# FINAL REPORT

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**Tomato: Reducing waste disposal costs through the use of sustainable wood-based growth media.**

March 2006

**Commercial – In Confidence**

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|---|---|
| Project Title**:** | Tomato: Reducing waste disposal costs through the use of sustainable wood-based growth media. |
| Project number: | PC 209 |
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| Report: | Final report |
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The results and conclusions in this report are based on a carefully monitored applied experiment in a large-scale experimental glasshouse. The conditions under which the studies were carried out and the results have been reported with detail and accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with the interpretation of the results especially if they are used as the basis for commercial product recommendations.

## Authentication

I declare that this work was done according to the procedures described herein and that this report represents a true and accurate record of the results obtained.

Signature…………………………………………………………………………….

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# GROWER SUMMARY

## Headline

- Agronomic assessments revealed that there were no consistent differences between tomato plants (cv Aranca) grown on fine-composted conifer bark (FCCB) and rockwool substrates. A good quality crop was produced in both FCCB treatments with numbers of marketable trusses harvested comparable to that achieved from a rockwool-grown crop. Fruit weight was slightly lower in the reduced irrigation FCCB treatment but not below the supermarket specification.
- The most cost effective option for a secondary use of the FCCB medium was application to agricultural land. However, waste regulations soon to be implemented might make this a less attractive choice.
- Processing once-used FCCB for secondary use, either via a green waste handler or growing media manufacturer, is economically viable and more environmentally beneficial than disposal to landfill.

## Background and Expected Deliverables

The UK Government has set targets for reducing the amount of waste entering landfill as this resource is now in short supply. Tax levies on material entering such sites have increased significantly to encourage industries to develop more sustainable solutions to waste disposal. This has placed a considerable financial burden on protected salad growers who have to dispose of rockwool-based growing media at the end of each season.

The overall aim of this work was to improve waste management and reduce the cost of disposal of used growing media for the UK tomato industry. The approach was to assess the potential of candidate forest-residue-based growing media for glasshouse tomatoes. The supply chain for the raw materials was recognised as becoming increasingly reliable with the material derived from an environmentally sustainable source. It was proposed that at the end of a full-season tomato trial the successful medium, chosen from initial trials investigating a range of candidate materials, would be composted and assessed for secondary use as a soil conditioner and / or growing medium for other crops. This would obviate the need for disposal to landfills.

## Summary of the project and main conclusions

### Preliminary trials:

Initial trials with tomato plants (cv Aranca) were conducted to assess the agronomic performance of four candidate test growing media (TGM) against a commercial rockwool control. TGM evaluated in this trial were:

Fine composted conifer bark (FCCB)

Fine composted wood fibre (FCWF)

Fine composted post-industrial wood blends (FCI)

Fresh pine fines (FPF)

Based on previous work, composted materials were shown to be more stable than fresh material. However, FPF was included as a trial treatment to further assess whether composting is necessary prior to use as a growth substrate for tomato crops.

These trials revealed little difference with regard to the measured agronomic parameters (*i.e*. internode length, stem diameter, leaf length, plant extension) between the various TGM and rockwool. Fruit development also remained the same, until the fourth truss stage was reached. At this time plants grown on rockwool had slightly higher numbers of fruit developing on this truss. The extent of root development within the TGM was shown to be similar to that seen in rockwool. In the absence of any significant differences in agronomic performance between the TGM, FCCB was chosen as the best candidate material to take forward. This was based on price, availability and previous experience with this material.

### Full season trial:

A full season tomato trial was established to further evaluate the performance of FCCB against a rockwool control. Two 200 $m^2$ modern glasshouse units were made available for this work. Rockwool and FCCB substrate treatments were allocated to separate glasshouse units. A sub-treatment was included with the FCCB media to investigate the effect of a reduced irrigation strategy. One treatment received the same irrigation volume as rockwool (designated M100) and the other was supplied with irrigation at 80% of that supplied to rockwool (designated M80).

Agronomic assessments revealed that there were no significant differences between FCCB and rockwool grown plants irrigated at the same level in terms of plant extension, stem diameter and truss development. Plants in the M80 treatment developed thinner stems after 16 weeks of growth. This became less pronounced towards the end of the assessment period (week 28). Leaf area was also slightly reduced in the FCCB treatments.

Measurements of fruit yield showed that there were no differences in the numbers of fruit harvested between treatments. Trusses harvested from plants in the M80 treatment were lower in weight than those from M100 and rockwool (MW) treatments. However, they were still within the supermarket weight specification for this variety and so there was no reduction in value.

The FCCB media retained a moisture content slightly higher than that measured in rockwool and root development under both irrigation regimes was comparable, if not more extensive (certainly in the M80 treatment), than in the rockwool system. Drain measurements showed that run-off from both FCCB treatments was similar and slightly higher than shown for rockwool, re-affirming the potential for lower water application when using FCCB substrate.

End-of season analysis of FCCB medium revealed that it retained its original structure, with negligible breakdown of components.

## Financial benefits to growers

One of the main motivations for this project was to provide data on the feasibility of growing media for protected crops that could avoid costly disposal to landfill and provide a resource that could be re-used as an environmentally sustainable product.

**Economic evaluation of FCCB**:

The producers of FCCB media (Melcourt Industries Ltd.) indicate that FCCB slabs can be commercially produced at levels competitive with rockwool. There are no extra costs associated with the primary use of FCCB for tomato production. The costs associated with transport away from site and preparation for secondary use are addressed in the next section.

**Economic evaluation of wood based growing media for secondary use:**

The various options for processing the once-used FCCB media were investigated. The economic analysis revealed:

- The most cost effective option for a secondary use of the FCCB media was in its application to agricultural land. However, waste regulations soon to be implemented might make this a less attractive choice.
- Processing FCCB for secondary use, either to a green waste handler, or collection by growing medium manufacturer for re-composting and re-use as growing medium or soil improver, are both more economically viable and environmentally beneficial than disposal to landfill.

## Action points for growers

- From this work it has been shown that FCCB material can realistically be used for the commercial production of tomato crops without a significant loss in yield and quality compared with the current industry standard of growing in rockwool.

- Evaluation of secondary uses for FCCB material indicate that the options of application to land, disposal via green waste operator, and collection by growing media manufacturer, are economically more viable, and allow a more sustainable use of resources compared with disposal to landfill.

- UK growers of protected crops are being made more aware of the commercial potential of FCCB growing media and its secondary use potential. This will allow a greater flexibility of choice when faced with increasing landfill charges and the need to reduce these costs, both environmentally and economically.

# Science Section

## 1. INTRODUCTION

Mineral wool (rockwool / MW) is currently the most widely used hydroponic substrate for commercial salad production in the UK. Its biologically inert nature allows optimum control of crop nutrition. It was calculated that the total area for salad crops (tomatoes, cucumbers, sweet peppers) grown in rockwool growing media was 401 hectares for the 1999 – 2000 growing season, although this may have since declined. This represented approximately 80% of the area grown for these crops (Drakes *et al*, 2001). Despite the fact that growers may re-use their rockwool slabs for several seasons, and that a recycling plant for rockwool exists, a large proportion of used slabs are still disposed to landfill. However, due to the Government's strategy for waste management, an increasing tax is being levied on material entering landfill to encourage industries to adopt more sustainable approaches to waste disposal. This increasing financial burden on protected salad growers has led to investigations into alternative media.

The potential of forest-residue-based growing media (FRGM) was individually explored by several tomato growers in association with Melcourt Industries Ltd. and in other private trials (Harriman, pers. comm. 1995). These preliminary results were promising and laid the foundations for further investigation. The supply chain for these raw materials is increasingly reliable and is derived from an environmentally sustainable source.

This project seeks to develop a more sustainable approach to glasshouse tomato production. It is proposed that after initial use in tomato production, a wood based growing media could be re-composted, eliminating disposal to landfill, and then re-used as a soil conditioner or growing media for other crops (e.g. as a blend with green waste for peat-free compost). To work towards this goal, the project consortium includes applied scientists, commercial tomato growers and a growing media producer.

Following the results of initial trials at Stockbridge Technology Centre (STC) in 2004, fine composted conifer bark (FCCB) was chosen as the material that performed the best overall and offered the most assurance in terms of financial considerations. The aim of the work in 2005 was to assess the agronomic performance of a tomato crop grown in FCCB media in a season-long trial against rockwool as a commercial standard comparison.

Initial work has shown that FCCB has a lower water retention compared with rockwool. It was therefore decided to split the FCCB media into two treatments to look at potential water saving. One treatment received the same irrigation volume as rockwool (M100) and the other was supplied with irrigation at 80% of that supplied to rockwool (M80).

## 2. GLASSHOUSE TRIAL

### Materials & Methods

**Cultural Details**

Tomato seeds, cultivar Aranca (Enza Zaden, UK) were sown onto either rockwool or standard seedling compost (Levingtons, M3) on the 12 December 2004. Young plants were transferred on the 10 February 2005 into two approx 200m$^2$ venlo glasshouse units. One glasshouse was used for each type of growing medium. Each glasshouse contained ten rows (8 experimental rows plus two guard rows) of either rockwool slabs (11L volume) or FCCB bags (20L volume). Four plants were allocated per bag to give a planting density of 2.6m$^{-2}$, giving a total of 320 experimental plants in each glasshouse unit. Plants for the FCCB treatments (M80 & M100) were planted directly into this media rather than placed on top of the slab, as was the case with plants raised in rockwool (MW).

Each crop was grown according to commercial practice, with eight fruit allowed to develop to maturity on individual trusses. Biological control was used to control pests and fungicides used according to disease level. Table 1 summarises glasshouse environmental control parameters and irrigation frequency for this work.

**Table 1. Environmental set-points for growth of a Tomato crop**

| | |
|---|---|
| **Temperature** | |
| am | 17 ºC |
| pm | 18 ºC |
| Pre-night | 16 ºC |
| Night | 17 ºC |
| **Irrigation (radiation sum mls joule$^{-1}$ m$^{-2}$)** | |
| MW & M100 | 3 |
| M80 | 2.4 |
| **$CO_2$ enrichment set-point** | 950 ppm |

Two weeks after plants were transferred to the glasshouse, additional heads were taken (1 every other plant) to give a final head density of 4 per $m^2$.

When the crops had matured, a continual de-leafing strategy was adopted which subsequently allowed approximately 18 leaves to remain on each plant. Crop management tasks (layering, twisting, and leaf removal) were carried out weekly. When the crops were producing ripe fruit, harvests were taken three times a week.

## Irrigation and Nutrition

A typical commercial rockwool feed for tomato crops, as advised by the project consultant, was employed for the duration of the trial for all treatments. Regular monitoring of electrical conductivity (EC) and pH in the run-off was carried out to ensure correct levels were maintained in each treatment. When the crop reached maturity, irrigation was switched to radiation starts and applied at the rate of 3 ml per joule per $m^2$. This was altered accordingly for the M80 treatment.

## Assessments

### *Crop growth and fruit development*

Plant growth was monitored weekly by tagging the growing point of the plant (20 plants were monitored for each treatment) from the beginning of the investigation and measurements were taken for:

1) Weekly plant extension.
2) Stem diameter (measurements taken at beginning of current weeks growth).
3) Truss development - the number of open flowers and number of fruit set measured at the end of a 1 week growth period.
4) Leaf area. The three lowest leaves were taken from eight plants per treatment on two separate occasions (12$^{th}$ May & 13$^{th}$ July). Leaf area was determined using a Li-3100 Area Meter (Li-Cor Inc., USA).

Growth measurements were initiated on the 1$^{st}$ March (Week 1 on graphs), 26 days after planting and 8 days after the separate irrigation treatments were imposed.

***Fruit yield & quality***

Numbers of trusses and bulk fresh weight were recorded for each treatment on a row basis. Harvests were carried out three times a week. Individual fruits (15 per treatment) were taken at the same stage of fruit ripeness at two time points during the growing season and the Brix Value (Total Dissolved Sugars [TDS]) was measured.

***Irrigation measurements***

Daily water application was monitored using spare drippers on each treatment line.
The run-off from each treatment was monitored with troughs placed beneath two rockwool slabs / media bags in two rows per treatment and collected in containers at the end of each row. Measurements were initially taken weekly and this was subsequently increased to three times a week.

The moisture content of the substrate in each treatment was monitored at regular intervals using a W.E.T sensor (Delta T systems, Cambridge, UK). On each occasion 15 measurements were taken per treatment.

***M80 & M100 analysis***

A sample was taken for analysis at the mid-point of the trial (15 weeks after planting) in order to assess for any changes in the chemical or physical characteristics of the media. Samples were also taken in June and July to look for any gross differences in the composition of nutrients in the solution draining from the rockwool or FCCB treatments (M80 & M100).

## Results & Discussion

### Crop Growth

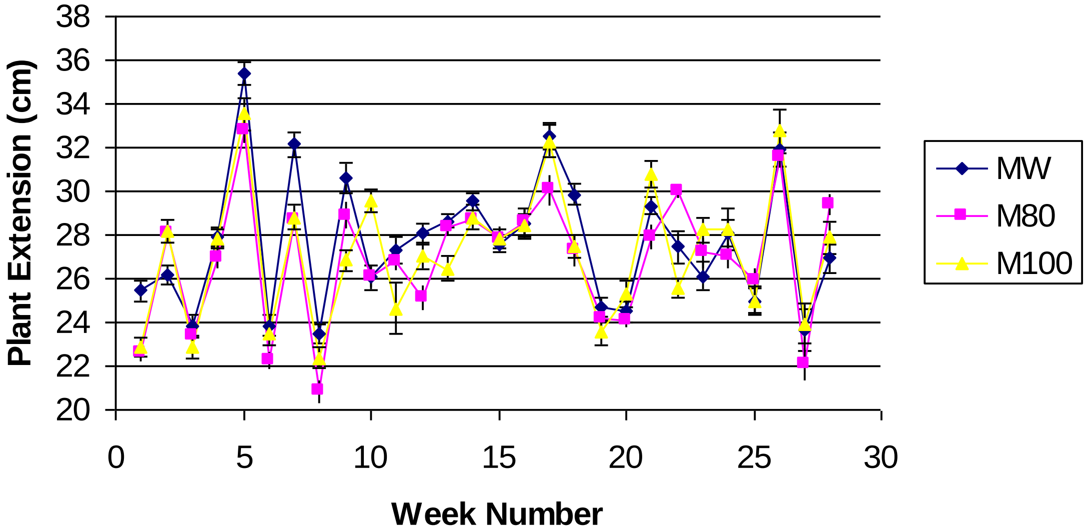
As mentioned in the Methods section, plants destined for the FCCB media were raised in Levingtons compost initially and transplanted directly into the treatment bags rather than placed on top of the substrate, which was the case for rockwool plants. It became apparent that this caused a transfer stress that slowed early development of

M80 and M100 treatment plants. At the end of the first week the plants in rockwool treatments had developed to the second truss, whilst only the first truss was developing in the FCCB treatments (See Appendix B for data from a small scale trial on plant raising in peat-free media similar to FCCB). As a consequence, the side shoots that were used to provide additional heads were taken a truss lower in FCCB treatments than in rockwool.

## Plant Extension

The weekly plant extension measurements (Figure 1) highlight the initial difference in growth between treatments, but this had disappeared by week 2. Overall, it can be seen that there were no consistent significant differences between the three treatments over the measurement period.

**Figure 1. Mean weekly plant extension measurements. Data represents the mean of 20 samples per treatment ± SE. (NB: Week 1 was 1 March 2005, MW = rockwool)**




## Leaf Area

Initially, as the crop in each treatment approached maturity, there were little visible signs of differences between treatments. However, after 14 weeks of growth in the trial glasshouse (week commencing 12th May) the foliage in the M80 treatment had become visibly less dense than in the other treatments. Table 2 shows that plants grown in FCCB treatments had a lower leaf area compared with the rockwool control.

**Table 2. Mean leaf area (cm²) of the lowest three leaves from eight plants from each treatment ± SE.**

| | Treatment | | |
|---|---|---|---|
| **Date** | **Rockwool (MW)** | **M100** | **M80** |
| 12th May (Week 14) | 1781.89 | 1417.37 | 1372.23 |
| 13th July (Week 24) | 2037.01 ± 112.6 | 1600.45 ± 45.44 | 1411.45 ± 72.52 |
| 21st October (Week 37) | 2164.83 ± 119.2 | 1444.83 ± 91.1 | 1460.1 ± 87.5 |

Figures 2-4 show the crop in each treatment at approximately the same time as the first leaf samples were taken for area determinations. The differences highlighted in Table 2 suggest there is a reduction in leaf area in plants grown using FCCB media. The glasshouse environment for FCCB grown plants in this trial was kept the same as for the rockwool crop. The changes in leaf area seen have been modified by manipulating the night temperature to influence vegetative growth.

**Figure 2. Rockwool Crop**

**Figure 3. M100 Crop**

**Figure 4. M80 Crop**

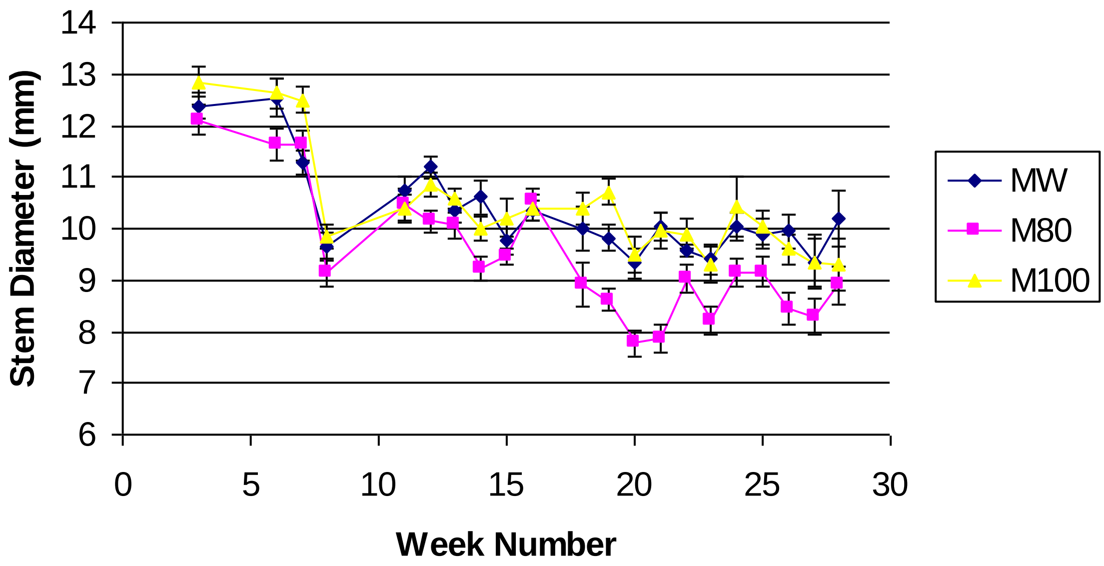

## Root Development

At the end of the trial (41 weeks after glasshouse planting) FCCB bags were cut open and the root development assessed before media was re-bulked for re-composting. It was apparent that the root mass in the M80 bags was much higher than in the M100 counterparts. This is not straightforward to explain as the moisture contents in both these treatments were similar, but may be due to higher phosphorus levels remaining in the M80 bags (Appendix A, Table A). This element is known to affect root growth by affecting the extent to which organic acids are released by the plant that enable myccorrhizal connection to be made and hence efficient nutrient uptake. If the phosphorus level is too high then these connections are not formed and the plant has to invest more energy in producing a larger root network (Chalker-Scott, 2005).

## Stem Diameter

Figure 5 shows that there are negligible differences in stem diameter between the rockwool (MW) and FCCB treatment applied the same irrigation volume (M100). From week 18, the mean stem diameter in the reduced irrigation FCCB treatment (M80) deviates significantly from the rockwool and M100 treatment to a mean stem diameter of 7.8 cm. Mean stem diameter then increases from this point whereas at week 28 it is statistically insignificant compared with the M100 treatment, but still remains significantly lower than the rockwool treatment.

**Figure 5. Mean stem diameter. Data represents the mean of 20 samples per treatment ± SE. Week 1 was 1 March 2005.**




## Truss Development

Overall, growth rate was such that plants in each treatment developed three leaves and a truss each week. Assessments were carried out on the previous weeks growth and in each case there was a truss whose fruit were in the process of setting (truss 1, at the base of the previous week's growth) and a younger truss (truss 2, at the base of the current week's growth) undergoing anthesis. Trusses were trimmed once eight fruit had set. There were no clear treatment differences in the number of flowers developing on the youngest two trusses (Figures 6 & 7). There were more open flowers on truss 1 on 15 June in rockwool-grown plants compared with other treatments. This is reflected in a lower number of fruit set (Figure 8). Fruit set for truss 1 only differed significantly at the start of the trial, due to the initial lag caused by the transfer of the plants from pots to FCCB treatments and was before truss trimming was employed. Overall, the data presented in Figures 6 - 8 show there are no consistent significant differences in the rate of truss development between treatments.

**Figure 6. Mean number of open flowers on truss 1 (oldest truss on previous weeks growth). Data represents the mean of 20 samples per treatment ± SE.**

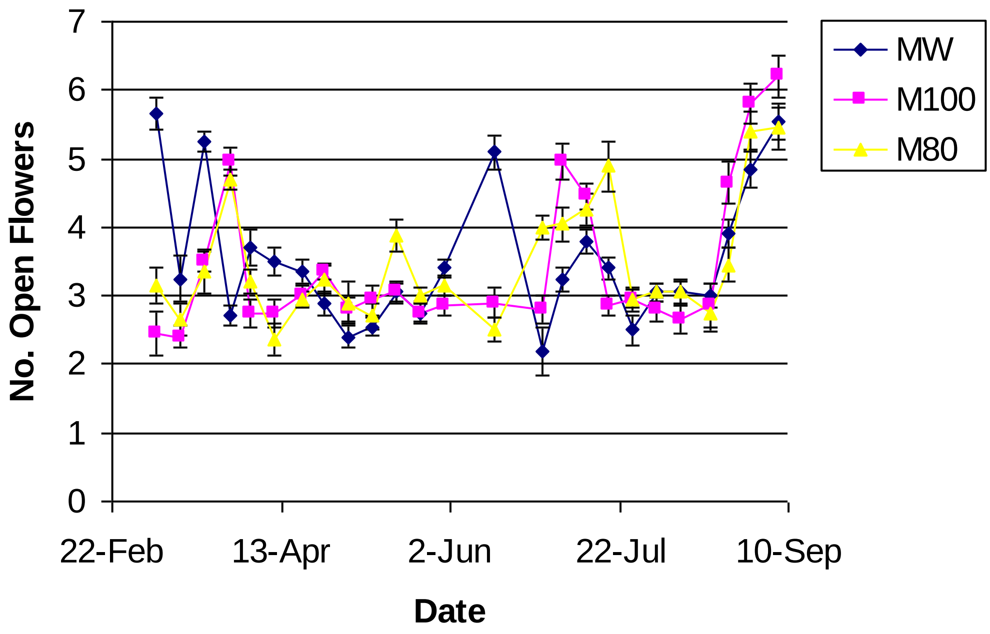



**Figure 7. Mean number of open flowers on truss 2 (youngest truss on previous weeks growth). Data represents the mean of 20 samples per treatment ± SE.**

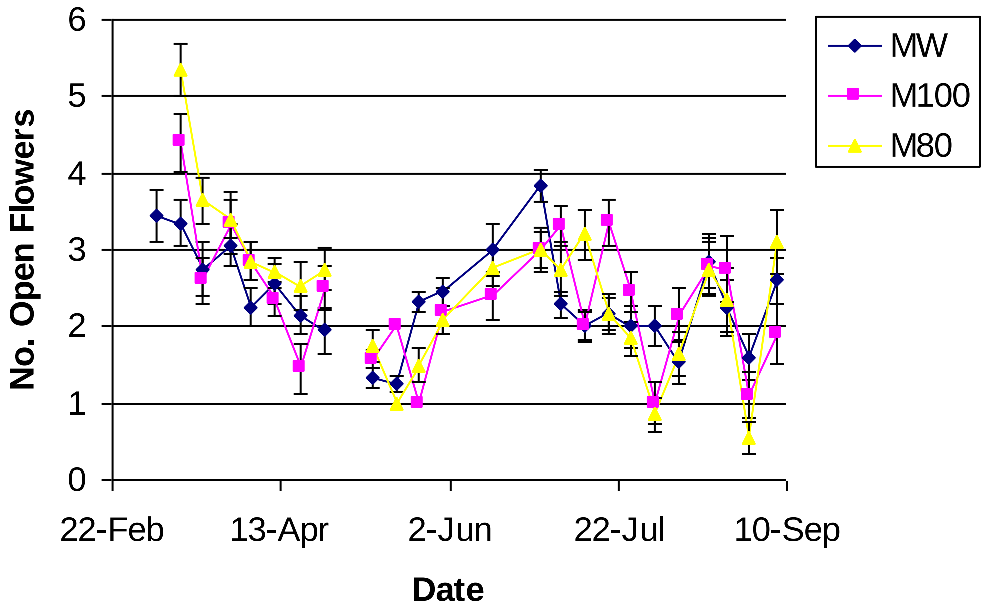
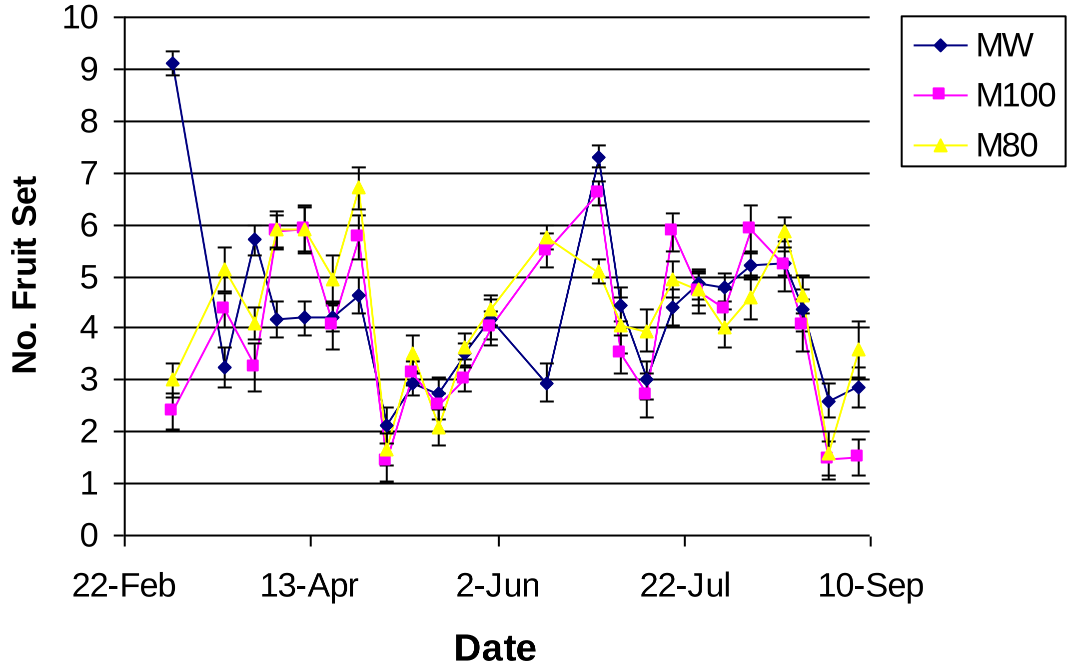


**Figure 8. Mean number of fruit set on truss 1 (oldest truss on previous weeks growth). Data represents the mean of 20 samples per treatment ± SE.**




## Yield

Harvests began in all treatments on the 24 April (Harvest week 1) and were carried out three times a week until the end of the trial. The cumulative data presented in Figure 9 shows that the number of trusses harvested from each treatment was similar between treatments and almost identical from harvest week 15. The slight difference during the early phase of the trial may be attributed to the slower start in the FCCB treatments (M100 & M80) caused by the different planting method at the outset. There was a larger difference in the yield for the M80 treatment when expressed on a fresh weight basis (Figure 10) with a lower cumulative yield apparent. This was due to smaller fruits developing (Figure 11) in this treatment. However, these fruits were still within the supermarket specifications for the Aranca variety (Specification: 230g per truss for Tesco, 248g per truss for Sainsbury's) and would not have caused a reduction in income.

Individual fruits taken for Brix assessment gave mean TDS levels of 6.6, 6.6 and 7.1 for rockwool, M100, and M80 respectively. The difference was analysed as not significant, although the trend in M80 is perhaps not surprising given the lower irrigation application and thus smaller fruit leading to a concentration of sugars.

**Figure 9. Cumulative yield (Number of trusses / m²) in respective treatments.**

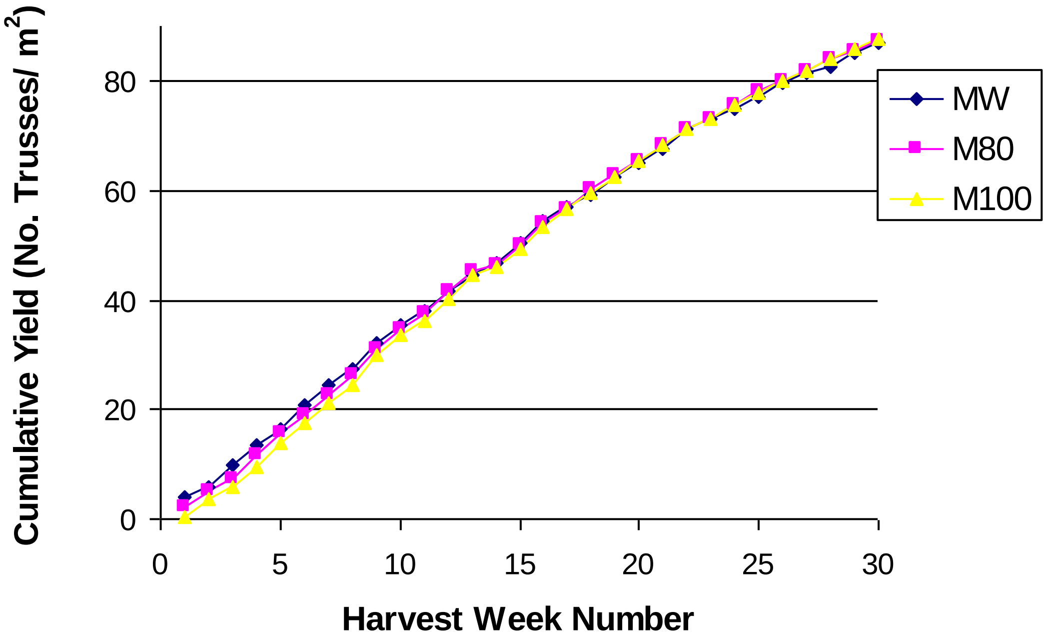



**Figure 10. Cumulative yield, expressed on a fresh weight basis (kg/m²) in respective treatments.**

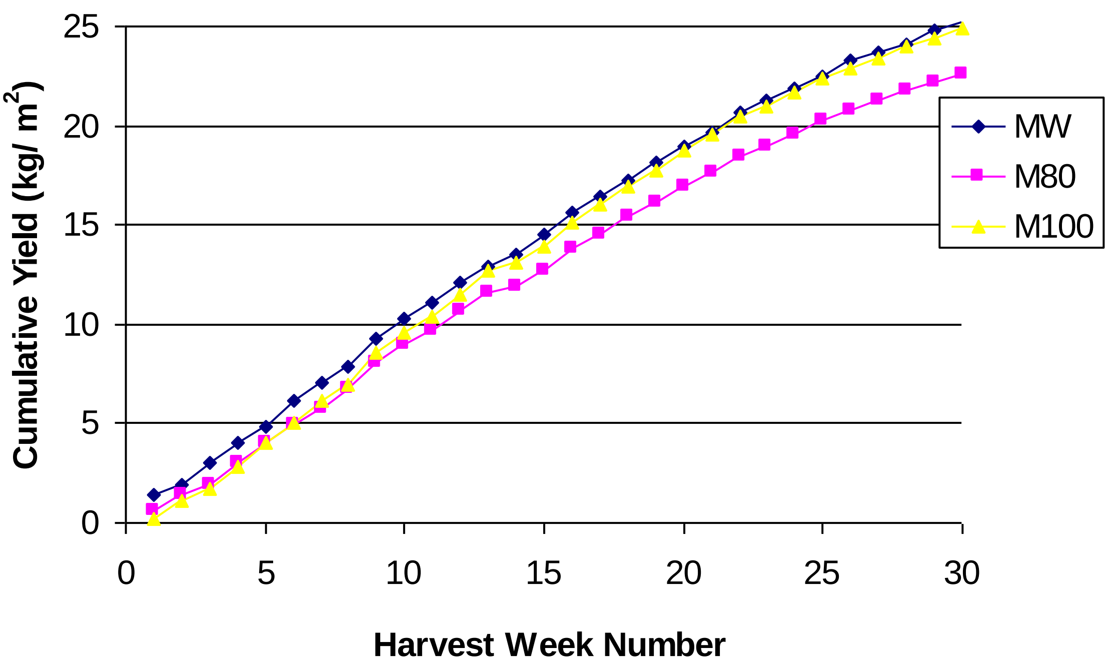
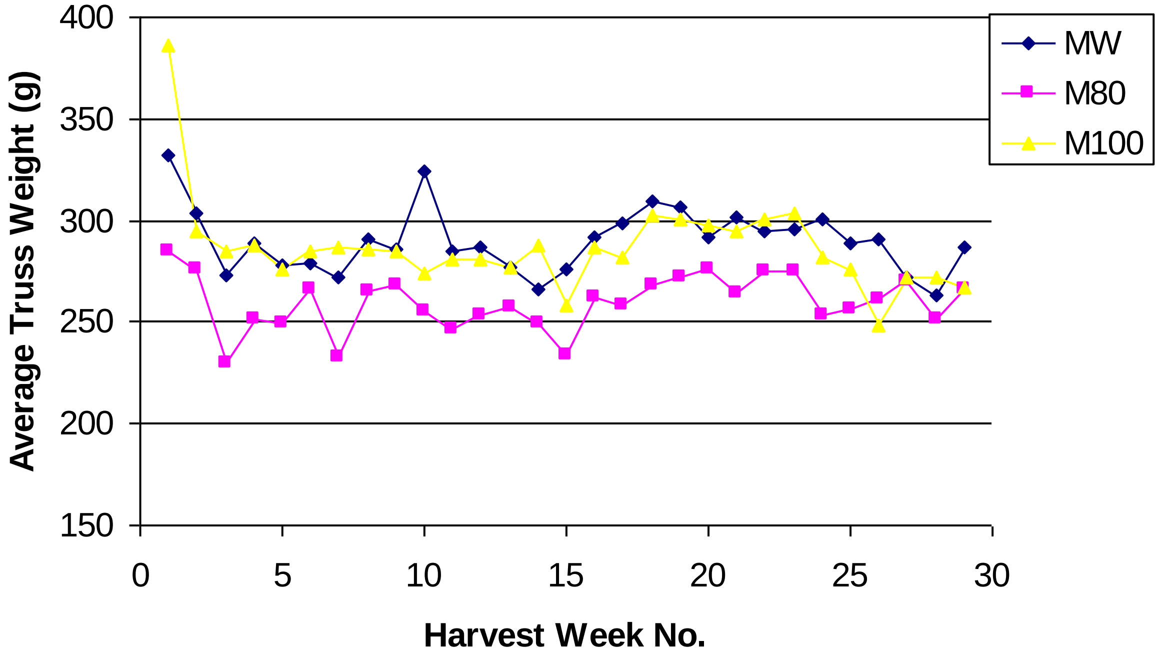


**Figure 11. Mean truss weight for each harvest from respective treatments.**




At the end of the trial (14th November), 41 weeks after glasshouse planting, all remaining unripe trusses were removed from the crops. Numbers of trusses still developing, per $m^2$, were 0.63, 1.25, and 1.07 for rockwool, M100 and M80 respectively.

## Yield From Industry Partners

Total fruit yield was also recorded from trials on commercial nurseries involved in this work. Table 3 shows the yield from Flavourfresh Salads Ltd. The variety used was Classy. Two rows ($53.6m^2$) comprising FCCB media were compared with two rows of the commercial standard rockwool over the period of fruit harvesting (week 13 – week 41).

**Table 3. Yield data from Flavourfresh Salads Ltd.**

| Media | Average Truss Weight (kg) | Total Number Trusses per $m^2$ | Cumulative Fresh Weight (kg) |
|---|---|---|---|
| FCCB | 0.57 | 53.62 | 2874 |
| Rockwool | 0.56 | 47.65 | 2554 |

## Water use & moisture content

Figure 12 shows the daily irrigation levels for each treatment. The rockwool (MW) and M100 treatments irrigation application were indistinct throughout the majority of the trial, hence the reason for not seeing the rockwool data on the graph. An average of 86% reduction of this amount over the trial duration was achieved for the M80 treatment.

The measurements of run-off from slabs at the end of treatment rows were compared with application volume from the same area (see Appendix A, Figure A for drain data). Table 4 shows the percentage run-off figures based on these values. There is a slight difference in the percentage run-off between treatments, with a 5% increase apparent between rockwool and FCCB media irrigated at the same volume (M100). The similar run-off % in the M80 treatment suggests that plants may have been using less water than in the other treatments. This could explain the lower leaf area and smaller fruit size data presented earlier.

**Figure 12. Irrigation levels for duration of trial in respective treatments.**

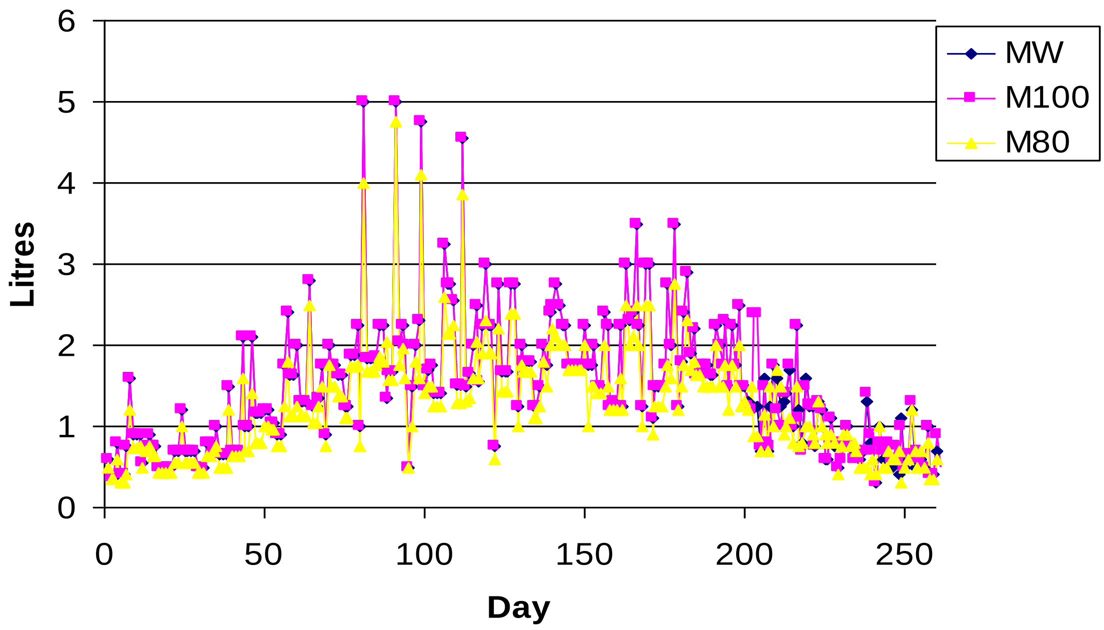


**Table 4. Percentage run-off from respective treatments.**

| Treatment | Irrigation Volume Applied (Litres) | Drain Volume (Litres) | % Run-Off |
|---|---|---|---|
| **Rockwool** | 4317.6 | 780.8 | 18.08 |
| **M100** | 4332.2 | 1001.9 | 23.13 |
| **M80** | 3623.4 | 791.5 | 21.84 |

However, despite the difference in irrigation level imposed in the FCCB media, the moisture content and temperature, measured at 4pm, remained very similar between treatments (Table 5).

**Table 5. Mean moisture and temperature in trial media over the trial duration. Data represents the mean of 15 measurements per treatment on each occasion.**

| Date | Rockwool | | M80 | | M100 | |
|---|---|---|---|---|---|---|
| | Moisture (%) | Temp. (°C) | Moisture (%) | Temp. (°C) | Moisture (%) | Temp. (°C) |
| 1/3 | 45.95 | 18.25 | 30.12 | 17.71 | 31.21 | 17.26 |
| 21/3 | 51.11 | 19.1 | 41.48 | 19.95 | 42.52 | 19.44 |
| 8/4 | 54.61 | 21.01 | 41.7 | 20.46 | 37.46 | 20.35 |
| 12/4 | 50.61 | 21.85 | 53.06 | 21.7 | 46.17 | 21.3 |
| 14/4 | 59.98 | 21.85 | 52.09 | 18.77 | 49.08 | 18.46 |
| 19/4 | 52.73 | 23.14 | 54.11 | 22.26 | 45.47 | 21.85 |
| 5/5 | 52.64 | 21.41 | 57.3 | 21.05 | 60.09 | 20.91 |
| 9/5 | 49.15 | 23.87 | 53.31 | 23.89 | 52.47 | 23.69 |
| 11/5 | 43.07 | 24.97 | 56.29 | 23.61 | 50.27 | 23.56 |
| 16/5 | 51.10 | 20.45 | 52.64 | 19.81 | 54.7 | 19.83 |
| 25/5 | 50.18 | 24.65 | 52.88 | 24.83 | 52 | 25.18 |
| 1/6 | 51.88 | 21.3 | 53.01 | 21.31 | 54.01 | 25.18 |
| 3/6 | 49.86 | 23.69 | 54.11 | 23.8 | 65.48 | 24.33 |
| 16/6 | 52.86 | 22.43 | 56.77 | 22.63 | 54.88 | 22.64 |
| 20/6 | 44.15 | 24.19 | 53.24 | 22.23 | 47.49 | 22.42 |
| 30/6 | 51.48 | 25.23 | 66.44 | 25.79 | 61.44 | 25.94 |
| 6/7 | 57.89 | 20.39 | 62.25 | 20.39 | 57.08 | 20.56 |
| 15/7 | 54.91 | 26.2 | 68.84 | 27.8 | 61.63 | 27.38 |
| 21/7 | 46.49 | 24.05 | 64.69 | 25.58 | 59.22 | 25.63 |

## <u>Solution and FCCB (M80 & M100) analysis</u>

The data for the mid season media analysis and drain analysis (taken on three occasions) are presented in Appendix A (Tables A and B). Although there were no obvious visual nutritional effects between these treatments, FCCB experiencing a reduced irrigation volume had at least two times higher phosphorus, potassium and sulphate levels compared with the M100 treatment. The significance of these observations in relation to crop growth is not clear and the consultant to this project did not feel the changes would have an adverse effect on plant quality. The analysis of the media at the end of the trial again shows that the M80 media has a higher nutrient content than the M100 media, but this difference is less pronounced than the results obtained at the mid-trial analysis.

It is believed that the extra nutrient present will have little consequence for proposed secondary use, as either the re-composting process will use these additional nutrients or the once-used media will be diluted with fresh bark material for re-processing to the extent that the additional nutrient will become insignificant.

The data in Appendix A, Table B shows that, on the occasions sampled, there was less boron and sulphur in the solution draining from both FCCB treatments compared with that from rockwool. A slightly higher electrical conductivity in the drain from M80 compared with M100 treatments suggests preferential uptake of water by plants in this media. These differences were not perceived to be of detriment to the successful growth of a tomato crop.

Potential structural changes occurring in the FCCB media were addressed by analysing the particle size distribution before and after the full season trial. It is important that any material used to support tomato and other protected salads growth in hydroponic systems not only has a particle size distribution suitable to allow the correct flow of nutrient solution, but that it also retains its structure throughout the life of the crop. If the structure was to degrade over the course of the season this could lead to an impedance of flow and hence restrict the growth of the crop. The results from this analysis (Appendix A, Table C) show that, as with the preliminary trials, the particle size distribution of both M80 and M100 media has changed very little over the trial period. This indicates that the FCCB media is structurally sound and that its physical characteristics remain unchanged after initial use.

## Conclusion

This work has shown that a commercially realistic tomato crop can be grown using FCCB medium. The medium irrigated at a 20% reduction in volume (M80) compared to the rockwool standard developed similar numbers of trusses but did develop smaller fruit, reduced canopy area and thinner stems at some stage during the trial. However, the fact that the irrigation level can be reduced by 20% and still produce a good crop of tomatoes (the growing environment could be altered to compensate to some degree) demonstrates that the media does have a buffering capacity around the optimal irrigation levels which should give growers additional confidence when using the product.

## 3. ECONOMIC EVALUATION OF FCCB FOR PRIMARY USE

**Methodology / task undertaken:**

Technical evaluation of wood-based growing media was achieved by the completion of a full season tomato growing trial in conjunction with similar trials on two growers holdings (Wight Salads & Flavourfresh Ltd.). The results of these trials were presented at the 2005 Tomato Conference and were favourably received. In addition to this, an evaluation of the associated costs for the supply of FCCB and rockwool (including disposal of rockwool) was undertaken.

**Economic evaluation of rockwool system:**

Consultation with several tomato growers who use rockwool has found that the cost of rockwool is currently in the region of £1 per slab (1m x 15cm x 7cm). However, this does vary depending on the quantity purchased.

Additional costs, associated with the disposal of used rockwool, are covered in Section 4 (page 30).

**Economic evaluation of FCCB system:**

Current indications are that FCCB slabs can be commercially produced at levels that are competitive with rockwool slabs, i.e. around £1.00 to £1.10 per slab. As is the case with rockwool, the actual prices will vary from site to site depending on the quantity purchased and the transport costs incurred.

It was considered that the primary use of the medium, and hence any additional costs, ends once tomato production in the media has been completed. Costs associated with transport away from the site (including de-sleeving of FCCB slabs) will be incorporated into the economic evaluation for the secondary use of this product.

**Summary of economic evaluation:**

It can be seen from the cost projections for production of the FCCB bags that there is no difference in price compared to rockwool slabs at the point of sale. It should also be noted that there is currently no anticipated crop value gained from using FCCB over rockwool but that plants grown in FCCB media closely match the industry standard in terms of fruit yield and quality. Greater efficiency in water use may become apparent with FCCB media in time if growers switch from rockwool production and so fine tune their irrigation strategies for FCCB media.

# 4. ECONOMIC EVALUATION OF FCCB FOR SECONDARY USE.

**Introduction:**

Current practice with the standard tomato industry substrate, rockwool slabs, is that at the end of the growing season the slabs are disposed of into landfill. A principal advantage of the FCCB used in this project is that it can be recycled in various ways, thus obviating the need for landfill. The aim of this section of the report is to present scenarios for the processing of once-used tomato growing media. The economics of removing the media from the plastic sleeves, onward transport costs and preparation for secondary use will be taken into consideration.

**Methodology / task undertaken:**

As the fate of the once-used growing media will depend to a certain degree on local factors and management choices of individual nurseries, economic evaluations for several scenarios are presented to take into account the range of options that are available. These scenarios for handling the material once its use as a tomato growing media ends include:

1. Disposal to landfill
2. Disposal onto adjacent land
3. Disposal into a green waste facility
4. Collection by growing medium manufacturer for recomposting and reuse in ornamentals growing media or soil improver product.

[NB: The Waste Management Licensing (England and Wales) (Amendment and Related Provisions) (No 3) Regulations 2005 are relevant to the handling of waste. They are currently under review. The latest guidance can be found at the Environment Agency website: www.environment-agency.gov.uk]

## Findings / Results:

Typical costs associated with the handling of the post-season tomato substrate are:

***1. Disposal to Landfill***

1. Skip hire - £22 per tonne
2. Transportation to waste site - £5 - £16 per tonne depending on distance (and assuming waste disposal site to be no further than 25 miles from nursery).
3. Landfill tax – currently £18 per tonne, rising to £21 per tonne in May 2006. Thereafter rising each year to a £35 per tonne by 2010. See www.businesslink.gov.uk for further details on landfill tax charges.

This totals between £45 and £56 per tonne.

***2. Disposal onto adjacent land***

Assuming the landowner does not charge for the facility and / or this is allowed under the new waste handling regulations:

1. Labour cost of plastic sleeve removal – estimate 120 bags per man hour at a basic wage of £5.76 per hour. This equates to approximately £7.00 per tonne using typical bulk density values for post-primary use FCCB.
2. Labour cost of spreading onto adjacent land – approximately £6.00 per hour. Assume that 6 tonnes could be spread in one hour this adds £1.00 per tonne.

This totals £8.00 per tonne.

***3. Removal into a green waste facility***

Costs as for landfill (above), less the Landfill Tax, plus sleeve removal (£7 per tonne) (although some waste handling companies impose a charge for the cost of producing green compost, typically around £9 per tonne). This brings the approximate cost to £33 – £45 per tonne (plus £9 per tonne in the event of a green waste handling fee being charged).

***4. Collection by growing medium manufacturer for recomposting and reuse in ornamentals growing media or soil improver product.***

1. Labour cost of plastic sleeve removal - £7.00 per tonne
2. Cost of transport to growing medium manufacturer - £10 - £30 per tonne

depending on distance

3. Cost of processing approximately £3.00 per tonne

This gives a total cost of between £20 and £40 per tonne for the finished product.

**To summarise:**

1. Cost of disposal into landfill - £45–56 per tonne (£19.57 – £24.35 per $m^3$)
2. Disposal onto adjacent land - £8.00 per tonne (£3.48 per $m^3$)
3. Removal to a green waste facility - £33-£54 per tonne (£14.34–£23.47 per $m^3$)
4. Collection by growing media manufacturer for re-use - £20-£40 per tonne (£8.70–£17.40 per $m^3$).

It is probable that no single method of disposal would be employed and that local conditions will determine where the once-used material would go. Although it is probably the easiest option for growers, the highest costs are likely to be incurred when using landfill. However, these costs are set to rise consistently and significantly, which will make the recycling options more attractive.

Disposal onto adjacent land is the most economical way of disposing of the material, but this may be more tightly controlled when the new waste regulations come into force.

Removal from site to a green waste facility could provide a very cost-effective means of disposal, particularly if the waste processor is close to the nursery. As with disposal onto land this would involve the grower in de-sleeving prior to removal, but the costings indicate that this could be increasingly cheaper than landfill if the distance is not too great.

Collection by a growing media manufacturer for recycling into growing media could also be cost-effective if the transport costs are not too high. The costs would also be offset to some degree by the value of the product resulting from the recycling. This type of material currently achieves a price of between £30 and £45 per tonne.

[NB: The regulations on the handling of waste suggest that any company taking the once-used substrate for recycling into another product would be required to hold an appropriate waste licence, although it is understood that the quantities for an exemption are currently under review. See the Environment Agency website for further details: www.environment-agency.gov.uk]

**Evaluation of market size and volume:**

Current horticultural statistics (http://statistics.defra. gov.uk/esg/ publications/ bhs/2005/ veg.pdf) for the 2003-2004 give the total planting area for tomatoes, cucumbers, and sweet peppers as 187, 130 and 55 hectares respectively. Although there will be variations in planting density in these crops, we can assume that an individual growing bag / slab will occupy 1.6m$^2$ of glasshouse space (growing slabs are generally 1m long and gaps between rows a standard 1.6m). This will result in a total growing media market size of 2.35 million slabs for the protected commodities described. If all this material were sent to landfill each year (this does not happen in reality as growers often re-use the same mineral wool slab for a few seasons, and dispose of the material via other means e.g. spread onto land or recycled) the volume would exceed 30,000 m$^3$. This is estimated as being approximately 12,000 – 16,000 tonnes in weight (Derek Hargreaves, pers. comm.) and would cost the industry £540,000 to £896,000 in disposal costs.

Given that the cost of a rockwool slab and a FCCB slab is approximate to £1, one arrives at a combined potential market value of £2.35m (42,300m$^3$ / 17,000 tonnes) for the UK tomato, cucumber and sweet pepper industries.

# 5. CONCLUSIONS & RECOMMENDATIONS

Trials assessing the agronomic performance of FCCB medium have shown that a good quality crop can be produced with this material with maybe only very small adjustments from standard commercial practice necessary to optimise production in this medium.

Work on the stability of the FCCB material confirms that negligible changes in structure in terms of particle size distribution occur during a growing season and that any additional nutrient content will be eliminated during a re-composting cycle.

The economic evaluation of secondary uses indicate that all options discussed (application to land, removal into a green waste facility, collection by growing media manufacturer for re-composting and re-use as an ornamentals growing media or soil improver) are economically more favourable than disposal to landfill. The comparison with rockwool is complicated as this material is often compressed before disposal and also has varying moisture content, depending on individual nurseries practices. Despite this potential large variation it can still be predicted that a whole-scale industry adoption of FCCB as a growing medium would result in the prevention of approximately 12,000 – 16,000 tonnes of waste (rockwool) entering landfill.

In summary, FCCB media provides growers of protected crops with further options regarding the use of resources and realistic possibilities for reducing their own waste disposal costs in the face of increasing landfill charges, whilst improving the sustainability of their operations.

## 6. INFORMATION DISSEMINATION

This work has been disseminated through a variety of technology transfer events. These have included:

1. A presentation given at the 2005 HDC and British Tomato Growers' Association - supported Tomato Conference in September 2005.
2. An article on the project appeared in October 2005 edition of HDC News.
3. There were also opportunities during the full-season trial to show interested parties the crop at STC.
4. A poster of current trial progress produced for an Open Day at Melcourt Industries Ltd. in June 2005.
5. Product and marketing information produced by Melcourt Industries Ltd. for major supermarkets and growers of protected crops.

## 7. REFERENCES

Chalker- Scott, L. (2005). The myth of beneficial bonemeal. http://www.puyallup.wsu.edu/ ~Linda Chalker-Scott/.

Drakes, D., Briercliffe, T., Lightfoot- Brown, S., Arnold, D., Mackay, N. (2001). The use and disposal of growing media. Report to PSD by ADAS.

# 8. APPENDICES

## Appendix A: Additional data from full-season trial.

**Figure A. Mean drain measurements from each treatment, with the irrigation from 6 plants draining into one of two drains per treatment.**

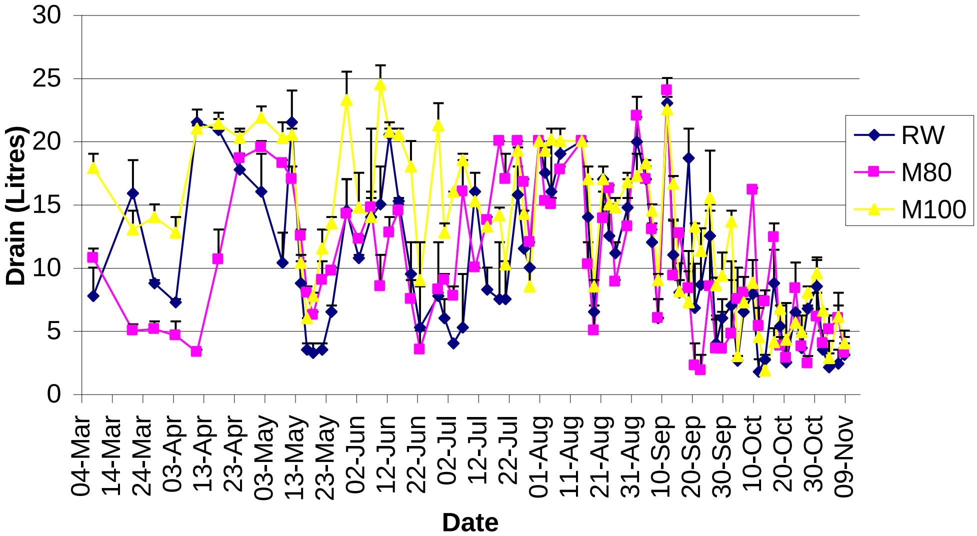



**Table A. Mid-trial chemical analysis of FCCB growing media**

| | Pre-Trial | Mid-Trial | | Post-Trial | |
|---|---|---|---|---|---|
| **Determinant** | **FCCB** | **M80** | **M100** | **M80** | **M100** |
| pH | 5.28 | 4.82 | 4.78 | 5.63 | 5.52 |
| Density (kg $m^{-3}$) | 426 | 495 | 484 | 453 | 439 |
| Dry Matter (%) | 42.6 | 38.7 | 38.3 | 44.4 | 44.5 |
| Dry Density (kg $m^{-3}$) | 181.5 | 191.6 | 185.4 | 201.1 | 195.4 |
| Conductivity (µS) | 47 | 1571 | 998 | 623 | 317 |
| | | | | | |
| **Nutrient (mg $l^{-1}$)** | | | | | |
| Phosphorus | 9.2 | 136.2 | 6.9 | 25.4 | 10.4 |
| Potassium | 40.8 | 636.7 | 250.9 | 447.8 | 281 |
| Magnesium | 0.7 | 630.9 | 401.6 | 131 | 55 |
| Calcium | 1.7 | 947.6 | 497 | 326.4 | 88.9 |
| Sodium | 12.5 | 96.2 | 134.1 | 60.6 | 51.7 |
| Ammonia-N | 4.3 | 1.2 | 2.4 | 5.8 | 4.3 |
| Nitrate-N | <0.6 | 626.2 | 484.9 | 208.7 | 68.4 |
| Total Soluble N | 4.3 | 627.4 | 487.3 | 214.5 | 72.7 |
| Sulphate | 13 | 2975.6 | 1615.3 | 1017.3 | 517.1 |
| Boron | <0.06 | 0.59 | 0.3 | 1.01 | 0.91 |
| Copper | <0.06 | <0.06 | 0.07 | <0.06 | <0.06 |
| Manganese | <0.06 | 4.11 | 4.08 | 0.22 | 0.12 |
| Zinc | 0.08 | 3.32 | 3.55 | 1.05 | 0.68 |
| Iron | 0.57 | 6.01 | 11.42 | 1.91 | 1.83 |
| Chloride | 32.9 | 20.8 | 35.1 | 36 | 21.7 |

**Table B. Chemical composition of drain and slab solution from trial treatments on three dates (3rd June, 4th July, 21st July).**

| Nutrient (mg $l^{-1}$) | RW Slab | RW Drain | M100 Drain | M80 Drain |
|---|---|---|---|---|
| **Calcium** | 685, 963, 691 | 795, 539, 953 | 497, 316, 377 | 648, 458, 713 |
| **Magnesium** | 372, 393, 293 | 438, 215, 420 | 267, 150, 161 | 305, 160, 407 |
| **Manganese** | 0.5, 0.05, 0.05 | 0.41, 0.01, 0.14 | 0.76, 0.01, 0.25 | 0.5, 0.26, 0.5 |
| **Boron** | 5.06, 1.15, 0.69 | 3.95, 0.78, 0.81 | 1.04, 0.56, 0.45 | 0.67, 0.41, 1.06 |
| **Copper** | 0.42, 0.28, 0.22 | 0.27, 0.21, 0.25 | 0.21, 0.1, 0.1 | 0.19, 0.13, 0.2 |
| **Molybdenum** | 0.13, 0.15, 0.1 | 0.21, 0.06, 0.15 | 0.03, 0.01, 0.02 | 0.02, 0.02, 0.03 |
| **Iron** | 3.34, 0.17, 1.11 | 2.05, 0.83, 0.92 | 2.76, 0.98, 1.04 | 1.14, 1.32, 0.83 |
| **Zinc** | 1.61, 2.8, 2.16 | 1.66, 1.16, 2.89 | 2.1, 1.13, 1.14 | 3.46, 1.75, 2.3 |
| **Sulphur** | 442, 455, 368 | 475.0, 244, 581 | 268, 176, 215 | 299, 206, 503 |
| **Phosphorus** | 105, 0.46, 3 | 52, 3, 1 | 71, 20, 23 | 26, 31, 102 |
| **Potassium** | 1152, 339, 704 | 1218, 413, 736 | 813, 490, 600 | 770, 584, 1465 |
| **Nitrate-N** | 857, 644, 655 | 1116, 445, 760 | 662, 341, 445 | 769, 447, 907 |
| **Ammonia-N** | 0.5, 1.4, 1.29 | 0.9, 0.2, 1.32 | 0.9, 0.5, 1.53 | 1.8, 4, 3.19 |
| **Sodium** | 91, 155, 108 | 113, 82, 155 | 68, 54, 59 | 70, 46, 81 |
| **Chloride** | 64, 53, 86 | 69, 68, 110 | 61, 84, 72 | 53, 93, 86 |
| **Bicarbonate** | 116, 195, 195 | 122, 116, 220 | 67, 55, 104 | 73, 43, 85 |
| | | | | |
| **pH** | 6.2, 8.3, 7.1 | 6.8, 7.3, 7.4 | 6, 6.9, 6.7 | 6.7, 5.8, 5.9 |
| **E.C. (mmhos/cm)** | 9.5, 8.46, 7.66 | 10, 5.32, 9.8 | 6.91, 4.24, 4.97 | 7.74, 5.08, 10.08 |

**Table C. Pre and post-trial analysis of particle size distribution for FCCB media. Analysis was carried out by Melcourt Industries Ltd. Figures refer to percentage by weight of air-dried material left on screens of the given square aperture size.**

| Treatment | >4.75mm | >2.36mm | >1.00mm | >0.50mm | <0.50mm |
|---|---|---|---|---|---|
| **FCCB pre-trial** | **1.0** | **26.4** | **33.9** | **19.4** | **19.3** |
| **post-trial 100%** | **0.3** | **24.0** | **34.1** | **19.8** | **21.8** |
| **post-trial 80%** | **0.9** | **25.0** | **33.6** | **19.5** | **21.0** |
| **FCCB typical commercial specification** | **0.5** | **26.5** | **33.8** | **18.1** | **21.1** |

## Appendix B: Propagation of tomato plants in peat-free growing medium.

### Introduction

Conventionally tomato transplants are raised in rockwool blocks prior to being placed onto the rockwool slabs at the beginning of the growing season. In this study tomato plants destined for the FCCB slabs were raised in a peat based medium prior to being transplanted, as described above. A supplementary study was undertaken to compare rockwool raised transplants with those raised in a fertilized bark / woodfibre medium (BWF) that is similar in nature to the FCCB. The advantage of using such a medium would be that at the end of the season the entire slab together with the transplant block could be composted to provide a peat-free growing medium ingredient.

### Materials and Methods

Four batches of tomato seeds, cultivar Aranca, were sown at seven-day intervals from the 1 June 2005. 20 seeds were sown directly onto either rock wool substrate or BWF media. Leaf area, plant height and number or leaves was determined four weeks after sowing. The data from the four sowing dates was combined to give an overall average.

### Results & Discussion

The results are presented in Table D.

**Table D. Mean leaf area, plant height, and number of leaves four weeks post-sowing. Data represent the mean of 40 samples ± SE.**

| | Rock wool | BWF |
|---|---|---|
| **Leaf Area** | 421 ± 15.05 | 328.9 ± 328.9 |
| **Plant Height** | 26.9 ± 0.71 | 22.3 ± 0.51 |
| **Number of Leaves** | 6.45 ± 0.1 | 6.1 ± 0.08 |

Statistical analysis of the data shows that leaf area and plant height were significantly higher in the seedlings grown on rockwool compared to BWF raised plants. It should be noted that the latter plants were watered without feed for the first two sowings whilst the rockwool-raised plants were watered a nutrient solution each time. When these batches were removed from the dataset the average leaf area difference was less pronounced (396 $cm^2$, 337 $cm^2$ for rockwool and BWF respectively). Therefore, it is believed that BWF media could be used in a propagation situation for this system. Indeed, discussions with Delfland Nurseries (UK tomato plant raisers) have indicated that according to their commercial experience, the BWF media would not pose any problems.