		
	None	None	MKP	Mean
standard seedlings		16.3	16.9	16.6
float speedlings 200 cell	2.3	20.5	18.3	19.4
float speedlings 128 cell	1.6	17.8	21.3	19.5
overhead watered 128 cell seedlings	1.5	19.0	20.8	19.9
overhead watered 153 cell (black plastic)	1.2	18.0	16.3	17.1
pine bark seedlings - uncoated seed	1.6	19.4	18.8	19.1
pine bark seedlings - pelleted seed	2.7	20.4	20.6	20.5
Mean		18.8	19.0	

† The seedling data was not analysed because it was not replicated in the seedbed

Table 70. Saleable yield of tobacco (kg/ha)

Seedling type	Monopotassium phosphate (MKP)		
	None	MKP	Mean
standard bare-root	3685	3894	3789
float speedlings 200 cell	3557	3570	3563
float speedlings 128 cell	3717	3678	3697
overhead watered 128 cell seedlings	3700	3668	3684
overhead watered 153 cell (black plastic)	3517	3695	3606
pine bark seedlings - uncoated seed	3899	3823	3861
pine bark seedlings - pelleted seed	3767	3791	3779
Mean	3692	3731	3711

t (p=0.05, df = 39) 2.023

CV%		5.5
SED	Seedling type	102.9
	MKP	55.0
	Seedling type x MKP	145.5

There was no significant difference in yield or quality of tobacco in this experiment (Tables 70 and 71). This is contrary to the previous seedling-type experiment (98 PH07S/K) where the float seedlings had the greatest yield and grade index. Nonetheless, these two experiments showed that both the 128 and 200 cell float seedlings can perform as well as standard seedlings even in relatively harsh conditions. There was little difference in the results between the 128 and 200 cell float seedlings.

Table 71. Grade index (quality)

Seedling type	Monopotassium phosphate (MKP)		
	None	MKP	Mean
standard bare-root	65	65	65
float speedlings 200 cell	63	67	65
float speedlings 128 cell	67	66	66
overhead watered 128 cell seedlings	65	64	64
overhead watered 153 cell (black plastic)	64	65	64
pine bark seedlings - uncoated seed	66	65	65
pine bark seedlings - pelleted seed	64	66	65
Mean	65	65	65

t (p=0.05, df = 39) 2.023

CV%		3.4
SED	Seedling type	1.10
	MKP	0.59
	Seedling type x MKP	1.56

DISCUSSION

The results show that float seedlings can be hardened. Two experiments to evaluate MKP as a drench to harden seedlings yielded no positive results and so further work on this method of hardening is not planned.

The 128 cell tray has generally been used as the standard in our trials because early work showed that it produced a seedling very similar, in all aspects, to the traditional seedling. However, our work shows that the size of the float seedling is not as critical as first supposed and that the seedlings produced in 200 cell trays, though smaller at transplanting, grow well in the field with no yield or quality differences. There are obvious economic advantages from using the 200 cell seedling trays (see Economic Discussion, page 84) and, because it is now apparent that 200 cell seedlings are as successful in the field as the 128 seedlings, we intend concentrating on this size of tray for future float development in an effort to establish it as the standard option for float seedbed production in Zimbabwe.

In one experiment, the float seedlings produced a higher yield of tobacco compared with traditional seedlings. This may have been associated with the intact-root, compared with the bare-root. However, there were no differences between seedling source in the second experiment and therefore yield advantage was not included as a benefit in the economic studies. Although there are unlikely to be yield benefits from using float seedlings, growers will probably prefer them because the seedlings are more uniform which makes the crop easier to manage, especially for topping.

Trial work being done this season tests the hardening of float seedlings through the withdrawal of nitrogen rather than the traditional method of withdrawing water completely at hardening time. These will be planted out into the field in a dryland situation. Also, hard and soft seedlings produced in both 128 and 200 cell trays will be transplanted into the field as an irrigated crop to determine whether float seedlings need to be hardened by withdrawing water and to compare again the different cell sizes.

2.6. ACQUIRING AND DISSEMINATING THE INFORMATION ON ALTERNATIVES TO METHYL BROMIDE

INTRODUCTION

The UNIDO demonstration was done to comply with the Terms of Reference (Point 16) which states that we must, "during the second cropping season, and in three different sites, representative of the climatological and soil conditions of Zimbabwe, prepare and carry out at full commercial scale three demonstration tests using the best technologies selected. These full scale demonstration tests have to be done in areas where tobacco is grown by small holders and the surface should not be less than one hectare each."

This section also very briefly describes some of the workshops, conferences and study tours attended. Full reports have been submitted to UNIDO.

RESULTS

UNIDO demonstration of alternative seedbed systems

The aim was to demonstrate alternatives to methyl bromide in the production of tobacco seedlings at four sites around Zimbabwe. Research staff at the Tobacco Research Board and both small scale and commercial farmers were invited to attend field days/ workshops at the different sites during the relevant season.

Design: Four non-replicated treatments at four different demonstration sites around Zimbabwe to show alternative tobacco seedling production methods, three of which do not utilise methyl bromide.

Sites: Irrigated beds

- ❖ Blackfordby Agricultural Institute, Concession - 1 June 1999 sowing
- ❖ Kutsaga Research Station, Harare - 8 June 1999 sowing

Dryland (rainfed) beds

- ❖ Trelawney Training Centre, Trelawney - 29 June 1999 sowing
- ❖ Dozmery Training Centre, Marondera - 20 July 1999 sowing

Treatments demonstrated:

1. Traditional seedbed fumigated with methyl bromide for comparison. Uncoated seed sown with watering can and boom, overhead watered.
2. Traditional seedbed, sterilized with "burn and EDB" technique. Uncoated seed sown with watering can and boom, overhead watered.
3. "Speedling" tray floats (128 cells) with 50% pine bark, 40% river sand and 10% vermiculite grade 3. Sown with pelleted seed and watered by capillary action from the float water.
4. Open 100% pine bark in budget permanent brick bed. Uncoated seed sown with watering can and boom, overhead watered. (Except Kutsaga where an additional bed was sown with precision sower and pelleted seed).

In each UNIDO Demonstration seedbed site, we produced the above treatments with general monitoring of all aspects of their growth during the seedling growth period. The variety was Kutsaga K RK6 and the media used was as stated in each individual treatment above.

The standard methyl bromide seedbeds, the EDB + burn seedbeds and the permanent pine bark seedbeds were watered using whatever overhead irrigation equipment was available at each site.

General report on the field days to demonstrate the alternatives to methyl bromide

The Field Days were held as follows:

- Blackfordby Agricultural Institute - a ZTA training facility for commercial tobacco managers and foremen, north of Harare - Field Day held on 17 August, 1999. Also used to show students and farmers attending seedbed courses at the Institute over a period of two months.
- Kutsaga Research Station - parent demonstration site - Field Days held on 26 and 30 August, 1999.
- Trelawney Training Centre - a ZTA training centre for small growers, north-west of Harare. Two Field Days held, for Mhondoro/Karoi districts on 21 September, 1999 and for Mt. Darwin/Guruve districts on 30 September, 1999
- Dozmery Training Centre - a ZTA training facility for small growers, east of Harare. Two Field Days held, for distant growers on 12 October, 1999 and for nearby growers on 19 October, 1999.

It is estimated that approximately 450 growers in total attended the various demonstrations. Research staff at the Tobacco Research Board and a member of the Ozone Office from the Ministry of Mines Environment and Tourism also visited the sites. The interest shown was very encouraging and several growers (both commercial and small holder) voiced their intention to set up a trial float bed on their own farm next season, purely as way of gaining experience and investigating any possible shortcomings. We have encouraged this approach and have offered any assistance and materials, such as pine bark and pelleted seed, to anyone wishing to experiment this coming season.

Growers perceptions of the seedbed demonstrations

The general feeling was that the float seedbed method was the best. Growers said it was the best because of:

1) ease of management
2) fewer inputs required
3) the permanent site for seedbed
4) the ease of pulling the seedling and the undisturbed root structure
5) no major watering requirements for seedbed

Most of the people consulted were less concerned about the cost compared to the standard seedbed because they saw it as a relatively economic way of producing seedlings with more advantages than any other systems so far demonstrated. Their main worry was one of disease but they felt that as research was still ongoing, such problems would be overcome.

Study tours
Dr K. Flower, Dr D. Cole and Miss J. Way went on a study tour of the USA, France and Spain. A great deal of information was obtained which enabled the Tobacco Research Board to begin development of the float system at a relatively advanced stage. Dr Flower also visited Australia to study the composting of pine bark and its use in the float system. It was

very interesting to see the Australians using mechanical sowers for placing uncoated tobacco seed into "speedling" trays and this aspect will be followed up in Zimbabwe.

Conferences and workshops

Dr V.E.C. Stubbs, a nematologist at the Tobacco Research Board, has given talks on alternatives to methyl bromide for use in tobacco seedbeds on three occasions; for a media workshop organized by the Ozone Office, a workshop for farm managers and supervisors organized by the Export Flower Growers Association of Zimbabwe, at which methyl bromide alternatives for horticulture used elsewhere were also discussed as part of her talk; and at the UNEP workshop on methyl bromide alternatives, held in Malawi.

Dr C.B. Cottrell and Mr G. Thomas attended the 14th International Plant Protection Congress in Israel, which included sessions on alternatives to methyl bromide. Dr D. Cole attended a workshop on Alternatives to "Methyl Bromide for the Control of Plant Pathogens" in Stellenbosch, South Africa and presented a paper at the "National Workshop on Alternatives to Methyl Bromide for Soil Fumigation in the Peoples Republic of China", Beijing. Mr G. Thomas gave a presentation to the "National Workshop on Alternatives to Methyl Bromide for Soil Fumigation" in Joinville, Brazil. Separate reports have been submitted with the relevant Progress Reports.

DISCUSSION

The various study tours, workshops and conferences were vital in acquiring information on seedling production and making contacts with other research people. This has resulted in a significant decrease in the time required to develop the systems. The demonstrations made tobacco growers aware of the pending ban on methyl bromide as well as the systems that are likely to replace the current practices. Field days to demonstrate the float system to tobacco growers are planned for the coming season and the system will be discussed in the tobacco extension tours in June 2001. It is likely that many growers will begin to use the system after the extension tours.

3. Economic Comparison of the Alternatives to Methyl Bromide

INTRODUCTION

The aim of the project was to demonstrate the technical and economic feasibility of alternative methods to the use of methyl bromide as a fumigant in tobacco seedbeds under experimental conditions. This economic analysis compared the traditional method of seedling production with the methods that use soilless media: 128 and 200 cell polystyrene trays in the float system, 128 and 153 cell polystyrene and black plastic trays (suspended), respectively, watered by microjet and the permanent pine bark seedbed.

RESULTS

Seedling production costs

The economic analysis carried out during the first phase of the study focused on the costs incurred for the different seedbed techniques (Half-Yearly Report 1). The discounted cost estimates for the different seedbed techniques indicated that the most expensive technique is that involving the use of permanent pine bark (Table 72). The rest of the seedbed techniques were ranked as follows (with the most expensive at the top):

- 128 cell Suspended seedbed;
- 128 cell Float seedbed;
- traditional seedbed
- 153 cell Suspended seedbed;
- 200 cell Float seedbed.

Table 72. Net Present Value of seedling production costs by seedbed technique

Seedbed type	Investment period*	Discount factor %**	NPV in US$
Traditional	10	8,5	1002,43
Permanent pine bark	10	8,5	1677,01
128 cell Float	10	8,5	1027,60
200 cell Float	10	8,5	785,77
128 cell Suspended	10	8,5	1122,83
153 cell Suspended	10	8,5	941,20

* longest life expectancy of the investment items used

** discount factor based on estimated inflation rate of 31,5% and prime lending rate of 40%.

Overall enterprise viability

The second phase of the economic analysis sought to establish the impact of the various seedbed techniques on overall enterprise viability (Half-Yearly Report 2). Table 73 summarises the relative enterprise values for the crops produced with the different seedbed techniques, on a per hectare basis.

Table 73. Net Present Value of overall enterprise by seedbed technique

Seedbed type	Investment period*	Discount factor %**	NPV in US$
Traditional	10	8,5	7768.69
Permanent pine bark	10	8,5	6820.36
128 cell Float	10	8,5	8198.17
200 cell Float	10	8,5	8386.41
128 cell Suspended	10	8,5	8219.60
153 cell Suspended	10	8,5	8421.09

* longest life expectancy of the investment items used

** discount factor based on estimated inflation rate of 31,5% and prime lending rate of 40%.

The results show that the various seedbed production techniques can be ranked as follows (with the best crop values at the top):

- 153 cell suspended;
- 200 cell float;
- 128 cell suspended;
- 128 cell float;
- traditional; and
- permanent pine bark.

For the analysis carried out during phase 3, the estimates made during the second phase were updated (Half-Yearly Report 3). Table 74 summarises the relative enterprise values for the crops produced with the different seedbed techniques, on a per hectare basis.

Based on this analysis the various techniques were ranked as follows (with the most valuable at the top):

- 153 cell suspended;
- 200 cell float;
- 128 cell suspended;
- 128 cell float;
- traditional; and
- permanent pine bark.

Table 74. Net Present Value enterprise by seedbed technique

Seedbed type	Investment period*	Discount factor %**	NPV in US$
Traditional	10	8,5	4 526,08
Permanent pine bark	10	8,5	3 586,46
128 cell Float	10	8,5	4 933,26
200 cell Float	10	8,5	5 121,50
128 cell Suspended	10	8,5	4 954,69
153 cell Suspended	10	8,5	5 156,18

* longest life expectancy of the investment items used

** discount factor based on estimated inflation rate of 31,5% and prime lending rate of 40%.

Thus the observations made during the second phase were confirmed during the third phase. However, a decline in the NPV's was noted, illustrating a possible cost-price squeeze affecting the tobacco producers, under the macro-economic environment prevailing at the time (characterised by high rates of inflation and a pegged exchange rate).

The fourth phase (Final Report) of the study seeks to review the findings of the previous three phases with a view to identifying the emerging trends and drawing conclusions on the overall findings of the study. Based on the findings of the first two phases the study was reconfigured to focus on three techniques:

- 200 cell float;
- 128 cell float; and
- traditional seedbed technique.

In addition, each of these techniques has been studied to show the difference between the cheap (low capital input, but high replacement costs) and expensive approaches (high capital input, but low replacement costs) to seedbed establishment. Table 75 summarises the findings of the study (detailed in Appendix Tables A2.1 to A2.8). The results show that the 200 cell float (cheap) technique gives the best return over a ten-year period followed by the 200 cell float (dear). Both the 128 cell float (dear) and 128 cell float (cheap) methods have a lower crop value than the traditional seedbeds. The overall values of the crops compared to the base case (traditional-cheap) are:

- 0,91 per cent lower for the traditional (dear);
- 9,38 per cent lower for the 128 cell float (cheap);
- 12,21 per cent lower for the 128 cell float (dear);
- 5,96 per cent higher for the 200 cell float (cheap); and
- 3,51 per cent higher for the 200 cell float (dear).

Table 75. Net Present Value enterprise by seedbed technique

Seedbed type	Investment period*	Discount factor %**	NPV in US$
Traditional (cheap)	10	4	4519.66
Traditional (dear)	10	4	4478.47
128 cell Float (cheap)	10	4	4095.68
128 cell Float (dear)	10	4	3967.73
200 cell Float (cheap)	10	4	4789.39
200 cell Float (dear)	10	4	4678.41

* longest life expectancy of the investment items used

** discount factor based on estimated inflation rate of 58,75% and prime lending rate of 62,5%.

DISCUSSION

The overall results of this study show that the use of alternative techniques is a viable option. In fact, the results achieved over the past two seasons with the 200 cell trays illustrate that the value of the enterprise could actually be higher than those produced with the traditional seedbed techniques. The 128 cell float method has a lower net present value than the traditional seedbeds. These results show that the 200 cell float method is the best option from both the practical and economic aspects.

A word of caution has to be expressed in interpreting the results of this economic analysis. Throughout the study period, and especially in the past five to six months, the macro-economic environment prevailing in the country has been very turbulent. The high rates of inflation have contributed to a rapid increase in the cost of production. On the other hand, the authorities have insisted on maintaining a fixed exchange rate (against the US dollar) resulting in an overall cost price squeeze in the tobacco production sector. Under these conditions the overall effect is to subsidize those activities with a higher import intensity (assuming that the foreign exchange is available) while at the same time placing an additional tax on the income realised from the tobacco crop. Given the fact that the formal market is currently characterised by serious shortages of foreign exchange, the reality facing the tobacco farmers is that they are not benefiting from the implied subsidy while they are being taxed through a fixed exchange rate and thus the overall effect is a deterioration in their terms of trade.

4. References

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5. Appendix

Table A1.1. Fertilizer applied in the float system

Fertilizer applied into the float water at sowing (0.75 kg mix /1000 litres water)	kg/100 kg mix
Ammonium nitrate	17
Potassium nitrate	43
Monoammonium phosphate	37
Magnesium sulphate	1.52
Manganese sulphate	0.2
Sodium molybdate	0.38
Zinc sulphate	0.22
Boric acid	0.11
Copper sulphate	0.2
Fertilizer applied into the float water at 5 and 8 weeks after sowing (0.29 kg/1000 litres water)	
Ammonium nitrate	100

Table A1.2. Composition of fertilizers used in the overhead watered system

Haifa Poly 19:19:19 + microelements	
N	19 %
P	19%
K	19%
Fe	1000 ppm
Cu	110 ppm
Zn	150 ppm
B	200 ppm
Mo	70 ppm
Mn	500 ppm
Magnesium sulphate ($MgSO_4.7H_2O$)	
Mg	9.8%
S	13%

Table A1.3. Fertilizer applied in the overhead watered system.

Weeks after sowing	Amount of Haifa Poly/application† (g/m^2)	Amount of magnesium sulphate† (g/m^2)
1	0.97	0.25
2	0.97	0.25
3	1.90	0.50
4	3.89	1.00
5	7.78	2.00
6	7.78	2.00
7	7.78	2.00
8	7.78	2.00

† Two applications were made each week

Table A2.1 Projected cashflow: Traditional Seedbed (cheap) Net present value (US$) = 4519.66

Description	Expenditure per hectare by year - US$									
Year	1	2	3	4	5	6	7	8	9	10
Capital expenditure:										
Motorised mower										
Overhead watering system	27.34					27.34				
Watering cans	21.80					21.80				
Sub-total	49.14	0.00	0.00	0.00	0.00	49.14	0.00	0.00	0.00	0.00
Recurrent expenditure:										
Preparations and daily procedures										
General labour (seedbed prep)	42.75	42.75	42.75	42.75	42.75	42.75	42.75	42.75	42.75	42.75
Fuel (tractor)	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19
Gro-Shield FRC	43.91	43.91	43.91	43.91	43.91	43.91	43.91	43.91	43.91	43.91
Labour (sowing)	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
Tobacco seed (raw)	14.35	14.35	14.35	14.35	14.35	14.35	14.35	14.35	14.35	14.35
Water	19.15	19.15	19.15	19.15	19.15	19.15	19.15	19.15	19.15	19.15
Chemicals										
Methyl bromide	32.21	32.21	32.21	32.21	32.21	32.21	32.21	32.21	32.21	32.21
Fumigation hire	3.49	3.49	3.49	3.49	3.49	3.49	3.49	3.49	3.49	3.49
Acephate	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28
Monocrotophos	5.40	5.40	5.40	5.40	5.40	5.40	5.40	5.40	5.40	5.40
Triadimenol	21.26	21.26	21.26	21.26	21.26	21.26	21.26	21.26	21.26	21.26
Chlorothalonil	14.27	14.27	14.27	14.27	14.27	14.27	14.27	14.27	14.27	14.27
Copper oxychloride	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32
Mancozeb	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
Fertilisers										
Compound S	5.49	5.49	5.49	5.49	5.49	5.49	5.49	5.49	5.49	5.49
Nitrate of soda	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83
Miscellaneous										
Clipping by hand	5.73	5.73	5.73	5.73	5.73	5.73	5.73	5.73	5.73	5.73
Miscellaneous overheads	19.74	19.74	19.74	19.74	19.74	19.74	19.74	19.74	19.74	19.74
Sub-total	234.35	234.35	234.35	234.35	234.35	234.35	234.35	234.35	234.35	234.35
Total seedbed expenditure	283.49	234.35	234.35	234.35	234.35	283.49	234.35	234.35	234.35	234.35
Field and other expenditure:										
Labour	606.96	606.96	606.96	606.96	606.96	606.96	606.96	606.96	606.96	606.96
Coal	257.44	257.44	257.44	257.44	257.44	257.44	257.44	257.44	257.44	257.44
Fertiliser	274.84	274.84	274.84	274.84	274.84	274.84	274.84	274.84	274.84	274.84
Chemicals	265.45	265.45	265.45	265.45	265.45	265.45	265.45	265.45	265.45	265.45
Fuel	117.81	117.81	117.81	117.81	117.81	117.81	117.81	117.81	117.81	117.81
R&M machinery	338.63	338.63	338.63	338.63	338.63	338.63	338.63	338.63	338.63	338.63
R&M buildings	45.51	45.51	45.51	45.51	45.51	45.51	45.51	45.51	45.51	45.51
Hail insurance	186.92	186.92	186.92	186.92	186.92	186.92	186.92	186.92	186.92	186.92
Field to floor insurance	13.63	13.63	13.63	13.63	13.63	13.63	13.63	13.63	13.63	13.63
Packing material	25.44	25.44	25.44	25.44	25.44	25.44	25.44	25.44	25.44	25.44
Transport to floors	68.26	68.26	68.26	68.26	68.26	68.26	68.26	68.26	68.26	68.26
Levy charges	370.51	370.51	370.51	370.51	370.51	370.51	370.51	370.51	370.51	370.51
Selling expenses	96.32	96.32	96.32	96.32	96.32	96.32	96.32	96.32	96.32	96.32
Government levy	194.71	194.71	194.71	194.71	194.71	194.71	194.71	194.71	194.71	194.71
Overhead costs	300.39	300.39	300.39	300.39	300.39	300.39	300.39	300.39	300.39	300.39
Management costs	184.97	184.97	184.97	184.97	184.97	184.97	184.97	184.97	184.97	184.97
Total other expenditure	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80
Total expenditure	3631.29	3582.15	3582.15	3582.15	3582.15	3631.29	3582.15	3582.15	3582.15	3582.15
Income estimates:										
Price in US$/kg	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66
Yield in kg/ha	2500.00	2500.00	2500.00	2500.00	2500.00	2500.00	2500.00	2500.00	2500.00	2500.00
Value of crop	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00
Net project cashflow	518.71	567.85	567.85	567.85	567.85	518.71	567.85	567.85	567.85	567.85

Net present value (US$) = 4478.47

Description	Expenditure per hectare by year - US$									
Year	1	2	3	4	5	6	7	8	9	10
Capital expenditure:										
Motorised mower	46.05					46.05				
Overhead watering system	27.34					27.34				
Watering cans	21.80					21.80				
Sub-total	95.19	0.00	0.00	0.00	0.00	95.19	0.00	0.00	0.00	0.00
Recurrent expenditure:										
Preparations and daily procedures										
General labour (seedbed prep)	42.75	42.75	42.75	42.75	42.75	42.75	42.75	42.75	42.75	42.75
Fuel (tractor)	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19
Gro-Shield FRC	43.91	43.91	43.91	43.91	43.91	43.91	43.91	43.91	43.91	43.91
Labour (sowing)	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
Tobacco seed (raw)	14.35	14.35	14.35	14.35	14.35	14.35	14.35	14.35	14.35	14.35
Water	19.15	19.15	19.15	19.15	19.15	19.15	19.15	19.15	19.15	19.15
Chemicals										
Methyl bromide	32.21	32.21	32.21	32.21	32.21	32.21	32.21	32.21	32.21	32.21
Fumigation hire	3.49	3.49	3.49	3.49	3.49	3.49	3.49	3.49	3.49	3.49
Acephate	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28
Monocrotophos	5.40	5.40	5.40	5.40	5.40	5.40	5.40	5.40	5.40	5.40
Triadimenol	21.26	21.26	21.26	21.26	21.26	21.26	21.26	21.26	21.26	21.26
Chlorothalonil	14.27	14.27	14.27	14.27	14.27	14.27	14.27	14.27	14.27	14.27
Copper oxychloride	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32
Mancozeb	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
Fertilisers										
Compound S	5.49	5.49	5.49	5.49	5.49	5.49	5.49	5.49	5.49	5.49
Nitrate of soda	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83
Miscellaneous		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mechanical clipping	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
Miscellaneous overheads	19.74	19.74	19.74	19.74	19.74	19.74	19.74	19.74	19.74	19.74
Sub-total	229.48	229.48	229.48	229.48	229.48	229.48	229.48	229.48	229.48	229.48
Total seedbed expenditure	324.67	229.48	229.48	229.48	229.48	324.67	229.48	229.48	229.48	229.48
Field and other expenditure:										
Labour	606.96	606.96	606.96	606.96	606.96	606.96	606.96	606.96	606.96	606.96
Coal	257.44	257.44	257.44	257.44	257.44	257.44	257.44	257.44	257.44	257.44
Fertiliser	274.84	274.84	274.84	274.84	274.84	274.84	274.84	274.84	274.84	274.84
Chemicals	265.45	265.45	265.45	265.45	265.45	265.45	265.45	265.45	265.45	265.45
Fuel	117.81	117.81	117.81	117.81	117.81	117.81	117.81	117.81	117.81	117.81
R&M machinery	338.63	338.63	338.63	338.63	338.63	338.63	338.63	338.63	338.63	338.63
R&M buildings	45.51	45.51	45.51	45.51	45.51	45.51	45.51	45.51	45.51	45.51
Hail insurance	186.92	186.92	186.92	186.92	186.92	186.92	186.92	186.92	186.92	186.92
Field to floor insurance	13.63	13.63	13.63	13.63	13.63	13.63	13.63	13.63	13.63	13.63
Packing material	25.44	25.44	25.44	25.44	25.44	25.44	25.44	25.44	25.44	25.44
Transport to floors	68.26	68.26	68.26	68.26	68.26	68.26	68.26	68.26	68.26	68.26
Levy charges	370.51	370.51	370.51	370.51	370.51	370.51	370.51	370.51	370.51	370.51
Selling expenses	96.32	96.32	96.32	96.32	96.32	96.32	96.32	96.32	96.32	96.32
Government levy	194.71	194.71	194.71	194.71	194.71	194.71	194.71	194.71	194.71	194.71
Overhead costs	300.39	300.39	300.39	300.39	300.39	300.39	300.39	300.39	300.39	300.39
Management costs	184.97	184.97	184.97	184.97	184.97	184.97	184.97	184.97	184.97	184.97
Total other expenditure	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80
Total expenditure	3672.47	3577.29	3577.29	3577.29	3577.29	3672.47	3577.29	3577.29	3577.29	3577.29
Income estimates:										
Price in US$/kg	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66
Yield in kg/ha	2500.00	2500.00	2500.00	2500.00	2500.00	2500.00	2500.00	2500.00	2500.00	2500.00
Value of crop	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00
Net project cashflow	477.53	572.71	572.71	572.71	572.71	477.53	572.71	572.71	572.71	572.71

Table A2.3 Projected cashflow: 128 cell Float Seedbed (cheap) Net present value (US$) = 4095.68

Description	Expenditure per hectare by year - US$									
Year	1	2	3	4	5	6	7	8	9	10
Capital expenditure:										
Seeder/dibbler	164.47									
Speedling trays	308.68			308.68			308.68			308.68
Black plastic	51.69		51.69		51.69		51.69		51.69	
Bricks only	21.27									
Seedbed building	86.44									
Watering cans	21.80					21.80				
Sub-total	654.36	0.00	51.69	308.68	51.69	21.80	360.37	0.00	51.69	308.68
Recurrent expenditure:										
Preparations and daily procedures										
General labour (seedbed prep)	20.48	20.48	20.48	20.48	20.48	20.48	20.48	20.48	20.48	20.48
Composted pine bark	8.89	8.89	8.89	8.89	8.89	8.89	8.89	8.89	8.89	8.89
River sand washed	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76
Gro-Shield FRC	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60
Labour (sowing)	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Tobacco seed (pelleted)	13.94	13.94	13.94	13.94	13.94	13.94	13.94	13.94	13.94	13.94
Water	3.49	3.49	3.49	3.49	3.49	3.49	3.49	3.49	3.49	3.49
Chemicals										
Acephate	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
Triadimenol	10.20	10.20	10.20	10.20	10.20	10.20	10.20	10.20	10.20	10.20
Monocrotophos	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60
Chlorothalonil	6.84	6.84	6.84	6.84	6.84	6.84	6.84	6.84	6.84	6.84
Copper oxychloride	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
Mancozeb	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
Fertilisers										
Soluble fertiliser blend	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45
Miscellaneous										
Clipping by hand	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Miscellaneous overheads	19.74	19.74	19.74	19.74	19.74	19.74	19.74	19.74	19.74	19.74
Sub-total	110.15	110.15	110.15	110.15	110.15	110.15	110.15	110.15	110.15	110.15
Total expenditure	764.51	110.15	161.84	418.84	161.84	131.95	470.52	110.15	161.84	418.84
Field and other expenditure:										
Labour	606.96	606.96	606.96	606.96	606.96	606.96	606.96	606.96	606.96	606.96
Coal	257.44	257.44	257.44	257.44	257.44	257.44	257.44	257.44	257.44	257.44
Fertiliser	274.84	274.84	274.84	274.84	274.84	274.84	274.84	274.84	274.84	274.84
Chemicals	265.45	265.45	265.45	265.45	265.45	265.45	265.45	265.45	265.45	265.45
Fuel	117.81	117.81	117.81	117.81	117.81	117.81	117.81	117.81	117.81	117.81
R&M machinery	338.63	338.63	338.63	338.63	338.63	338.63	338.63	338.63	338.63	338.63
R&M buildings	45.51	45.51	45.51	45.51	45.51	45.51	45.51	45.51	45.51	45.51
Hail insurance	186.92	186.92	186.92	186.92	186.92	186.92	186.92	186.92	186.92	186.92
Field to floor insurance	13.63	13.63	13.63	13.63	13.63	13.63	13.63	13.63	13.63	13.63
Packing material	25.44	25.44	25.44	25.44	25.44	25.44	25.44	25.44	25.44	25.44
Transport to floors	68.26	68.26	68.26	68.26	68.26	68.26	68.26	68.26	68.26	68.26
Levy charges	370.51	370.51	370.51	370.51	370.51	370.51	370.51	370.51	370.51	370.51
Selling expenses	96.32	96.32	96.32	96.32	96.32	96.32	96.32	96.32	96.32	96.32
Government levy	194.71	194.71	194.71	194.71	194.71	194.71	194.71	194.71	194.71	194.71
Overhead costs	300.39	300.39	300.39	300.39	300.39	300.39	300.39	300.39	300.39	300.39
Management costs	184.97	184.97	184.97	184.97	184.97	184.97	184.97	184.97	184.97	184.97
Total other expenditure	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80
Total expenditure	4112.32	3457.96	3509.64	3766.64	3509.64	3479.76	3818.33	3457.96	3509.64	3766.64
Income estimates:										
Price in US$/kg	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66
Yield in kg/ha	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
Value of crop	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00
Net project cashflow	37.68	692.04	640.36	383.36	640.36	670.24	331.67	692.04	640.36	383.36

Table A2.4 Projected cashflow: 128 cell Float Seedbed (dear) Net present value (US$) = 3967.73

Description	Expenditure per hectare by year - US$									
Year	1	2	3	4	5	6	7	8	9	10
Capital expenditure:										
Seeder/dibbler	164.47									
Speedling trays	308.68			308.68			308.68			308.68
Black plastic	51.69		51.69		51.69		51.69		51.69	
Brick, cement, brickforce, etc	88.68									
Motorised mower	46.05					46.05				
Seedbed building	86.44									
Watering cans	21.80					21.80				
Sub-total	767.82	0.00	51.69	308.68	51.69	67.85	360.37	0.00	51.69	308.68
Recurrent expenditure:										
Preparations and daily procedures										
General labour (seedbed prep)	20.48	20.48	20.48	20.48	20.48	20.48	20.48	20.48	20.48	20.48
Composted pine bark	8.89	8.89	8.89	8.89	8.89	8.89	8.89	8.89	8.89	8.89
River sand washed	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76
Gro-Shield FRC	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60	15.60
Labour (sowing)	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Tobacco seed (pelleted)	13.94	13.94	13.94	13.94	13.94	13.94	13.94	13.94	13.94	13.94
Water	3.49	3.49	3.49	3.49	3.49	3.49	3.49	3.49	3.49	3.49
Chemicals										
Acephate	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
Triadimenol	10.18	10.18	10.18	10.18	10.18	10.18	10.18	10.18	10.18	10.18
Monocrotophos	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59
Chlorothalonil	6.84	6.84	6.84	6.84	6.84	6.84	6.84	6.84	6.84	6.84
Copper oxychloride	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
Mancozeb	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
Fertilisers										
Soluble fertiliser blend	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45
Miscellaneous										
Mechanical clipping	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
Miscellaneous overheads	19.74	19.74	19.74	19.74	19.74	19.74	19.74	19.74	19.74	19.74
Sub-total	107.99	107.99	107.99	107.99	107.99	107.99	107.99	107.99	107.99	107.99
Total expenditure	875.81	107.99	159.68	416.67	159.68	175.84	468.36	107.99	159.68	416.67
Field and other expenditure:										
Labour	606.96	606.96	606.96	606.96	606.96	606.96	606.96	606.96	606.96	606.96
Coal	257.44	257.44	257.44	257.44	257.44	257.44	257.44	257.44	257.44	257.44
Fertiliser	274.84	274.84	274.84	274.84	274.84	274.84	274.84	274.84	274.84	274.84
Chemicals	265.45	265.45	265.45	265.45	265.45	265.45	265.45	265.45	265.45	265.45
Fuel	117.81	117.81	117.81	117.81	117.81	117.81	117.81	117.81	117.81	117.81
R&M machinery	338.63	338.63	338.63	338.63	338.63	338.63	338.63	338.63	338.63	338.63
R&M buildings	45.51	45.51	45.51	45.51	45.51	45.51	45.51	45.51	45.51	45.51
Hail insurance	186.92	186.92	186.92	186.92	186.92	186.92	186.92	186.92	186.92	186.92
Field to floor insurance	13.63	13.63	13.63	13.63	13.63	13.63	13.63	13.63	13.63	13.63
Packing material	25.44	25.44	25.44	25.44	25.44	25.44	25.44	25.44	25.44	25.44
Transport to floors	68.26	68.26	68.26	68.26	68.26	68.26	68.26	68.26	68.26	68.26
Levy charges	370.51	370.51	370.51	370.51	370.51	370.51	370.51	370.51	370.51	370.51
Selling expenses	96.32	96.32	96.32	96.32	96.32	96.32	96.32	96.32	96.32	96.32
Government levy	194.71	194.71	194.71	194.71	194.71	194.71	194.71	194.71	194.71	194.71
Overhead costs	300.39	300.39	300.39	300.39	300.39	300.39	300.39	300.39	300.39	300.39
Management costs	184.97	184.97	184.97	184.97	184.97	184.97	184.97	184.97	184.97	184.97
Total other expenditure	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80
Total expenditure	4223.61	3455.79	3507.48	3764.48	3507.48	3523.65	3816.16	3455.79	3507.48	3764.48
Income estimates:										
Price in US$/kg	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66
Yield in kg/ha	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
Value of crop	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00
Net project cashflow	-73.61	694.21	642.52	385.52	642.52	626.35	333.84	694.21	642.52	385.52

Table A2.5 **Projected cashflow: 200 cell Float Seedbed (cheap)** **Net present value (US$) = 4789.39**

Description	Expenditure per hectare by year - US$									
Year	1	2	3	4	5	6	7	8	9	10
Capital expenditure:										
Seeder/dibbler	164.47									
Speedling trays	199.08			199.08			199.08			199.08
Black plastic	33.09		33.09		33.09		33.09		33.09	
Bricks only	13.62									
Seedbed building	55.34									
Watering cans	21.80					21.80				
Sub-total	487.41	0.00	33.09	199.08	33.09	21.80	232.17	0.00	33.09	199.08
Recurrent expenditure:										
Preparations and daily procedures										
General labour (seedbed prep)	13.11	13.11	13.11	13.11	13.11	13.11	13.11	13.11	13.11	13.11
Composted pine bark	5.69	5.69	5.69	5.69	5.69	5.69	5.69	5.69	5.69	5.69
River sand	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13
Gro-Shield FRC	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99
Labour (sowing)	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Tobacco seed (pelleted)	13.95	13.95	13.95	13.95	13.95	13.95	13.95	13.95	13.95	13.95
Water	2.23	2.23	2.23	2.23	2.23	2.23	2.23	2.23	2.23	2.23
Chemicals										
Acephate	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39
Triadimenol	6.52	6.52	6.52	6.52	6.52	6.52	6.52	6.52	6.52	6.52
Monocrotophos	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66
Chlorothalonil	4.38	4.38	4.38	4.38	4.38	4.38	4.38	4.38	4.38	4.38
Copper oxychloride	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41
Mancozeb	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
Fertilisers										
Soluble fertilizer blend	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57
Miscellaneous										
Clipping by hand	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62
Miscellaneous overheads	19.74	19.74	19.74	19.74	19.74	19.74	19.74	19.74	19.74	19.74
Sub-total	82.64	82.64	82.64	82.64	82.64	82.64	82.64	82.64	82.64	82.64
Total expenditure	570.05	82.64	115.73	281.72	115.73	104.44	314.81	82.64	115.73	281.72
Field and other expenditure:										
Labour	606.96	606.96	606.96	606.96	606.96	606.96	606.96	606.96	606.96	606.96
Coal	257.44	257.44	257.44	257.44	257.44	257.44	257.44	257.44	257.44	257.44
Fertiliser	274.84	274.84	274.84	274.84	274.84	274.84	274.84	274.84	274.84	274.84
Chemicals	265.45	265.45	265.45	265.45	265.45	265.45	265.45	265.45	265.45	265.45
Fuel	117.81	117.81	117.81	117.81	117.81	117.81	117.81	117.81	117.81	117.81
R&M machinery	338.63	338.63	338.63	338.63	338.63	338.63	338.63	338.63	338.63	338.63
R&M buildings	45.51	45.51	45.51	45.51	45.51	45.51	45.51	45.51	45.51	45.51
Hail insurance	186.92	186.92	186.92	186.92	186.92	186.92	186.92	186.92	186.92	186.92
Field to floor insurance	13.63	13.63	13.63	13.63	13.63	13.63	13.63	13.63	13.63	13.63
Packing material	25.44	25.44	25.44	25.44	25.44	25.44	25.44	25.44	25.44	25.44
Transport to floors	68.26	68.26	68.26	68.26	68.26	68.26	68.26	68.26	68.26	68.26
Levy charges	370.51	370.51	370.51	370.51	370.51	370.51	370.51	370.51	370.51	370.51
Selling expenses	96.32	96.32	96.32	96.32	96.32	96.32	96.32	96.32	96.32	96.32
Government levy	194.71	194.71	194.71	194.71	194.71	194.71	194.71	194.71	194.71	194.71
Overhead costs	300.39	300.39	300.39	300.39	300.39	300.39	300.39	300.39	300.39	300.39
Management costs	184.97	184.97	184.97	184.97	184.97	184.97	184.97	184.97	184.97	184.97
Total other expenditure	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80
Total expenditure	3917.85	3430.44	3463.54	3629.52	3463.54	3452.24	3662.61	3430.44	3463.54	3629.52
Income estimates:										
Price in US$/kg	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66
Yield in kg/ha	2500.00	2500.00	2500.00	2500.00	2500.00	2500.00	2500.00	2500.00	2500.00	2500.00
Value of crop	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00
Net project cashflow	232.15	719.56	686.46	520.48	686.46	697.76	487.39	719.56	686.46	520.48

Table A2.6 Projected cashflow: 200 cell Float Seedbed (dear) Net present value (US$) = 4678.41

Description	Expenditure per hectare by year - US$									
Year	1	2	3	4	5	6	7	8	9	10
Capital expenditure:										
Seeder/dibbler	164.47									
Speedling trays	199.08			199.08			199.08			199.08
Black plastic	33.09		33.09		33.09		33.09		33.09	
Brick, cement, brickforce, etc	56.77									
Motorised mower	46.05					46.05				
Seedbed building	55.34									
Watering cans	21.80					21.80				
Sub-total	576.61	0.00	33.09	199.08	33.09	67.85	232.17	0.00	33.09	199.08
Recurrent expenditure:										
Preparations and daily procedures										
General labour (seedbed prep)	13.11	13.11	13.11	13.11	13.11	13.11	13.11	13.11	13.11	13.11
Composted pine bark	5.69	5.69	5.69	5.69	5.69	5.69	5.69	5.69	5.69	5.69
River sand	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13
Gro-Shield FRC	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99	9.99
Labour (sowing)	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Tobacco seed (pelleted)	13.95	13.95	13.95	13.95	13.95	13.95	13.95	13.95	13.95	13.95
Water	2.23	2.23	2.23	2.23	2.23	2.23	2.23	2.23	2.23	2.23
Chemicals										
Acephate	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39
Triadimenol	6.52	6.52	6.52	6.52	6.52	6.52	6.52	6.52	6.52	6.52
Monocrotophos	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66
Chlorothalonil	4.38	4.38	4.38	4.38	4.38	4.38	4.38	4.38	4.38	4.38
Copper oxychloride	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Mancozeb	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
Fertilisers										
Soluble fertiliser blend	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57
Miscellaneous										
Mechanical clipping	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Miscellaneous overheads	19.74	19.74	19.74	19.74	19.74	19.74	19.74	19.74	19.74	19.74
Sub-total	81.26	81.26	81.26	81.26	81.26	81.26	81.26	81.26	81.26	81.26
Total expenditure	657.88	81.26	114.35	280.34	114.35	149.11	313.43	81.26	114.35	280.34
Field and other expenditure:										
Labour	606.96	606.96	606.96	606.96	606.96	606.96	606.96	606.96	606.96	606.96
Coal	257.44	257.44	257.44	257.44	257.44	257.44	257.44	257.44	257.44	257.44
Fertiliser	274.84	274.84	274.84	274.84	274.84	274.84	274.84	274.84	274.84	274.84
Chemicals	265.45	265.45	265.45	265.45	265.45	265.45	265.45	265.45	265.45	265.45
Fuel	117.81	117.81	117.81	117.81	117.81	117.81	117.81	117.81	117.81	117.81
R&M machinery	338.63	338.63	338.63	338.63	338.63	338.63	338.63	338.63	338.63	338.63
R&M buildings	45.51	45.51	45.51	45.51	45.51	45.51	45.51	45.51	45.51	45.51
Hail insurance	186.92	186.92	186.92	186.92	186.92	186.92	186.92	186.92	186.92	186.92
Field to floor insurance	13.63	13.63	13.63	13.63	13.63	13.63	13.63	13.63	13.63	13.63
Packing material	25.44	25.44	25.44	25.44	25.44	25.44	25.44	25.44	25.44	25.44
Transport to floors	68.26	68.26	68.26	68.26	68.26	68.26	68.26	68.26	68.26	68.26
Levy charges	370.51	370.51	370.51	370.51	370.51	370.51	370.51	370.51	370.51	370.51
Selling expenses	96.32	96.32	96.32	96.32	96.32	96.32	96.32	96.32	96.32	96.32
Government levy	194.71	194.71	194.71	194.71	194.71	194.71	194.71	194.71	194.71	194.71
Overhead costs	300.39	300.39	300.39	300.39	300.39	300.39	300.39	300.39	300.39	300.39
Management costs	184.97	184.97	184.97	184.97	184.97	184.97	184.97	184.97	184.97	184.97
Total other expenditure	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80
Total expenditure	4005.68	3429.06	3462.16	3628.14	3462.16	3496.92	3661.23	3429.06	3462.16	3628.14
Income estimates:										
Price in US$/kg	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66
Yield in kg/ha	2500.00	2500.00	2500.00	2500.00	2500.00	2500.00	2500.00	2500.00	2500.00	2500.00
Value of crop	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00
Net project cashflow	144.32	720.94	687.84	521.86	687.84	653.08	488.77	720.94	687.84	521.86

Table A2.7 Summary of projected cashflows by seedbed technique

Description	Expenditure per hectare by year - US$									
Year	1	2	3	4	5	6	7	8	9	10
Capital expenditure:										
Traditional seedbed (cheap)	49.14	0.00	0.00	0.00	0.00	49.14	0.00	0.00	0.00	0.00
Traditional seedbed (dear)	95.19	0.00	0.00	0.00	0.00	95.19	0.00	0.00	0.00	0.00
128 cell Float seedbed (cheap)	654.36	0.00	51.69	308.68	51.69	21.80	360.37	0.00	51.69	308.68
128 cell Float seedbed (dear)	767.82	0.00	51.69	308.68	51.69	67.85	360.37	0.00	51.69	308.68
200 cell Float seedbed (cheap)	487.41	0.00	33.09	199.08	33.09	21.80	232.17	0.00	33.09	199.08
200 cell Float seedbed (dear)	576.61	0.00	33.09	199.08	33.09	67.85	232.17	0.00	33.09	199.08
Recurrent expenditure:										
Traditional seedbed (cheap)	234.35	234.35	234.35	234.35	234.35	234.35	234.35	234.35	234.35	234.35
Traditional seedbed (dear)	229.48	229.48	229.48	229.48	229.48	229.48	229.48	229.48	229.48	229.48
128 cell Float seedbed (cheap)	110.15	110.15	110.15	110.15	110.15	110.15	110.15	110.15	110.15	110.15
128 cell Float seedbed (dear)	107.99	107.99	107.99	107.99	107.99	107.99	107.99	107.99	107.99	107.99
200 cell Float seedbed (cheap)	82.64	82.64	82.64	82.64	82.64	82.64	82.64	82.64	82.64	82.64
200 cell Float seedbed (dear)	81.26	81.26	81.26	81.26	81.26	81.26	81.26	81.26	81.26	81.26
Total expenditure:										
Traditional seedbed (cheap)	283.49	234.35	234.35	234.35	234.35	283.49	234.35	234.35	234.35	234.35
Traditional seedbed (dear)	324.67	229.48	229.48	229.48	229.48	324.67	229.48	229.48	229.48	229.48
128 cell Float seedbed (cheap)	764.51	110.15	161.84	418.84	161.84	131.95	470.52	110.15	161.84	418.84
128 cell Float seedbed (dear)	875.81	107.99	159.68	416.67	159.68	175.84	468.36	107.99	159.68	416.67
200 cell Float seedbed (cheap)	570.05	82.64	115.73	281.72	115.73	104.44	314.81	82.64	115.73	281.72
200 cell Float seedbed (dear)	657.88	81.26	114.35	280.34	114.35	149.11	313.43	81.26	114.35	280.34
Field and other expenditure:										
Traditional seedbed (cheap)	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80
Traditional seedbed (dear)	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80
128 cell Float seedbed (cheap)	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80
128 cell Float seedbed (dear)	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80
200 cell Float seedbed (cheap)	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80
200 cell Float seedbed (dear)	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80	3347.80
Income estimates:										
Traditional seedbed (cheap)	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00
Traditional seedbed (dear)	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00
128 cell Float seedbed (cheap)	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00
128 cell Float seedbed (dear)	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00
200 cell Float seedbed (cheap)	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00
200 cell Float seedbed (dear)	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00	4150.00
Net project cashflow:										
Traditional seedbed (cheap)	518.71	567.85	567.85	567.85	567.85	518.71	567.85	567.85	567.85	567.85
Traditional seedbed (dear)	477.53	572.71	572.71	572.71	572.71	477.53	572.71	572.71	572.71	572.71
128 cell Float seedbed (cheap)	37.68	692.04	640.36	383.36	640.36	670.24	331.67	692.04	640.36	383.36
128 cell Float seedbed (dear)	-73.61	694.21	642.52	385.52	642.52	626.35	333.84	694.21	642.52	385.52
200 cell Float seedbed (cheap)	232.15	719.56	686.46	520.48	686.46	697.76	487.39	719.56	686.46	520.48
200 cell Float seedbed (dear)	144.32	720.94	687.84	521.86	687.84	653.08	488.77	720.94	687.84	521.86

Table A2.8 Net Present Value of enterprise by seedbed technique

Description of seedbed technique	Period in years	Discount* %	NPV in US$**
Traditional seedbed (cheap)	10	4	4519.66
Traditional seedbed (dear)	10	4	4478.47
128 cell Float seedbed (cheap)	10	4	4095.68
128 cell Float seedbed (dear)	10	4	3967.73
200 cell Float seedbed (cheap)	10	4	4789.39
200 cell Float seedbed (dear)	10	4	4678.41

* Annual average inflation estimated at 58.5% and prime lending rates at 62.5%

** Exchange rate at official rate of 1US$:Z$38.

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(2 of 2)

Demonstration Project on Alternatives to the Use of Methyl Bromide

UNIDO PROJECT MP/ZIM/97/182

Fact Sheet for Final Report

(June 2000)

by

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FINAL Report - June 2000

Introduction

Project Details

Country:	Zimbabwe
Counterpart institution:	Tobacco Research Board
Location:	Harare, Zimbabwe
Sector covered:	Tobacco
Estimated ODS use by sector:	500 tonnes/annum
Project duration:	May 1998 to June 2000
Project Objectives:	To develop and demonstrate the use of alternatives to methyl bromide in the production of tobacco seedbeds in the project area.

The aim of the project was to demonstrate the technical and economic feasibility of two alternative methods to the use of methyl bromide as a fumigant in tobacco seedbeds under experimental conditions. The two approaches studied were:

- the application of various mixtures of other chemicals in low doses; and
- the use of non-soil techniques.

The alternative methods were used in combination with an integrated pest management (IPM) programme wherever possible. The results of this study will be disseminated among qualified specialists and farmers.

All experiments outlined in the Terms of Reference (Project MP/ZIM/97/182, Annex B) have been completed and these are: 1) Use of other fumigants and burn techniques in seedbeds - 99 NM02S, 2) Alternatives against cutworm damage - 98 EN10S, 3) Combinations of dazomet/plastic sheeting - 98AG01S, 4) Alternatives for hardening seedlings - 98 PH07S/K and 5) Substrate alternatives in different seedbed systems - 98 PH08S. A number of additional experiments were carried out where necessary in order to obtain more information and develop practical recommendations.

The results of the completed experiments as well as an overview of the work and an economic comparison of these alternatives with traditional seedbed production with methyl bromide are presented. This report has three main sections:

1. **Alternative fumigants in traditional seedbeds;**
2. **Alternative seedling production systems; and**
3. **An Economic comparison of alternatives to methyl bromide.**

1. Alternative Fumigants in Traditional Seedbeds

Two separate topics are discussed in this section. The first deals with alternative fumigants, such as dazomet, metham sodium, EDB (ethylene dibromide) and 1,3-D (dichloropropene), and the second discusses methods to improve insect control in traditional seedbeds.

1.1. ALTERNATIVE FUMIGANTS

INTRODUCTION

When the use of methyl bromide is stopped it is expected that most tobacco growers will change to the float system using soilless media. However, some growers may not be able, or want, to change so work on different fumigants is being done to provide another alternative for tobacco growers which would not require major changes to their current method of production.

Methyl bromide is a very effective fumigant which controls diseases, nematodes and weeds and it is a difficult task to find alternative chemicals that match its efficacy. EDB and 1,3-dichloropropene (1,3-D) are being tested as nematicides, and the incorporation of chloropicrin with 1,3-D should improve the control of diseases. The other major problem is weed control and the chemicals dazomet and metham sodium are considered to have both weed and nematicidal properties. Consequently, the research effort is mainly aimed at testing various combinations of these chemicals.

Five trials were done to test alternative chemicals in traditional seedbeds, three using metham-sodium in comparison with a burn and ethylene dibromide (EDB) treatment, one comparing EDB, 1,3-dichloropropene (1,3-D) and a mixture of 65% 1,3-D and 35% chloropicrin (1,3-D/C-35) and one testing combinations of dazomet and plastic covers for weed control.

DISCUSSION OF RESULTS

Both the methyl bromide and burn plus EDB treatments gave excellent control of broadleaf weeds, grasses, nematodes and good growth of tobacco seedlings, and these were the best treatments. However, the burn and EDB is unlikely to be recommended as an alternative because of the environmental implications of burning. EDB on its own had no herbicidal effect, however 1,3-D and the 1,3-D/C-35 mixture appeared to have some control of grasses. Neither EDB + metham sodium at 15 ml/m^2 or at 25 ml/m^2 controlled weeds satisfactorily. Only the high rate of 35 ml/m^2 metham sodium gave reasonable control in some experiments, although it was not satisfactory in others. Metham sodium at 50 ml/m^2 and dazomet gave good control of weeds. However, the latter fumigant appears to be too unpredictably phytotoxic to be used in tobacco seedbeds.

Further work is necessary to finalise suitable treatments for recommendation. However, EDB + metham sodium and 1,3-D or 1,3-D/C-35 are the most promising alternatives. For the metham-sodium/EDB treatments, a rate should be finalised this season and for the possible use of 1,3-D or 1,3-D/C-35, a trial similar to last year's will be done, omitting EDB.

1.2. IMPROVING THE CONTROL OF INSECT PESTS IN CONVENTIONAL TOBACCO SEEDBEDS

INTRODUCTION

Current Tobacco Research Board (TRB) recommendations for nematode, disease and weed control in conventional seedbeds rely very much on an initial methyl bromide fumigation. This is not the case for the recommendations on insect pest control. Although methyl bromide is an excellent insecticide, it has no residual effects. Termites and true ants are commonly observed to move back into a seedbed area within days of the completion of a fumigation. The time that elapses before the seed germinates and the seedlings have begun to increase in size is ample to allow the arrival, from outside the fumigated area, of other seedbed pests such as cutworms and aphids. Since current insect pest control practices are designed to correct such immigration, the lack of an initial methyl bromide fumigation will have little or no *direct* effect on their efficacy.

The disappearance of methyl bromide could, however, conceivably bring about changes in current insect control practices in an indirect manner through the widespread adoption of new methods of seedling production. For instance, methods that involve the use of float systems in low or high tunnel-like structures would result in environments closer to those found in greenhouses than to those of conventional seedbeds. This might, in time, bring about some shifts in the arthropod pest spectrum. It is conceivable that whiteflies and dipterous leaf-miners, which are not currently a problem in conventional seedbeds, could become more important. Whiteflies are notorious for their ability to rapidly become resistant to new pesticides. The long-term control of these insects thus requires resistance management strategies that incorporate planned switches between materials having different modes of insecticidal action.

Until it has become clear which of the new techniques of seedling production will become widely used in Zimbabwe and what, if any, new pest challenges will arise as a result, it is difficult to predict what changes in pest control practices may be needed. However, our ability to react quickly to any new situation will certainly be enhanced if a wide selection of effective, non-phytotoxic pesticides of low mammalian toxicity and belonging to different chemical groups, is available to choose from. Unfortunately, the recent changes in pesticide regulations in many developed countries increasingly threaten the availability of many proven chemicals of the older groups (organophosphates, carbamates and pyrethroids). Thus the entomological research connected with UNIDO project MP/ZIM/97/182 has concentrated on testing the efficacy of a range of new "green" chemicals, used in a variety of strategies in conventional seedbeds.

As the result of the work of other contributors to the project, it now seems very probable that seedling production techniques based on floating "speedling" trays, with their cells filled with artificial media, will dominate new production methods in Zimbabwe. Such systems have, up to now, proved remarkably free of arthropod pest problems but the situation could change as they become widespread.

Future entomological research on seedling protection will be directed towards (i) devising the most economical strategies that can be devised using currently available chemicals and (ii) examining to what extent the final stages of the seedling protection strategies can be adapted to provide bridging protection for the period immediately after transplanting the seedlings into the field.

DISCUSSION OF RESULTS

The research on control strategies for insect pests of tobacco seedlings in conventional seedbeds conducted under UNIDO project MP/ZIM/97/182 concerned both preventative aphicides that can be applied before sowing and cutworm preventatives that are applied at intervals after germination.

Pre-sowing Aphicides

Imidacloprid, a chloronicotinyl insecticide, has been shown to provide better protection against aphid infestations than the currently registered disulfoton (an organo-phosphate). This protection will last for at least ten weeks (experiments 00 EN06S & 00 EN07S). Thiamethoxam (another chloronicotinyl), is as effective as imidacloprid (00 EN07S) while a third member of the same group may prove to be similarly effective when its effects are disentangled from the aphicidal effects of the cutworm preventative (the synthetic pyrethroid, deltamethrin) with which it was combined (in 00 EN07S). These chloronicotinyls are likely to prove equally effective in seedling production systems that involve floating trays and they are also likely to be effective against whiteflies should problems from these insects arise as the result of changes in seedling production practices. However, cases of whitefly populations becoming resistant to chloronicotinyls are already known.

Cutworm Preventatives

The efficacies of the currently registered organophosphate cutworm preventatives, monocrotophos, acephate and methamidophos were re-tested (98 EN10S, 00 EN06S and 00 EN07S). All three have important aphicidal effects in addition to their actions against cutworms, but their future availabilities (especially those of monocrotophos and methamidophos) are under threat from regulatory reviews that are currently underway. As a cutworm preventative, monocrotophos is definitely inferior to the other two and it should be de-registered for this usage. Methamidophos is undesirable on account of its high mammalian toxicity. Deltamethrin (a synthetic pyrethroid) has been shown to be an excellent cutworm preventative (00 EN06S, 00 EN07S) but is not currently registered for this purpose. This omission is for reasons associated with the Zimbabwean insecticide resistance management strategy that is aimed primarily at budworm, *Helicoverpa armigera*. This insect is not, however, a tobacco seedbed pest, so that the use of pyrethroids in this situation could be tolerated, since it would not increase this insect's exposure to this group.

The experiments cited have identified some promising substitute cutworm preventatives.
Of these, indoxacarb (a sodium channel inhibitor), chlorfenapyr (an uncoupler of oxidative phosphorylation), and lufenuron (a benzoylphenyl urea growth regulator) seem most promising, though spinosad (a biological produced from an Actinomycete) and fipronil (a phenyl pyrozole) may approach them in efficacy. None of these materials has any practical aphicidal effects. The recommended intervals between applications to seedbeds can certainly be extended from the current two weeks to three weeks without reducing cutworm control (98 EN10S) but, since several are slow acting, they must be present continuously in seedbeds if

cutworm larvae are to be killed when young, before they are capable of causing damage to the seedling stems.

Future seedbed insect control strategies

In terms of insecticide resistance strategies, it will clearly be unwise to rely too heavily on the chloronicotinyls for aphid control and it will therefore be necessary to search for alternative aphicides belonging to other groups.

In contrast, the wide variety of cutworm preventatives now appearing, promises considerable flexibility in the design of strategies for this application.

2. Alternative Seedling Production Systems

Six main topics are discussed in this section. The first deals with experiments on different systems of soilless seedling production. The next four topics describe testing various media, use of *Trichoderma* in the float seedbed system, methods of improving germination and hardening techniques. The last subject describes the various workshops/conferences attended and demonstrations to disseminate the information to farmers.

2.1. ALTERNATIVE SYSTEMS OF SEEDLING PRODUCTION IN SOILLESS MEDIA

INTRODUCTION

Methyl bromide is not required when tobacco seedlings are produced with non-soil techniques. Many systems have been developed and these include soilless media seedbeds (developed in South Africa) and Speedling® trays (expanded polystyrene seedling trays, called, in this report, "speedling" trays, being locally made but similar to Speedling® trays) with soilless media watered either by an overhead irrigation system or floated on water (developed in the USA). This part describes the experiments done to identify the most appropriate methods of seedling production using soilless media. The studies tested the following systems: pine bark seedbeds, microjet watering of "speedling" trays and floating "speedling" trays on water (float system). The media consisted of either pine bark alone for the pine bark seedbed and overhead watered (microjet) system, or pine bark mixed with river sand for "speedling" trays in the float system.

DISCUSSION OF RESULTS

Overall, the seedlings grown in "speedling" trays with the overhead watering system were much smaller than those grown in a pine bark seedbed with the same watering system, and those in the float system. The slow growth was because the fertilizer was incorporated as a basal in the medium and, consequently, leaching of nutrient occurred. Better results were obtained when the fertilizer was applied as a drench relatively frequently. The rate of growth of seedlings in the float and pine bark seedbed systems was comparable, if not better, than that in the traditional seedbeds.

The open pine bark bed works well and is used very effectively in South Africa but the main drawback in Zimbabwe is that it is considerably more expensive than the float or overhead (microjet) systems. This is primarily because more pine bark is required to produce a similar sized seedbed to the float system and considerably more area of seedbed is required per hectare. A further problem with this system is that if the entire Zimbabwean tobacco industry converted to it there may not be sufficient composted pine bark to meet the needs of all growers.

The overhead watered microjet system works and is economic. It is already used very successfully by nurserymen in Zimbabwe on other crops but the level of management required is considerably higher than float management especially for the watering and fertigation regimes. It has been shown that the leaching of nutrient (overwatering) and the rapid drying out of the cells (underwatering) can easily occur if attention to these details lapses for a short period.

Taking all aspects of these different systems into consideration and being well aware of the variation in management styles existent in the Zimbabwean tobacco growing sector it soon became apparent that the floating tray system would be most appropriate. It has been shown to work extremely well in trials and even in large demonstration projects. It is cost effective and does well in low management input situations. For these reasons we concentrated our efforts on improving the float system.

2.2. TESTING DIFFERENT MEDIA FOR THE FLOAT SYSTEM

INTRODUCTION

Composted pine bark has been used to produce seedlings in trays by nurseries in Zimbabwe, South Africa and Australia. However, little work has been done on the use of pine bark in the float system. The depth at which the trays float depends on the type of tray used (amount and density of the polystyrene) and the density of the media. It was therefore necessary to establish if pine bark could be used on its own or if it had to be mixed with other media such as river sand. This section describes the work done to identify the best pine bark/sand mix and experiments to test other locally available media, such as maize stover and groundnut shells, which could be used in addition to pine bark.

DISCUSSION OF RESULTS

The comparison of germination in the greenhouse and outdoors shows the importance of higher temperature in achieving good germination in the float system. Although dibbling showed no effect on germination or fall-outs, the practice will be continued as work in the USA has shown that it is beneficial. These trials also demonstrated that covering the seed in the float system was not necessary and this will be discontinued.

Pine bark is a good medium and will be adopted as the prime organic medium for use in floating trays. Sand is also an important constituent of the mix but it cannot form more than 50% of the mix as fallouts tend to occur. Best media combinations determined so far are 50:50 (pine bark:sand) and 50:40:10 (pine bark:sand:grade 3 vermiculite). Both of these are used as our "standard" media.

Despite its ready availability, especially in the small grower areas, maize stover or any extract of maize has no potential as a medium as the growth of seedlings is decreased. Bagasse could be incorporated up to a level of 10% but, because of its inaccessibility and transport problems, plus the fact that it would have to be sold at a burning fuel equivalent price, it is unlikely to be used.

Groundnut shells are more readily available and prices and supplies should make this a worthwhile medium. It has only recently been tested but it is showing great promise and may well be a substitute for composted pine bark, although will probably not be as readily available.

There were fewer spiral roots on seedlings in outdoor float beds compared with inside the greenhouse. In the greenhouse, seedlings growing in lighter media, such as bagasse or groundnut, appeared to have fewer spiral roots initially, possibly because the trays float higher and have better aeration; this does not appear to be the case outdoors.

2.3. THE ROLE OF THE BIOCONTROL AGENT, *TRICHODERMA HARZIANUM* (AGRICURA T77) IN THE PRODUCTION OF HEALTHY TOBACCO SEEDLINGS IN A FLOATBED SYSTEM.

INTRODUCTION

A local strain of *Trichoderma harzianum* isolated by research staff at Kutsaga Research Station, has been extensively tested against soil-borne pathogens, especially *Thanatephorus cucumeris* against which it is particularly effective. It is produced commercially under the name Agricura T77. New blends of organic substrate for production of the commercial product are presently being evaluated. In the interim we have used both the pure fungus and two new formulations in our trials.

In a series of experiments in which the fungus, *Trichoderma harzianum* was incorporated either as pure, dried fungus or grown on a blended organic base, into various combinations of soilless media, the effect of *Trichoderma* on seedling growth, root colonisation and pathogen control was monitored.

DISCUSSION OF RESULTS

Outdoor floatbed water temperatures which fluctuated between 14 and 27^{0}C and diurnally by several degrees during seedling production, did not appear to affect root colonisation of seedlings by *Trichoderma harzianum*.

In our experiments, both the media on which the *Trichoderma* was originally produced and the medium into which it was subsequently incorporated, affected the efficiency of root colonisation. The most successful root colonisations were either from *Trichoderma* produced in a medium containing maize residue as an organic base, or when *Trichoderma* was added without an organic base, if the soilless medium contained maize residue. The enhancement of *Trichoderma* root colonisation in the presence of maize residue is being studied on the T 77 production side, because maize residue as a component of soilless media is unsuitable for growing tobacco seedlings.

Because of the variability of seedling germination and growth in the outdoor experimental float beds, data on the efficacy of *Trichoderma* as a biocontrol agent was inconclusive. It had no adverse effect on seedling germination and growth, but because of the low root attachment in the experiment where dry mass was measured, there was no evidence that it enhanced seedling growth. Root attachment appeared to peak between 9 and 13 weeks after sowing which corresponds with transplanting and is ideal for the protection of transplants against field pathogens.

2.4. STUDIES TO IMPROVE GERMINATION AND INITIAL GROWTH IN THE FLOAT SYSTEM

INTRODUCTION

In order to make the float system viable there should be more than 85% pullable seedlings. To date, germination in this system has been variable and many factors, such as type of media, source of pellets and air and water temperatures, have been proposed as possible sources of variation.

Some tobacco producing countries, such as Spain, have had problems with erratic germination using locally pelleted seed. The germination improved dramatically once they used an internationally recognised company. Therefore, an experiment was done to investigate the effect of source of pelleting of locally produced seed, on germination and seedling growth. The stand count of seedlings can be decreased due to dry cells and media falling out of the trays (fallout). Different trays were compared in an experiment to identify those which were unsuitable.

Countries such as the USA produce the majority of their float seedlings in greenhouses. This could make the cost of replacing methyl bromide prohibitive in Zimbabwe and we have decided to try and grow our float seedlings under small plastic tents or with no tents under warmer conditions. The main problems in not using a greenhouse are very low temperatures and delayed germination. Considerable effort is being made to find ways of speeding up the germination process under these relatively cold conditions. A commercial producer of flower and vegetable seedlings suggested pre-germinating (incubating) the seed after sowing, but before floating the trays.

Disease in the float system is a potential hazard and tray sterilisation can be a major problem. Research is being done in the USA on the use of PVA paint mixed with copper to coat the trays in order to decrease disease incidence and extend the life of the trays. A preliminary experiment was done to test the phytotoxicity of various "home-made" copper/coloured paint mixes and a commercial product. Dark coloured paints such as black and red were used as it was noticed in the overhead watered system that seedlings in black trays grew faster than those in the white polystyrene trays.

DISCUSSION OF RESULTS

Trays with larger and fewer cells than the 128 were not suitable because the larger holes in the base of the cells encouraged higher levels of fallout and because of the higher costs associated with the larger area of seedbed required per hectare of tobacco planted. After several experiments using pelleted (coated) seed from various major overseas sources it appears that there is very little difference in the source of seed in regard to germination rates and growth performance. There were few differences between primed and unprimed seed. The primed seed germinated faster than the unprimed but there was little difference overall. It appears that the use of primed seed does not reduce the need for warm temperatures for rapid germination. However, we have seen seed pelleted in South Africa that appears to be sub-standard physically compared to what we have been working with.

In order to decrease the cost and risks associated with sending seed overseas for pelleting, the technology would have to be developed locally. This would require extensive research and capital input in the future. Consequently, we are investigating the possibility of sowing uncoated seed into floating trays, although there may still be a case for a certain percentage of our seed requirements to be pelleted, perhaps for some small growers who will not have easy access to the more sophisticated sowing techniques and machinery. In addition, work has shown that uncoated seed germinates faster and more uniformly than pelleted seed and as we are aiming for a minimum of 85% pullable seedlings per tray, the higher and more reliable our germination figures the easier it will be to maintain this minimum requirement.

Work continues with pre-germination techniques such as the stacking of trays, both in greenhouses and in the open, and it appears that an incubation period of 5 days in a stacked, high humidity and warm environment does stimulate better germination in outdoor float seedbeds. Stacking for longer than this resulted in etiolated seedlings which did not survive possibly due to the sudden and excessive changes in the environment.

Additional work on sterilising used trays and ensuring that they contain no plant pathogens using biocidal paints and steam are being evaluated. Dark coloured paints were chosen to increase the temperature surrounding the seedling so as to stimulate post-germination growth. None of the dips or paints used so far have had any detrimental effects on germination and it is difficult to establish whether the small growth differences observed in the seedlings were due to the effect of the different disease deterrent chemical additives or to the colour of the trays. This is now being further tested in an outdoor environment where the differences may become more apparent.

Experiments planned for this season involve identifying the best environment for pre-germination by stacking and whether simple plastic covered stacks outside in the middle of our winter will produce the desired effect. Studies on further seedling growth enhancement include using black painted trays to increase the surface temperature of the trays and documenting the difference between coated and uncoated seed in the rate of germination and subsequent growth of the seedlings.

2.5. HARDENING FLOAT SEEDLINGS TO WITHSTAND DRY PLANTING CONDITIONS

INTRODUCTION

Zimbabwe normally has dry conditions at the time of transplanting into the field and traditional seedlings are well hardened. Therefore, it was necessary to ensure that plants produced in "speedling" trays could be sufficiently hardened.

The recommended size for traditional seedlings is 15 cm in length and about pencil thickness (6 mm). Traditional seedlings that are smaller than this do not establish well under the hot conditions prevalent at planting time. The seedlings produced in 128 cell trays are similar in size to the traditional ones, however, these are more expensive to produce than those in the 200 cell trays. Therefore, it was necessary to test if the seedlings from the more economic 200 cell trays responded any differently in the field. It had been suggested that monopotassium phosphate (MKP) could be used as a drench in a situation where the hardening of seedlings was disrupted by the addition of water or by rain.

DISCUSSION OF RESULTS

The results show that float seedlings can be hardened. Two experiments to evaluate Monopotassium phosphate (MKP) as a drench to harden seedlings yielded no positive results and so further work on this method of hardening is not planned.

The 128 cell tray has generally been used as the standard in our trials because early work showed that it produced a seedling very similar, in all aspects, to the traditional seedling. However, our work shows that the size of the float seedling is not as critical as first supposed and that the seedlings produced in 200 cell trays, though smaller at transplanting, grow well in the field with no yield or quality differences. There are obvious economic advantages from using the 200 cell seedling trays (see Economic Discussion, page 14) and, because it is now apparent that 200 cell seedlings are as successful in the field as the 128 seedlings, we intend concentrating on this size of tray for future float development in an effort to establish it as the standard option for float seedbed production in Zimbabwe.

In one experiment, the float seedlings produced a higher yield of tobacco compared with traditional seedlings. This may have been associated with the intact-root, compared with the bare-root. However, there were no differences between seedling source in the second experiment and therefore yield advantage was not included as a benefit in the economic studies. Although there are unlikely to be yield benefits from using float seedlings, growers will probably prefer them because the seedlings are more uniform which makes the crop easier to manage, especially for topping.

Trial work being done this season tests the hardening of float seedlings through the withdrawal of nitrogen rather than the traditional method of withdrawing water completely at hardening time. These will be planted out into the field in a dryland situation. Also, hard and soft seedlings produced in both 128 and 200 cell trays will be transplanted into the field as an irrigated crop to determine if float seedlings need to be hardened by withdrawing water and to compare again the different cell sizes.

2.6. ACQUIRING AND DISSEMINATING THE INFORMATION ON ALTERNATIVES TO METHYL BROMIDE

INTRODUCTION

The UNIDO demonstration was done to comply with the Terms of Reference (Point 16) which states that we must, "during the second cropping season, and in three different sites, representative of the climatological and soil conditions of Zimbabwe, prepare and carry out at full commercial scale three demonstration tests using the best technologies selected. These full scale demonstration tests have to be done in areas where tobacco is grown by small holders and the surface should not be less than one hectare each." The objective was to demonstrate alternatives to methyl bromide in the production of tobacco seedlings at four sites around Zimbabwe. Research staff at the Tobacco Research Board and both small scale and commercial farmers were invited to attend field days/ workshops at the different sites.

This section also very briefly describes some of the workshops, conferences and study tours attended. Full reports have been submitted to UNIDO.

DISCUSSION OF RESULTS

The various study tours, workshops and conferences were vital in acquiring information on seedling production and making contacts with other research people. This has resulted in a significant decrease in the time required to develop the systems.

The demonstrations made tobacco growers aware of the pending ban on methyl bromide as well as the systems that are likely to replace the current practices.

Growers perceptions of the seedbed demonstrations

The general feeling was that the float seedbed method was the best. Growers said it was the best because of:

1) ease of management
2) fewer inputs required
3) the permanent site for seedbed
4) the ease of pulling the seedling and the undisturbed root structure
5) no major watering requirements for seedbed

Most of the people consulted were less concerned about the cost compared to the standard seedbed because they saw it as a relatively economic way of producing seedlings with more advantages than any other systems so far demonstrated. Their main worry was one of disease but felt that as research was still ongoing, such problems would be overcome.

Field days to demonstrate the float system to tobacco growers are planned for the coming season and the system will be discussed in the tobacco extension tours in June 2001. It is likely that many growers will begin to use the system after the extension tours.

3. Economic Comparison of the Alternatives to Methyl Bromide

INTRODUCTION

The aim of the project was to demonstrate the technical and economic feasibility of alternative methods to the use of methyl bromide as a fumigant in tobacco seedbeds under experimental conditions. This economic analysis compared the traditional method of seedling production with the methods that use soilless media: 128 and 200 cell polystyrene trays in the float system, 128 and 153 cell polystyrene and black plastic trays (suspended), respectively, watered by microjet and the permanent pine bark seedbed.

Seedling production costs

The economic analysis carried out during the first phase of the study focused on the costs incurred for the different seedbed techniques (Half-Yearly Report 1). The discounted cost estimates for the different seedbed techniques indicated that the most expensive technique is that involving the use of permanent pine bark. The rest of the seedbed techniques were ranked as follows (with the most expensive at the top):

- 128 cell Suspended seedbed;
- 128 cell Float seedbed;
- traditional seedbed;
- 153 cell Suspended seedbed;
- 200 cell Float seedbed.

Overall enterprise viability

The second and third phases of the economic analysis sought to establish the impact of the various seedbed techniques on overall enterprise viability (Half-Yearly Reports 2 and 3). For the analysis carried out during phase 3, the estimates made during the second phase were updated.

The results of both phases show that the various seedbed production techniques can be ranked as follows (with the best crop values at the top):

- 153 cell suspended;
- 200 cell float;
- 128 cell suspended;
- 128 cell float;
- traditional;
- permanent pine bark.

Thus the observations made during the second phase were confirmed during the third phase. However, a decline in the NPV's was noted, illustrating a possible cost-price squeeze affecting the tobacco producers, under the macro-economic environment prevailing at the time (characterised by high rates of inflation and a pegged exchange rate).

The fourth phase of the study seeks to review the findings of the previous three phases with a view to identifying the emerging trends and drawing conclusions on the overall findings of the study. Based on the findings of the first two phases the study was reconfigured to focus on three techniques:

- 200 cell float;
- 128 cell float;
- traditional seedbed technique.

In addition, each of these techniques has been studied to show the difference between the cheap and expensive approaches to seedbed establishment. The results show that the 200 cell float (dear) technique gives the best crop over a ten-year crop, while the traditional (dear) shows the lowest crop value. The overall values of the crops compared to the base case (traditional-cheap) are:

- 0,9% lower for the traditional (dear);
- 19,8% higher for the 128 cell float (dear);
- 20,9% higher for the 200 cell float (cheap);
- 22,1% higher for the 128 cell float (cheap);
- 27,7% higher for the 200 cell float (dear).

The overall results of this study show that the use of alternative techniques as illustrated would not have a negative impact on the crops grown. In fact, the results achieved over the past two seasons illustrate that the value of the crops produced could actually be better than those produced with the traditional seedbed techniques. The 200 cell float method is the best option from both the practical and economic aspects.

A word of caution has to be expressed in interpreting the results of this economic analysis. Throughout the study period, and especially in the past five to six months, the macro-economic environment prevailing in the country has been very turbulent. The high rates of inflation have contributed to a rapid increase in the cost of production. On the other hand, the authorities have insisted on maintaining a fixed exchange rate (against the US dollar) resulting in an overall cost price squeeze in the tobacco production sector.