HDC PROJECT HNS 66

FINAL REPORT

Non Chemical Weed Control in Container Grown Nursery Stock

December 1998

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1.0 PRACTICAL SECTION FOR GROWERS

1.1 Background and objectives

Chemical weed control in container grown plants is a complex subject and continued access to a range of suitable products is an ongoing concern across the industry. Several herbicides have ceased to be available to growers and there are label restrictions on those that remain. The exceptionally diverse range of nursery stock subjects in production, together with the different nursery systems used, also adds further complications in respect of phytotoxicity risks. For example, label restrictions severely limit the choice of herbicides for nursery stock grown under protection, where crop growth is much softer and more liable to damage from herbicide applications. Environmental concerns regarding potential pesticide leaching from modern container units underline further the need to evaluate alternatives to chemical weed control.

Alternative methods of weed control need to be researched. Pot toppers and loose fill mulches such as bark chips, cocoa shell or grit have the potential to control weeds in container plants and may provide useful alternatives to herbicides. A pot topper is a covering material or 'mat' which when fitted around the base of the plant forms a mulch over the compost surface. Ideally, the pot topper should be fitted when the plant is potted.

It is not intended that pot toppers or loose fill mulches should replace herbicides completely, rather that they may offer growers a broader range of options in situations where chemical control may be unsuitable. This, for example, may apply to choice, high value subjects where crop tolerance is unknown or, with specialist crops such as alpines or heathers where herbicide tolerance is marginal. Nursery stock crops grown under protection, for which very few herbicides have a label recommendation, are another example of a potential application.

The key objective behind this work was to identify materials which have commercial potential as alternatives to herbicides for successful weed control in container grown nursery stock.

The main aim of the first year trial was to assess the performance of a broad range of materials under commercial conditions and compare weed control results against those achieved using a standard herbicide programme. Each of the treatments were assessed with capillary sandbed and overhead irrigation systems to assess performance and behaviour in response to different watering regimes. These in turn created different weed pressures with the overhead system imposing the higher weed numbers and greater challenge. The best treatments were then carried forward for further evaluation in a second trial under overhead irrigation and embracing varieties with different growth habits (herbaceous subject, climber, conifer and deciduous shrub), to see if this influenced significantly the behaviour and performance of the treatments.

1.2 Summary of results

Although the herbicide treated plots consistently gave the highest levels of weed control throughout the trials, several materials emerged with genuine commercial potential. These included pot toppers made from coir, waste wool and jute. Each of these have provided commercially acceptable levels of weed control over a twelve month period with both capillary sandbed and overhead watering systems. Lightweight pot toppers made from 250 micron polythene (Hadodisc) and Spin-Out treated non woven matting (Geodisc) also have commercial potential in sheltered sites or under protection.

To be commercially viable, it is important that weed control can be maintained over a twelve month period. Some of the wool pot toppers began to break down towards the end of both trials and would struggle to maintain weed control beyond one year. Coir too, slowly deteriorated although not to the same extent and looked capable of sustaining weed control into the second summer under either watering regime.

Pot toppers made from 250 micron polythene (Hadodisc) and Spin-Out treated matting (Geodisc) provided good weed control on a sandbed irrigation regime but on occasions struggled with the greater weed pressures imposed by an overhead watering system. Moss and liverwort also developed in some pots underneath both of these pot toppers where they had failed to maintain close contact with the compost surface. Being lightweight materials, some of the pot toppers were blown away during both trials, indicating that in their present form they are perhaps better suited for use under protection or in sheltered situations

Most weeds that developed amongst the pot topper treatments did so near the edges of the pots where a gap had occurred between the pot topper and pot rim. This was due to either shrinkage or where the lightweight materials had failed to secure a close fit. Gaps in the centre of the pot around the neck of the plant also created opportunities for weed growth. Poorly sized pot toppers are difficult and time consuming to fit and this is an important commercial consideration. As a general comment, few weeds actually appeared to colonise the surface area of the pot toppers with the exception of those made from wool.

Weed control with the loose fill mulches of bark, wool pellets and cocoa shell was variable, including, in the case of the bark chips and wool pellets, under a sandbed irrigation system. The potential for spillage due to pots being blown or knocked over and removal by foraging birds was also highlighted in the trial. Though spillage was not a problem with the wool pellets due to their becoming hydrated after watering, weed control overall was poor. On the basis of this trial, loose fill mulches such as bark chips or cocoa shell are likely to be most effective on short term, multi-branched crops, ideally grown under protection. They may also have potential for moss/liverwort control but are likely to struggle against a backdrop of high pressure from broad-leaved weeds.

Observations from this work suggest that differences in plant morphology, whilst to some degree influencing weed pressure, are unlikely to significantly influence the performance and longevity of pot toppers or mulches. However, the second trial which embraced a range of subjects, each with different growth habits, confirmed the difficulties of using pot toppers

with herbaceous perennials, where a significant number of shoots arise from a main crown or sucker from below compost level. In several cases, the pot topper was pushed away from the compost surface, effectively creating an air pocket in which weed seeds germinated and/or moss/liverwort started to colonise. The thinner and more pliable wool and to a lesser degree jute pot toppers were more successful than those formed from coir but still became separated eventually from the compost surface. Loose fill mulches of bark chips, cocoa shell or perhaps grit are likely to be more successful in maintaining an acceptable level of weed control. They are also likely to be much easier and quicker to apply.

No commercially significant effects from any of the treatments on plant size, vigour or appearance were apparent. None of the materials created any difficulties in respect of phytotoxicity.

1.3 Action points for growers

- Pot toppers made from coir, wool, jute, 250 micron polythene (Hadodisc) and Spin-Out treated matting (Geodisc) are a commercially realistic alternative to the application of herbicides. With the exception of jute (currently planned for commercial release in 1999), each material is now available commercially to fit a range of pot diameters. They are however likely to be more costly than herbicides, although unlike many chemical products, they need only be applied once, are safe and pleasant to use and are environmentally more acceptable. Application of herbicides can be time consuming and expensive in terms of labour costs and requires trained and qualified staff to apply them.

- Loose fill mulches have potential for application to multi branched plants and herbaceous perennials where a pot topper may be unsuitable. Bark chips and cocoa shell each have potential for short term crops in situations of low background weed pressure and under protection where the choice of herbicide is currently very restricted. Bark chips and cocoa shell are particularly effective against moss and liverwort.

- For best results, pot toppers and mulches should be applied immediately after potting and the plants then irrigated in. Thorough watering is essential in the initial stages, particularly on sandbed systems and/or under protection. The level of compost in the pot also needs to be adjusted to accommodate the pot topper or mulch. Application of the pot topper or mulch at bench or trailer height during the potting operation before setting down is quicker and easier for staff.

- A well fitted pot topper is essential. They should be centralised and cover the whole compost surface, otherwise weeds, moss and liverwort can develop. Some pot toppers can be left in place during the marketing process to provide added value.

- Pot toppers or mulches are no substitute for good nursery hygiene and clean plugs or liners at potting.

1.4 Practical and financial benefits

- Safe and effective weed control with minimum environmental impact, as compared to the use of herbicides.

- Pleasant to use and, unlike chemicals, no protective clothing, formal training or certification is required

- Consumer friendly and may provide added value during marketing.

- Improved plant quality through reduced weed presence and competition for light, moisture and nutrients.

- Useful and practical alternative to chemicals for high value or specialist crops where the application of chemicals may carry a high degree of risk. Use around stock plants in containers will eliminate or reduce costly hand weeding (residual herbicides are not widely used in this situation, creating a need for hand weeding). Other examples include heathers, herbs, ferns, ornamental grasses and pot liner crops.

- Unrestricted use if required - herbicide products invariably carry label restrictions.

- Pot toppers and mulches usually only need to be applied once, unlike chemicals which often require top up treatments to maintain weed control.

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2.0 SCIENCE SECTION

2.1 Introduction

The modern market for container grown nursery stock is now highly competitive and current specifications require plants to be clean and free of weeds including, liverwort. Weed control in container grown plants using chemicals is complex. Many of the materials traditionally used such as Enide 50W, Tenoran and Surflan are no longer available to growers and there are restrictions with those that are, particularly in respect of crop tolerance. The exceptionally diverse range of subjects now in commercial production, often under protection, together with the range of different growing systems employed, complicates the situation still further.

Clearly, alternative methods of weed control need to be researched and the key objective behind this work was to evaluate and identify pot topper or mulch materials which offer genuine commercial potential.

To be commercially successful, pot toppers and mulches need to satisfy several important criteria. They should be ;

- Permeable to water for irrigation
- Non-phytotoxic
- Light excluding to discourage weed growth
- Stable, and resistant to being removed or dislodged by wind
- Resilient and capable of sustaining weed control for at least twelve months
- Price competitive
- Easy to fit or apply with potential to integrate with machine potting
- Accurately measured to achieve a good, precise fit
- Cosmetically attractive at point of sale
- Non shrinking
- Easily available from suppliers

It is difficult to quantify precisely or accurately the financial benefits of using pot toppers or loose fill mulches but container production is labour intensive and a considerable amount of time is spent on nurseries either applying herbicides or hand weeding. The use of mulches or pot toppers may offer genuine potential to reduce these costs, providing they can be applied in a commercially efficient manner. There are also a number of other significant advantages associated with the use of non chemical weed control methods and these are detailed at section 1.4 (Practical and Financial benefits).

Until this work began, only limited work with pot toppers and mulches had been carried out in the UK, most research has been done on the continent, primarily in Holland and Belgium. Dutch work had looked at the potential of bark and peat + perlite mulches and pot toppers made from jute and coir + jute. Belgian work carried out at Destelbergen focused on using paper waste, bark and pot covers made from woven polypropylene fibre. French interest has led to the development of a system which is based on heat sealing a non woven, permeable

black cloth 'pot topper' on to the container, through which the plants to be potted are inserted. This material allows water and air to pass through but not light and is reputed to last for up to 18 months. So far there is little evidence of it being adopted here in the UK.

2.2 Materials and Methods

First year trial (1995/96)

Production System

Two irrigation systems were used in order to compare the behaviour and performance of each material under different watering regimes. These comprised sub-irrigated capillary sandbeds and overhead irrigation on a 'Mypex' matting (woven polypropylene) base.

The trial location was Crowders Nurseries, Horncastle, Lincolnshire.

Growing Medium

The nursery's standard peat based compost with controlled release fertiliser was used for the trial.

Start Material

Well rooted, direct stuck 7 cm pot liners of *Escallonia* 'Peach Blossom' were potted on into 3 litre containers at the end of June 1995.

Design and Treatments

There were 10 treatments in total including a control with each treatment being replicated 3 times. Treatments were randomised in each replicated block as shown in Figure 1.

The treatments were:-

A) Untreated control

B) Herbicide application; 2 treatments each of Ronstar 2G and Flexidor 125*

C) Pelleted organic waste (75/25% waste wool + vegetable matter, APT Marketing)

D) Wool pot topper, 400g/m^2 (waste wool, APT Marketing)

E) Bark mulch (Melcourt Products)

F) Coir pot topper (Wessex Horticultural Products)

G) Spin-Out treated pot topper (Geodisc, Fargro)

H) Jute pot topper, 750g/m^2 (jute with goat hairs, Hy-Tex)

I) Plantex pot topper (thermal bonded polypropylene fibres, Plantex)

J) Hadodisc pot topper (polythene, 250 micron grade, Hado Polythene)

* The herbicide treatments were based on an alternating programme of Ronstar 2G and Flexidor 125 applied at 9 week intervals. Rates of use; Ronstar 2G, 200kg/ha, Flexidor 125, 1 litre/ha applied in 2000 litres of water/ha.

The mulch treatments were applied at potting (29 June) with the exception of treatments F) and H) which were applied on 30th June and 21 July respectively, due to late delivery from the suppliers.

All treatments were thoroughly watered in, as conditions were hot, bright and dry. Potting for the trial was done adjacent to the bed and involved no transport across nursery roads. In most commercial situations, where potting is carried out centrally, it is advisable to water the plants and treatments in before transporting to the beds in order to help them settle and minimise spillage. A thorough hand watering before transporting plants to the beds will also help ensure sufficient water penetrates beneath the mulches and toppers, most of which can be difficult to wet up initially. If bed watering is preferred, for example to reduce weight during transit, then this should follow promptly after setting down. It is advisable to do this by hand initially to ensure adequate water penetrates through the surface layer of the pot topper or mulch.

The coir pot topper appeared to repel water initially, as did the polythene based Hadodisc pot topper. The wool based pot topper also needed a considerable amount of water to wet up before sufficient penetration to the compost underneath was achieved. Similar remarks apply to the Plantex, Spin-Out (Geodisc) and jute pot toppers.

Records

Treatments were assessed for weed control (weed type and numbers) at quarterly intervals with the final assessment at the end of the trial. The data was analysed using the standard ANOVA analysis of variance to identify any treatment effects that were statistically significant.

Any significant effects on crop vigour or phytotoxicity symptoms were also noted.

Figure 1

TRIAL LAYOUTS

Capillary Sandbed

J1	D2	B3
H1	B2	J3
F1	H2	I3
B1	I2	D3
D1	F2	G3
I1	E2	H3
G1	A2	C3
E1	C2	A3
C1	G2	E3
A1	J2	F3
Replicate 1	Replicate 2	Replicate 3

Overhead Irrigation

A1	J2	C3
J1	I2	A3
I1	G2	I3
H1	D2	G3
F1	H2	F3
D1	E2	J3
G1	A2	E3
C1	B2	H3
E1	C2	D3
B1	F2	B3
Replicate 1	Replicate 2	Replicate 3

Treatment list;

A - Untreated control
B - Herbicide
C - Pelleted organic waste
D - Wool pot topper
E - Bark mulch
F - Coir pot topper
G - Spin-Out pot topper
H - Jute pot topper
I - Plantex pot topper
J - Hadodisc pot topper

Second year trial (97/98)

Production System

Pot liners of *Astilbe* 'Gladstone White', *Spiraea japonica* and *Jasminum stephanense* were potted into 3 litre containers on the 1st July 1997. Liners of *Chamaecyparis lawsoniana* 'Ellwoodii' were potted on at the same time but became badly infected with *Phytophthora cinnamomi* and had to be discarded. These were replaced with liners of *Thuya plicata* 'Atrovirens' potted on the 8th of September. These subjects were chosen to provide plants with contrasting growth habits, in order to assess whether this would significantly affect the performance of the different treatments.

The trial location was Crowders Nurseries, Horncastle, Lincolnshire.

Growing Medium

The nursery's standard peat based compost with controlled release fertiliser was used for the trial.

Start Material

Pot liners of four commercially representative subjects were machine potted into 3 litre containers and set down on an outdoor bed covered with matting and irrigated overhead.

Design and treatments

There were seven treatments in total including a control and each treatment was replicated three times. Treatments were randomised in each replicated block as shown in Figure 2. The treatments were:-

A) Untreated control

B) Herbicide programme (Ronstar 2G/ Flexidor 125 alternated at 9 week intervals)*

C) Wool pot topper (APT Marketing)

D) Coir pot topper (Wessex Horticulture)

E) Jute pot topper (Hy-Tex)

F) Geodisc pot topper (Fargro)

G) Cocoa shell loose-fill mulch (Peter Low & Co. Ltd)

* The Ronstar 2G was applied immediately after potting at the standard rate of 200 kg/ha. Flexidor 125 was applied at 1 litre/ha in 2000 litres of water/ha.

All the pot topper/mulch treatments were applied at potting. Plants were watered in thoroughly after setting down.

Records

Assessments for weed control (weed types and numbers) were made at quarterly intervals.

Weed data was analysed by standard ANOVA analysis of variance to identify any treatment effects that were statistically significant.

Vigour scores were taken at the final assessment, 12 months from the potting date.

Figure 2

TRIAL LAYOUT

E1	G2	A3
A1	D2	C3
F1	B2	E3
C1	F2	D3
B1	A2	G3
G1	E2	F3
D1	C2	B3
Replicate 1	Replicate 2	Replicate 3

Treatment list

A - Untreated control
B - Herbicide programme
C - Wool pot topper
D - Coir pot topper
E - Jute pot topper
F - Geodisc
G - Cocoa shell

2.3 Results

First year trial

There was a clear difference in weed pressure created by the two irrigation systems and significantly higher weed numbers were consistently recorded under the overhead watering regime. Bittercress and willowherb dominated the weed spectrum in both the capillary sandbed and overhead irrigated plots.

Although the herbicide treated plots consistently produced the best results, several pot topper materials also achieved levels of weed control which were commercially significant under either irrigation system. Tables 1 & 2 show percentage weed control figures for each treatment under both irrigation regimes. A summary of the statistical analysis can be found at Appendix II

Statistical analysis for capillary sandbed irrigation confirmed that discounting the herbicide treatment, the pot toppers based on coir, jute and waste wool each performed significantly better than the pellet and bark mulches and the pot toppers based on the Plantex, thermal bonded polypropylene and the Hadodisc 250 micron grade polythene. The Spin-Out (Geodisc), Plantex and Hadodisc pot toppers were also significantly better than the pelleted wool mulch. The Spin-Out treated pot topper was also significantly better than the bark mulch and Hadodisc pot topper.

Analysis for the overhead irrigation regime also showed that the coir, jute and wool based pot toppers each performed significantly better than both the loose fill mulches and better than the Spin-Out, Plantex and Hadodisc pot toppers. Spin-Out, Plantex and Hadodisc pot toppers were significantly better than either of the mulch treatments before rejection of outliers, although after their rejection there was no significant difference when compared with the pelleted wool mulch. Spin-Out was significantly better than the Plantex pot topper after the rejection of outliers.

The coir pot topper from Wessex Horticultural Products performed very well overall. Despite some deterioration towards the end, this material also looked capable of maintaining effective weed control well into the second summer. Aesthetically, this material appeared quite attractive, which is an advantage from a retailing perspective.

The Jute based topper from Hy-Tex also provided very good weed control under both irrigation regimes. The heavier ($750g/m^2$) grade of material was chosen for the trial and this also looks capable of sustaining weed control through into the summer. It was also well machined and easy to fit. Cosmetically, the material is not very attractive, especially after a year on the nursery and from a retailing viewpoint this is a disadvantage. A darker colour would be commercially beneficial, particularly as the toppers are difficult to remove after several months on the nursery due to a strong binding effect with the compost surface.

On the evidence of this trial the wool based topper looks very promising. There are different grades of this material and the heavier $400g/m^2$ grade was considered to be the most appropriate for nursery stock. The pot topper was beginning to break down towards the end of the trial under both irrigation regimes and may struggle to provide acceptable weed control beyond twelve months, particularly under overhead irrigation.. Occasional weed clusters formed in the centre of the pot, as the material began to break down. Some weed seeds also appeared to have germinated on the surface of the pot topper. The appearance of this pot topper is unattractive after several months on the nursery, which from a marketing viewpoint is a disadvantage. A tendency to bind on to the compost surface also means they may be difficult to remove at despatch.

Pot toppers based on polypropylene (Plantex), 250 micron grade polyethylene (Hadodisc) and Spin-Out treated matting (Geodisc) provided acceptable weed control on the capillary sandbed irrigated plots, where weed pressure was only moderate during the twelve month period. Although there was a downturn in weed control levels towards the end of the trial as weed pressure increased, there were no significant signs of deterioration of the materials. However, weed control with the Plantex and Hadodisc pot toppers in the overhead irrigated plots had begun to deteriorate more noticeably by late spring. Willowherb and bittercress were troublesome around the edges of some pots, where a gap had developed between the pot topper and the pot rim and along the line of the initial cut made to facilitate fitting. Constant removal by the wind was a problem with the Plantex and to a lesser extent Hadodisc pot toppers. The Spin-Out coated pot topper (Geodisc) held up well and maintained good levels of weed control into the spring and early summer.

Tables 1 and 2 summarise the percentage weed control, relative to the untreated control

Table 1

Weed Control - capillary sandbeds, first year trial 1995-96

Treatment	% Weed control at 3 months	6 months	9 months	12 months	Mean % weed control
A Untreated	-	-	-	-	-
B Herbicide	100	100	100	98.4	99.6
C WDI pelleted wool	83.3	100	79.7	28.4	72.8
D WDI wool pot topper	100	100	100	92.3	98.1
E Melcourt bark mulch	91.7	75	73.4	65.0	76.3
F Wessex Hort Products coir pot topper	100	100	100	98.4	99.6
G Spin-out pot topper (copper coated non woven matt)	100	100	100	86.3	96.6
H Hy-Tex pot topper (jute)	100	100	100	97.8	99.4
I Plantex pot topper (polypropylene)	100	100	95.3	72.7	92.0
J Hadodisc pot topper (polythene)	100	75	92.2	79.8	86.7

Table 2

Weed Control - overhead irrigation, first year trial 1995-96

Treatment	% Weed control at 3 months	6 months	9 months	12 months	Mean % weed control
A Untreated	-	-	-	-	-
B Herbicide	97.5	97.8	100	100	98.8
C WDI pelleted wool	59.5	69.1	83.2	42.9	63.6
D WDI wool pot topper	90.1	90.4	96.9	86.3	90.9
E Melcourt bark mulch	66.1	72.3	79.2	21.3	59.7
F Wessex Hort Products coir pot topper	97.5	96.8	98.0	93.3	96.4
G Spin-out pot topper (copper coated non woven matt)	93.4	86.2	93.9	80.0	88.4
H Hy-Tex pot topper (jute)	93.4	90.4	98.6	92.7	93.7
I Plantex pot topper (polypropylene)	81.0	87.2	92.6	65.9	81.7
J Hadodisc pot topper (polythene)	89.3	88.3	93.5	74.4	86.4

The loose fill bark mulch (1.5cm depth) is a pleasant and attractive material which has the advantage of being easier to apply around the base of multi-stemmed plant material (pot toppers are likely to leave gaps that weeds can quickly colonise). Weed control was disappointing, breaking down as early as three months into the trial, particularly under overhead watering. Overall, weed control under both watering regimes was poor. However, this type of mulch may have potential with short term crops where background weed pressure is not high. Multi-branched crops in tunnels or an sandbeds may be particularly suitable.

The performance of the pelleted wool mulch was also disappointing. Moss and liverwort as well as weeds became a concern towards the end of the trial. Trefoil contamination of the pellets contributed to weed numbers. Shrinkage of the hydrated pellets away from the edge of the pots allowed weeds to colonise and establish between the mulch and the rim of the pot

Most of the treatments kept moss and liverwort at bay throughout the twelve month period particularly, as might be expected, on the plots irrigated by capillary sandbeds. There was little sign of either moss or liverwort in the control plots of both irrigation regimes, the nursery has a very low background pressure and the direct stuck liners were clean when potted.

The wool pellets struggled to prevent liverwort during the latter stages of the trial. The Plantex pot toppers in the overhead irrigated plots also had difficulty in keeping liverwort in check, as the material lifted away from the compost surface to leave spaces which allowed the liverwort and to a lesser extent moss to establish in some of the pots. This is also a potential problem with the lightweight Hadodisc and Spin-Out coated pot toppers. Liverwort could be a problem with these materials if background pressure is high and they become separated from the compost surface.

Second year trial

The second trial concentrated on weed control under an overhead irrigation system. Weed pressure was high and this provided a good test for the various treatments. A similar pattern of results developed in this trial as occurred during the initial work. The herbicide treated plots again provided high levels of weed control, although liverwort began to establish significantly during the winter months. Background pressure from liverwort and to a lesser degree moss was greater in the second trial, encouraged largely by the exceptionally wet weather throughout the winter, spring and summer. Liverwort control is also a weakness of the Ronstar 2G/Flexidor 125 programme and the lack of competition from broad leaved weeds due to the programme, provided an added opportunity for liverwort to become established.

Whilst a standard herbicide programme was used as a yardstick against which to compare the other treatments, the primary objective of the trial was to identify which of the non chemical options could achieve weed control levels that, whilst not necessarily as high as

those achieved by the herbicide programme, were still commercially acceptable. Each of the non chemical treatments were successful in achieving this objective during the initial six months following potting. Thereafter, several of the treatments began to break down and struggled to maintain effective weed control the following spring. The clear exceptions were the pot toppers made from coir and jute each of which provided high levels of weed, moss and liverwort control throughout the twelve months of the trial.

Both the coir and jute pot toppers fitted well and showed little signs of shrinkage, thereby limiting opportunities for weed and liverwort colonisation. They were also quick and easy to put on when combined with the potting operation before setting down onto the beds. The attractive appearance of the coir pot topper also remained intact during the trial so allowing it to be marketed with the plant to offer added value. The appearance of the jute pot topper, whilst not as attractive remained acceptable, although it had begun to bind strongly to the compost surface by the end of the trial making removal at despatch difficult.

The pot topper made from jute repeated the high levels of weed control achieved in the first trial. This material may become commercially available as a pot topper in spring 1999. Moss and liverwort control was also of a high standard and there was little evidence of any shrinkage which might compromise weed control. The few weeds that developed tended to colonise the surface of the pot topper, in the absence of any gaps around the centre or margins of the pot. The natural binding effect which established between the jute and the compost helped prevent any of the pot toppers being blown away, although this might be a disadvantage when the plants are despatched, unless their appearance remains acceptable to consumers. To some degree, this will depend on how long they remain on the nursery.

The wool pot topper again gave high levels of weed control initially but had begun to deteriorate by the late spring. By this stage, weed seedlings particularly bittercress were germinating freely on the surface and around the edges, although moss and liverwort control remained intact. Fitting this pot topper was quick and easy, particularly as the material was thinner and more pliable than either the coir or jute based materials.

Weed control with the spin-out treated pot topper ('Geodisc') followed a similar pattern to the wool product and provided good levels of weed control during the initial few months. Very few weeds however germinated on the surface, confirming the efficacy of the spin-out treatment. Liverwort and moss control also held up well initially. However, several of the pot toppers were blown away by the wind, so allowing weeds to colonise quickly and some of the pot toppers became twisted and separated from the compost surface, creating air pockets in which weed seeds freely germinated. Also, this product relies heavily on the felt like undersurface forming a good contact with the compost surface to help prevent it being blown away. With several pot toppers this did not happen, due to an air gap forming between the pot topper and the compost surface, which had naturally settled with irrigation after potting. For best results, this product needs to be used on crops grown under protection or in very sheltered sites outdoors.

The cocoa shell loose fill mulch provided an interesting contrast to the pot toppers and provided high levels of weed control during the first six months. Weed control then began

to break down and weed numbers built up quickly in the spring. By the time of the last assessment in the summer, weed control had broken down completely. Moss and liverwort control remained intact until the summer. The main commercial role of this product is likely to be with short term, single season crops and multi branched subjects where the use of a pot topper may be impractical. Loose fill mulches are also likely to be more suitable for pot liners and specialist crops traditionally grown in smaller pot sizes for example, alpines and herbaceous perennials. Physical removal of the mulch by foraging birds occurred to a limited extent and this is a potential hazard which also happened with the bark mulch in the first trial.

Plant habit did not notably influence weed pressure or the performance and behaviour of the treatments. Overall weed numbers in the *Jasminum* and *Thuja* plots were no lower than in the *Spiraea*, which might have been expected to attract more weed pressure in winter on account of it being deciduous.

There was a surprisingly significant downturn in weed numbers with the *Astilbe* as compared to the other subjects. The dense crop canopy which persisted into the winter months discouraged weed, moss and liverwort establishment, as a result of which weed numbers recovered from the *Astilbe* were consistently lower across all treatments, with the exception of the wool pot topper, when assessed at the end of the trial.

The coir pot topper did not combine well with this herbaceous perennial and was frequently lifted away from the compost surface by basal shoots pushing up from the crown. Similar observations were made with the jute pot topper and it is likely that loose fill mulches are a better option for herbaceous subjects, particularly where background pressure may be high.

Each of the different pot toppers combined well with the *Spiraea, Jasminum* and *Thuja* and proved straightforward to fit.

Table 3 summarises the percentage weed control relative to the untreated control for the second year trial.

Table 3

Weed Control - overhead irrigation, second year trial 1997-98

Treatment	% Weed control at 3 months	6 months	9 months	12 months	Mean % weed control
A Untreated	-	-	-	-	-
B Herbicide	98.9	98.6	99.0	98.7	98.8
C Wool pot topper	78.7	80.5	3.9	3.9	41.7
D Coir pot topper	95.1	90.3	85.3	68.7	84.8
E Jute pot topper	94.7	93.9	73.2	61.1	80.7
F Geodisc pot top.	93.8	93.1	43.9	43.9	68.6
G Cocoa shell	85.5	88.6	9.8	2.0	46.6

With regard to the statistical analyses (detailed at Appendix III), the weed frequency data was difficult to analyse, principally due to the nature of the resulting data e.g. zero or low frequency data or mixtures of disparate and similar frequencies in the weed counts for a given month/variety. An analysis of variance using a split-plot analysis of the data, as if the varieties had been randomised, gave residual plots which could not be transformed to give satisfactory plots due to zeroes and low frequency count data. In an attempt to illicit a treatment effect, a randomized block design was contrived from the split plot design and each variety assumed to be a randomized block from which a Friedmans analysis could be performed. However, this randomized block analysis is likely to have a larger residual error than if the design was a randomized block design per se. Consequently, treatment effects may appear to be not so significant as they may otherwise be but the nature of the data ie, too many zero values makes accurate statistical analysis difficult if not impossible.

The data for each variety was analysed using Friedman's Analysis of Variance on a seasonal basis. The only weed count that appeared significant ($p=0.044$; for a Friedman's statistic of 12.92 for tied pairs) was for the *Astilbe* for the October assessment. The Friedman's analysis is a test which ranks the weed data for each treatment within a block and by virtue of this, it will not discriminate between large or small differences. However, if the differences are significant, it will still give a ranking. Because the Friedman's analysis lacks

power, it may fail to illicit statistical significances should differences exist in the data and therefore a visual presentation of the data as detailed at Table 3 provides a useful guide to treatment effects.

Liverwort and moss control, second year trial

Pressure from liverwort and to a lesser degree moss was greater in the second trial, encouraged to a large extent by the exceptionally wet weather during the winter, spring and summer. The majority of the treatments coped well with liverwort with the notable exceptions of the herbicide treated plots, where the percentage cover was greater than the untreated control at each of the four assessments. To a large degree, this was due to the success of the herbicide programme suppressing broad leaved weed pressure to such an extent that the liverwort could easily colonise an otherwise clean compost surface. By contrast, weed pressure in the control plots was significant and sufficient to smother and compete with the liverwort.

The pot toppers made from coir, wool and jute provided excellent liverwort control, as did the cocoa shell mulch, until it began to break down after the winter period. The Spin-Out treated pot toppers (Geodisc) also gave excellent control of liverwort where they had been able to sustain a close contact with the compost surface and had not either buckled or blown away. Buckled Geodisc pot toppers whereby parts of the product lift and separate away from the compost, create air pockets in which liverwort, moss and weed seedlings start to establish.

Table 4 shows the mean percentage liverwort cover per pot for each treatment at each assessment.

Table 4

Mean percentage liverwort control

	A	B	C	D	E	F	G
3 months	7.63	22.81	0	0	0.41	0	0
6 months	9.33	24.79	0	0	0	1.66	0
9 months	22.14	42.67	2.5	0	0	10.30	4.47
12 months	53.11	75.22	4.08	2.5	2.29	26.01	18.70

Moss did not establish to any significant degree during the trial though the pattern of control was broadly similar to the liverwort control. The main exception being a slight build up during the wet summer as highlighted at the final assessment. By the summer, moss had also started to colonise some of the pots treated with the Spin-out pot topper and loose cocoa shell mulch but not to any commercially significant extent.

Table 5 shows the mean percentage moss cover per pot for each treatment at each assessment.

Table 5

Mean percentage moss cover

	A	B	C	D	E	F	G
3 months	5.5	0	0	0	0	0	0
6 months	6.35	0	0	0	0	0	0
9 months	12.12	0.83	2.70	0	0	3.4	2.83
12 months	13.45	0.55	11.65	0.41	2.91	7.07	9.52

Vigour

Table 6 details the vigour assessments carried out at the end of the trial. None of the treatments conferred any deleterious effects on crop vigour and all plants were marketable although some were of a marginally better quality than others. None of the treatments produced any phytotoxic effects in either year of the trial.

Table 6

Vigour assessments, second year trial

Treatment	Spiraea	Jasminum	Astilbe	Thuja
Control	4.5	4.5	5	4.5
Herbicide	5.0	5.0	5.0	5.0
Wool	5.0	4.5	5.0	4.5
Coir	5.0	4.5	4.5	4.5
Jute	5.0	4.5	4.5	4.5
Geodisc	5.0	5.0	4.5	4.5
Cocoa shell	5.0	5.0	4.5	4.5

Key

0 - Dead
1 - Very poor quality
2 - Poor quality
3 - Average quality, not saleable
4 - Good quality, saleable as first grade plants
5 - Very good quality, saleable as first grade plants

Assessments carried out on the 7th July 1998 except *Thuja* (17th September 1998).

Discussion

There is little doubt that some pot toppers and loose fill mulch materials can provide commercially acceptable alternatives where the application of weed control chemicals may be impractical or inappropriate. Pot toppers made from coir, wool and jute are each capable of sustaining acceptable levels of weed control over a twelve month period. Pot toppers made from polythene (Hadodisc) and spin-out treated matt (Geodisc) may also have potential for use under protection but are likely to become dislodged outdoors. Distortion and separation from the compost surface may also be a problem with both products. With the exception of jute which is due for commercial release in spring 1999, each product is now commercially available to fit a range of pot diameters.

Loose fill mulches of bark and cocoa shell are more suitable for multi-branched subjects or those with a strongly suckering habit such as many herbaceous perennials. They are also an acceptable alternative for crops which are widely produced in small pots such as heathers, alpines, herbs and pot liners where the use of a pot topper may be impractical. Results from the trials however indicate that best results will be obtained with short term crops, either grown under protection or in sheltered positions, preferably on capillary sandbeds. Spillage where pots blow over and disturbance by foraging birds can also be a hazard to guard against.

Bark and cocoa shell mulches can be particularly effective at suppressing moss and liverwort colonisation - a frequent concern with crops in tunnels grown under intensive overhead irrigation. The attractive appearance of the mulch treatments offers an added marketing advantage and similar remarks apply to some pot toppers in particular those formed from coir.

There are a number of ground rules which need to be followed if good results are to be achieved. Many of these have been highlighted during the report. The key points embrace the need for the pot topper to be well fitted and of the correct size. They must also be put on immediately after potting, it is often easier and quicker to combine this task with the potting operation, working of a bench or trailer. Similar remarks apply to mulch treatments which must be of a sufficient depth to allow for some spillage or slumping. All non chemical treatments must be thoroughly watered in after application in order for them to settle and achieve good contact with the compost surface. Water also adds weight to reduce the risks of pot toppers being dislodged by the wind.

The thickness and weight of pot topper materials is important, particularly for outdoor crops exposed to winds.. Heavier grade materials, such as coir, jute and wool are much less likely to be removed. This is an important practical consideration, especially during the initial few weeks before the materials are fully wetted up and a protectant crop canopy cover has developed.

Weed colonisation during both trials tended to occur around the edges of the pots, where a gap had developed either due to shrinkage in the case of the wool pellets, or a poor initial fit

which occurred with some of the pot toppers, most notably the Plantex and the Spin-Out coated pot toppers. Few weeds actually appeared to grow directly on the surface of these materials. Similar remarks apply to the Hadodisc pot topper although weeds occasionally grew through the irrigation holes, punctured during manufacture of the topper. The wool pot topper tended to attract weed growth once it had begun to deteriorate after the winter period.

Pot toppers made from wool or jute and to a lesser degree coir, have a natural tendency to bind to the compost surface, which in turn reduces the potential for wind removal although, this effect can take several months to develop. In the case of wool and jute, this can be a disadvantage at marketing as their appearance from a consumer perspective tends to suffer during the winter months particularly those made from wool - where possible these are perhaps best removed at despatch.

The ease and speed with which pot toppers and mulches can be applied is an important consideration which will ultimately influence their commercial viability. Materials which are difficult and time consuming to apply are unlikely to be popular and attract commercial interest. The following observations were made during application of the materials at potting;

Pelleted wool waste - easy to apply by hand irrespective of the plant shape although this particular sample was a little dusty. Average time to apply was 5 seconds per pot. Application in a potting team is best handled by a dedicated person, rather than team members attempting to combine potting with pellet application. There is a need to irrigate to hydrate before transporting to the beds to reduce spillage on nursery roads.

Wool pot topper - probably the easiest pot topper to put on due to it being flexible and of a uniform size which was well matched to the pot diameter. Good contact with the compost surface was easy to achieve. Average time to apply was 4 seconds.

Bark and cocoa shell mulches - a clean, pleasant material to handle and apply by hand irrespective of plant shape. Care is needed during transportation to the beds if spillage is to be avoided. Water before moving to the beds. Average time to apply was 5 seconds.

Coir pot topper - the variable size and length of the fitting cut of the toppers complicated their application - average time taken was 7.5 seconds. Greater uniformity would ease and speed fitting.

Spin-Out treated non woven mat (Geodisc) - average application time was 5 seconds and fairly straightforward to put on. Wind removal can be a problem.

Jute pot topper - well machined and easy to apply, average time to put on was 4 seconds.

Thermal bonded polypropylene pot topper - awkward to put on particularly where more than one branch comes from the base. Central cut was too short on some toppers which made fitting time consuming and left some compost exposed. Average time to put on was 7.5 seconds. Difficult to get good contact between the topper and the compost surface due to its very light and flimsy nature.

Polythene (250 micron grade) pot topper (Hadodisc) - uniform size and shape eased application - average time taken was 5 seconds. The star incision in the middle of the topper made to hold and secure the material around the plant was helpful during fitting.

For trial purposes the mulches/ pot toppers were applied carefully by hand at a steady work speed. The depth of potting in particular needs to be adjusted in order that the pot can accommodate the materials. This is easier to do when hand potting but may present problems when machine potting where the tendency is to overfill the pot. Well made pot toppers were easy and quick to put on during hand potting, the loose fill bark and pellet mulches perhaps a little more awkward. Either however could be applied at a commercially acceptable work speed. Machine potted plants were used in the second trial with the treatments applied by hand before setting down. Excess compost was removed first so adding slightly to application times.

It is especially important with each of the pot toppers that the initial split or cut from the edge to the centre is done accurately to permit quick fitting. It is also important that plants are positioned in the middle of the pot if the pot topper is to cover all of the compost surface. Again this could complicate the fitting of pot toppers on a machine line where central positioning of the plants can be difficult to achieve consistently at speed. However, this did not prove to be a problem in the second trial when the plants were machine potted carefully.

Wind removal was a problem with the lighter materials based on polythene (Hadodisc) and polypropylene (Plantex) in the first trial and this did contribute to poorer weed control. This was particularly noticeable under overhead irrigation where moss, liverwort, willowherb and bittercress colonised air pockets which had developed between the cover and compost surface. Several pot toppers of each material were removed by the wind during the initial two months of the first trial, until natural canopy cover provided some protection. Both materials are very light although the Hadodisc has the advantage of being secured by the star shaped incision in the middle of the topper. The Plantex pot topper is extremely light and there is no method of securing it either to the plant or the compost surface. This material consequently was very prone to wind removal, which is a significant commercial disadvantage in terms of outdoor use. In the first trial, the Spin-out coated pot topper was also on occasions dislodged by the wind and in the second trial several pot toppers were blown away as the undersurface failed to establish a close contact with the compost surface.

Heavier grade materials such as the pot toppers made from coir, jute and wool were not prone to removal by the wind, even during the initial few weeks when this is most likely to occur. Towards the end of both trials there appeared to be a significant binding effect

between surface roots and the jute pot topper. This made the topper very difficult to remove either by the wind or manually for sales and this could arguably be a disadvantage from a retailing perspective, as the appearance of the material suffered during the winter months. Conversely, if the colour of the topper could be improved then this 'prolonged weed control' feature may be interpreted as a marketing advantage and so used to add value to the product. A similar situation occurred with some of the wool pot toppers although not to the same extent. The coir topper showed only limited binding in both trials.

Costs are clearly an important commercial consideration and current estimates are given in the table below:

Table 7

Estimated Costs of Treatments

Treatment/ Material	Approximate cost per 3 litre pot
Herbicide programme *	1.0p
Pelleted wool waste (1.5cm depth approx.)	4.5p
Wool pot topper (400g/m^2)	8.5p
Bark mulch (1.5cm depth approx.)	2.0p
Cocoa shell mulch (1.5 cm depth)	2.0p
Coir pot topper	9.0p
Geodisc pot topper	4.0p
Jute pot topper (750g/m^2)	8.5p
Plantex pot topper (bought as roll, then cut)	1.5p
Hadodisc pot topper	2.5p

* Based on two applications of Ronstar 2G (200kg/ha) and two applications of Flexidor 125 (1 litre/ha).

The estimated costs are for materials only and exclude application time.

The prices listed are for guidance only. They are likely to vary depending on the quantity purchased.

On the basis of these figures, the herbicide programme remains the cheapest as well as the most effective treatment. However, pot toppers are quicker, easier, cheaper and certainly safer to apply. Unlike chemicals, protective clothing or special training is not required for application. Certainly, from an operator's perspective they are more pleasant to apply and the work can be combined with potting for maximum efficiency.

Pot toppers could also provide added value and may prove a useful marketing advantage over plants which have been chemically treated. Weed control may be sustained during the retailing period on a garden centre and continued beyond consumer purchase. The customer is in effect buying the advantage of ready made and environmentally friendly weed control, which may continue after planting. Materials such as wool, coir and jute are biodegradable and will break down slowly after transplanting. In this context, it will be important that the pot topper is able to maintain an attractive appearance at point of sale after having spent several months in a nursery situation.

A selection of photographs highlighting some key aspects of the different treatments can be found at Appendix I

Conclusions

A number of important conclusions can be drawn from this work;

- Several pot topper materials have the potential to achieve sustained levels of weed control which are commercially acceptable in a nursery situation and which are similar to those offered by conventional herbicide programmes.

- The materials used in this trial were not phytotoxic to the crop and did not impart any deleterious effects on vigour.

- Although more expensive initially, non chemical options offer the advantages of being quicker, easier, and cheaper to apply than herbicides. They are environmentally more acceptable than weed control chemicals, user friendly and pleasant to use. No formal training or protective clothing is required. They may also offer added value at marketing.

- A good pot fit is important. To be effective and commercially viable, pot toppers must be quick and easy to put around the plant without leaving any compost surface exposed which may allow weeds to establish.

- Lightweight materials are prone to removal from the pot by wind and may also separate away from the compost. This can create exposed surfaces and allow weeds to germinate and become established. They are likely to have greater potential with crops grown under protection.

- From a retailing perspective, some pot toppers and mulches can provide added value which, together with their environmental acceptability (as compared to using chemical products), offers a useful marketing advantage which may become increasingly significant with major retailers.

Grateful thanks are expressed to the following companies for their support with this work:-

APT Marketing/Wool Development International (Wool pellets and pot toppers)
C/O APT Marketing
Park Farm
Kettlethorpe
Lincoln
LN1 2LD

Tel; 01522 704747

Melcourt Industries Ltd (Bark mulch)
8 Bells House
Church Street
Tetbury
Glos
GL8 8JG

Tel; 01666 503919

TDP Trade and DIY Products (Plantex pot topper)
The Pump House
Hazelwood Road
Duffield
Derby
DE6 4AA

Tel; 01332 842685

Wessex Horticultural Products Ltd (Coir pot topper)
South Newton
Salisbury
Wiltshire
SP2 OQW

Tel; 01722 337744

Hado Polythene (Hadodisc pot topper)
Spring Lane Industrial Estate
Malvern
Worcs
WR14 1AJ

Tel; 01684 574800

Fargro Ltd (Geodisc)
Toddington lane
Littlehampton
West Sussex
BN17 7PP

Tel; 01903 721591

Hy-Tex (UK) Ltd (Jute pot topper)
Hy-Tex
P.O.Box 97
Aldington
Ashford
Kent
TN25 7EA

Tel; 01233 720097

Peter Low & Company Ltd (Cocoa shell mulch)
45 Tile Farm Road
Orpington
Kent
BR6 9RY

Tel; 01689 861600

APPENDIX 1

Photographs

Plate 1

Trial layout (capillary sandbed), June 1995

Duncan's multiple range tests on treatment means of % weed control with outliers rejected.

Capillary bed irrigation.			Overhead irrigation.		
Treat. No.	Mean	Indices	Treat. No.	Mean	Indices
2	35.242	a	4	42.378	a
8	67.917	b	8	64.687	b
4	78.954	bc	2	67.007	b
6	78.961	bc	9	72.015	bc
9	65.691	cd	6	75.124	bc
3	90.046	cd	3	86.713	bcd
7	97.74	d	5	92.526	cd
5	98.305	d	7	93.228	cd
1	98.546	d	1	100	d

Duncan's multiple range tests on treatment means of % weed control squared and the previous outliers rejected.

Capillary bed irrigation.			Overhead irrigation.		
Treat. No.	Mean*	Indices	Treat. No.	Mean*	Indices
2	36.12	a	4	46.71	a
8	68.71	b	8	65.14	ab
4	80.11	bc	2	68.65	ab
6	80.25	bc	9	72.30	bc
9	86.83	cd	6	76.23	bc
3	90.43	cd	3	86.75	cd
7	97.79	d	5	92.67	d
5	98.33	d	7	93.24	d
1	98.56	d	1	100	d

***Means are back-transformed data.**

APPENDIX III

Summary of statistical analysis, second year trial

Analysis of weed data using Friedman's Analysis of Variance.

October 1997.

Friedman Test Variety 'Spiraea' coded '1'.

```
Friedman test for OctWNV1 by Treat__ blocked by Blk

S = 6.43  DF = 6  P = 0.377
S = 6.55  DF = 6  P = 0.365 (adjusted for ties)

                      Est    Sum of
Treat__         N   Median    Ranks
1               3    4.143     13.0
2               3    4.714     15.0
3               3    1.000      6.5
4               3    5.143     15.5
5               3   12.000     13.0
6               3    1.000      6.5
7               3    3.000     14.5

Grand median  =    4.429
```

Friedman Test Variety 'Jasminum' coded '2'.

```
Friedman test for OctWNV2 by Treat__ blocked by Blk

S = 4.79  DF = 6  P = 0.571
S = 4.87  DF = 6  P = 0.560 (adjusted for ties)

                      Est    Sum of
Treat__         N   Median    Ranks
1               3     1.00      6.0
2               3    23.57     15.0
3               3    16.29     15.0
4               3     3.57     12.5
5               3    10.29     11.5
6               3    57.86     14.5
7               3     2.43      9.5

Grand median  =    16.43
```

Friedman Test Variety 'Astilbe' coded '3'

```
Friedman test for OctWNV3 by Treat__ blocked by Blk

S = 12.00  DF = 6  P = 0.062
S = 12.92  DF = 6  P = 0.044 (adjusted for ties)

                      Est     Sum of
Treat__         N   Median     Ranks
1               3    0.000       7.0
2               3    0.000       5.0
3               3   10.143      20.0
4               3    1.000      13.0
5               3    1.000      12.0
6               3    0.857      10.0
7               3    3.000      17.0

Grand median    =    2.286
```

Friedman Test Variety 'Thuja' coded '4'.

```
Friedman test for OctWNV4 by Treat__ blocked by Blk

S = 11.25  DF = 6  P = 0.081
S = 11.32  DF = 6  P = 0.079 (adjusted for ties)

                      Est     Sum of
Treat__         N   Median     Ranks
1               3   34.57      16.5
2               3   15.00       8.0
3               3   10.71       6.0
4               3   51.00      17.0
5               3   28.71      16.5
6               3    9.00       6.0
7               3   25.00      14.0

Grand median    =   24.86
```

January 1998

Friedman Test for 'Spiraea'

Friedman test for JanWNV1 by Treat__ blocked by Blk

S = 5.04 DF = 6 P = 0.539
S = 5.16 DF = 6 P = 0.523 (adjusted for ties)

Treat__	N	Est Median	Sum of Ranks
1	3	14.429	16.5
2	3	5.143	15.5
3	3	1.429	9.5
4	3	0.286	8.5
5	3	12.714	14.5
6	3	2.000	8.5
7	3	2.000	11.0

Grand median = 5.429

Friedman Test for 'Jasminum'

Friedman test for JanWNV2 by Treat__ blocked by Blk

S = 5.86 DF = 6 P = 0.439
S = 6.04 DF = 6 P = 0.419 (adjusted for ties)

Treat__	N	Est Median	Sum of Ranks
1	3	2.00	5.5
2	3	34.86	16.5
3	3	9.43	14.5
4	3	4.00	12.0
5	3	2.00	9.0
6	3	28.86	14.0
7	3	4.86	12.5

Grand median = 12.29

Friedman Test for Astilbe

Friedman test for JanWNV3 by Treat__ blocked by Blk

S = 7.96 DF = 6 P = 0.241
S = 9.36 DF = 6 P = 0.154 (adjusted for ties)

Treat__	N	Est Median	Sum of Ranks
1	3	0.000	6.5
2	3	0.000	6.5
3	3	2.714	17.0
4	3	2.714	15.0
5	3	1.429	12.0
6	3	0.714	11.0
7	3	4.429	16.0

Grand median = 1.714

Friedman Test for 'Thuja'

Friedman test for JanWNV4 by Treat__ blocked by Blk

S = 5.14 DF = 6 P = 0.525

Treat__	N	Est Median	Sum of Ranks
1	3	11.14	13.0
2	3	6.57	8.0
3	3	6.86	8.0
4	3	34.29	18.0
5	3	18.00	13.0
6	3	10.43	11.0
7	3	18.71	13.0

Grand median = 15.14

April 1998

Friedman Test for 'Spiraea'

Friedman test for AprWNV1 by Treat__ blocked by Blk

S = 4.57 DF = 6 P = 0.600
S = 4.68 DF = 6 P = 0.585 (adjusted for ties)

Treat__	N	Est Median	Sum of Ranks
1	3	14.571	15.0
2	3	11.000	15.0
3	3	5.571	11.0
4	3	5.857	10.0
5	3	15.000	16.0
6	3	5.000	8.0
7	3	5.000	9.0

Grand median = 8.857

Friedman Test for 'Jasminum'

Friedman test for AprWNV2 by Treat__ blocked by Blk

S = 9.43 DF = 6 P = 0.151

Treat__	N	Est Median	Sum of Ranks
1	3	4.00	6.0
2	3	32.57	16.0
3	3	13.29	15.0
4	3	9.71	9.0
5	3	15.86	13.0
6	3	32.29	18.0
7	3	5.29	7.0

Grand median = 16.14

Friedman Test for 'Astilbe'

Friedman test for AprWNV3 by Treat__ blocked by Blk

S = 5.14 DF = 6 P = 0.525
S = 5.27 DF = 6 P = 0.510 (adjusted for ties)

Treat__	N	Est Median	Sum of Ranks
1	3	0.857	6.5
2	3	0.429	8.5
3	3	3.143	13.5
4	3	3.714	14.5
5	3	2.000	11.0
6	3	3.857	14.0
7	3	4.000	16.0

Grand median = 2.571

Friedman Test for 'Thuja'

Friedman test for AprWNV4 by Treat__ blocked by Blk

S = 5.86 DF = 6 P = 0.439

Treat__	N	Est Median	Sum of Ranks
1	3	116.9	15.0
2	3	18.0	8.0
3	3	14.0	8.0
4	3	50.6	12.0
5	3	46.6	13.0
6	3	30.3	10.0
7	3	174.7	18.0

Grand median = 64.4

July 1998

Friedman Test for 'Spiraea'

Friedman test for JulWNV1 by Treat__ blocked by Blk

S = 3.57 DF = 6 P = 0.734

Treat__	N	Est Median	Sum of Ranks
1	3	4.71	9.0
2	3	30.00	16.0
3	3	11.14	12.0
4	3	23.29	14.0
5	3	17.43	14.0
6	3	8.43	8.0
7	3	9.00	11.0

Grand median = 14.86

Friedman Test for 'Jasminum'

Friedman test for JulWNV2 by Treat__ blocked by Blk

S = 3.14 DF = 6 P = 0.791

Treat__	N	Est Median	Sum of Ranks
1	3	31.57	10.0
2	3	31.86	10.0
3	3	38.00	13.0
4	3	33.57	11.0
5	3	63.86	15.0
6	3	67.14	16.0
7	3	20.00	9.0

Grand median = 40.86

Friedman Test for 'Astilbe'

Friedman test for JulWNV3 by Treat__ blocked by Blk

S = 4.50 DF = 6 P = 0.609
S = 4.61 DF = 6 P = 0.595 (adjusted for ties)

Treat__	N	Est Median	Sum of Ranks
1	3	2.00	9.0
2	3	1.71	8.5
3	3	3.00	12.5
4	3	5.43	15.5
5	3	0.57	10.0
6	3	2.57	11.5
7	3	18.71	17.0

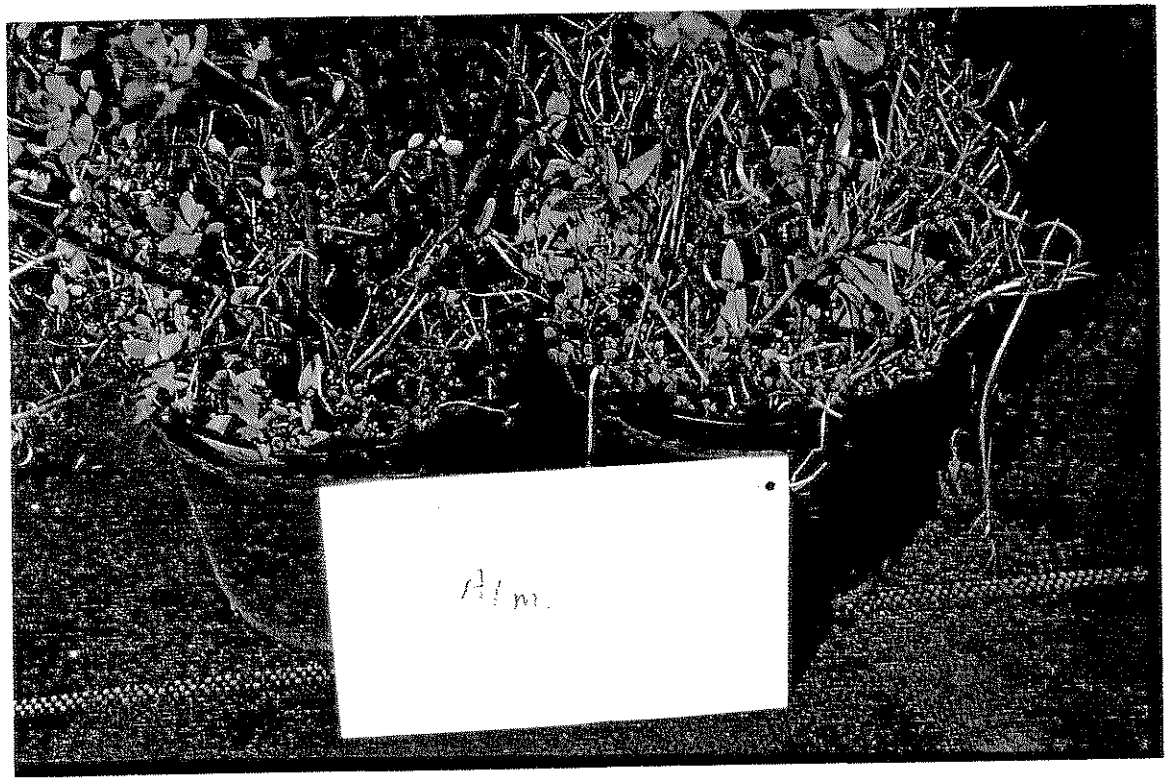
Grand median = 4.86

Friedman Test for 'Thuja'

```
Friedman test for JulWNV4 by Treat__ blocked by Blk

S = 7.39   DF = 6   P = 0.286
S = 7.44   DF = 6   P = 0.282 (adjusted for ties)

                      Est     Sum of
Treat__         N   Median     Ranks
1               3    55.00      17.5
2               3    16.00       7.0
3               3    18.43       9.5
4               3    43.00      17.0
5               3    39.71      13.0
6               3    17.43       8.0
7               3    36.43      12.0

Grand median    =    32.29
```

****

Plate 2



Untreated control (overhead irrigation), final assessment, July 1996

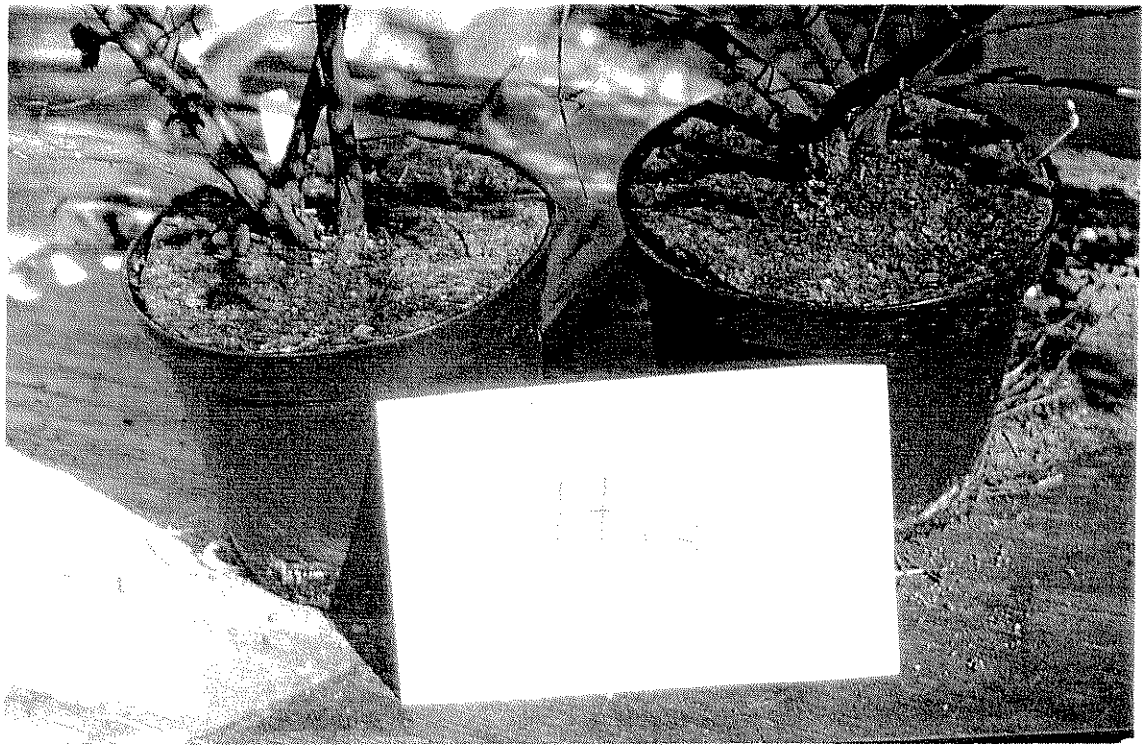
Plate 3

Coir pot topper (overhead irrigation), final assessment, July 1996

Plate 4

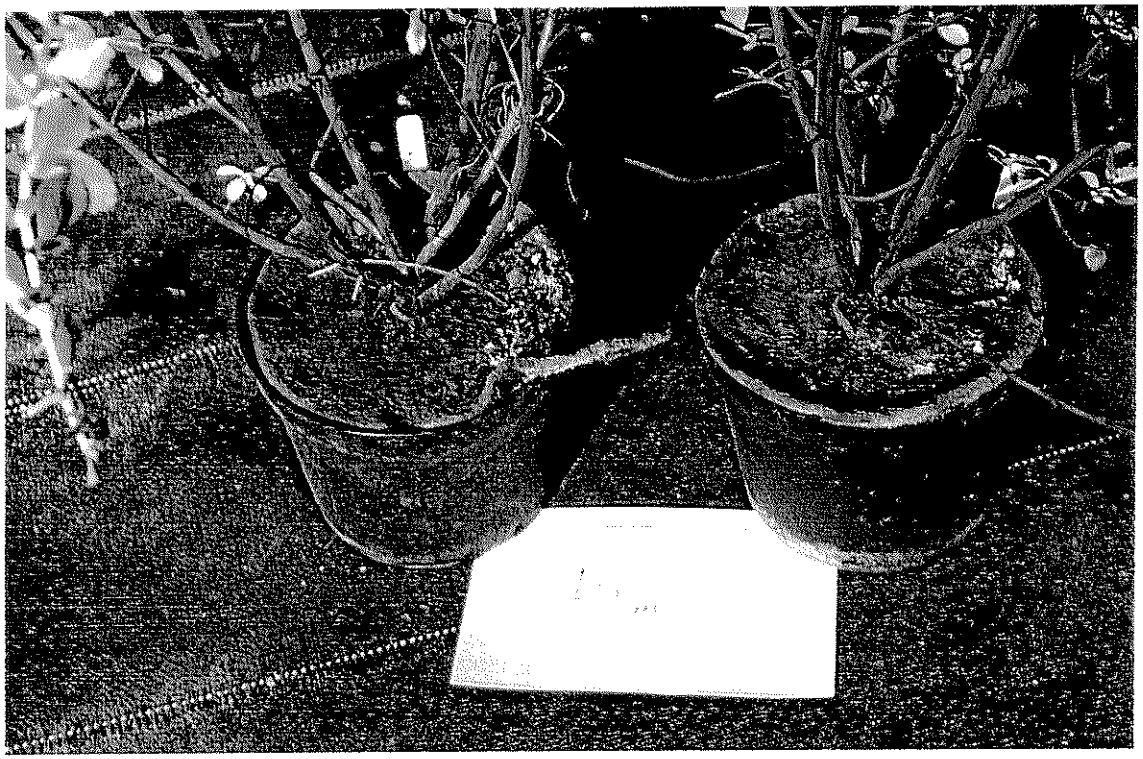
Jute pot topper (overhead irrigation), final assessment, July 1996

Plate 5



Jute pot topper (sandbed), final assessment, July 1996

Plate 6



Wool pot topper (overhead irrigation), final assessment, July 1996

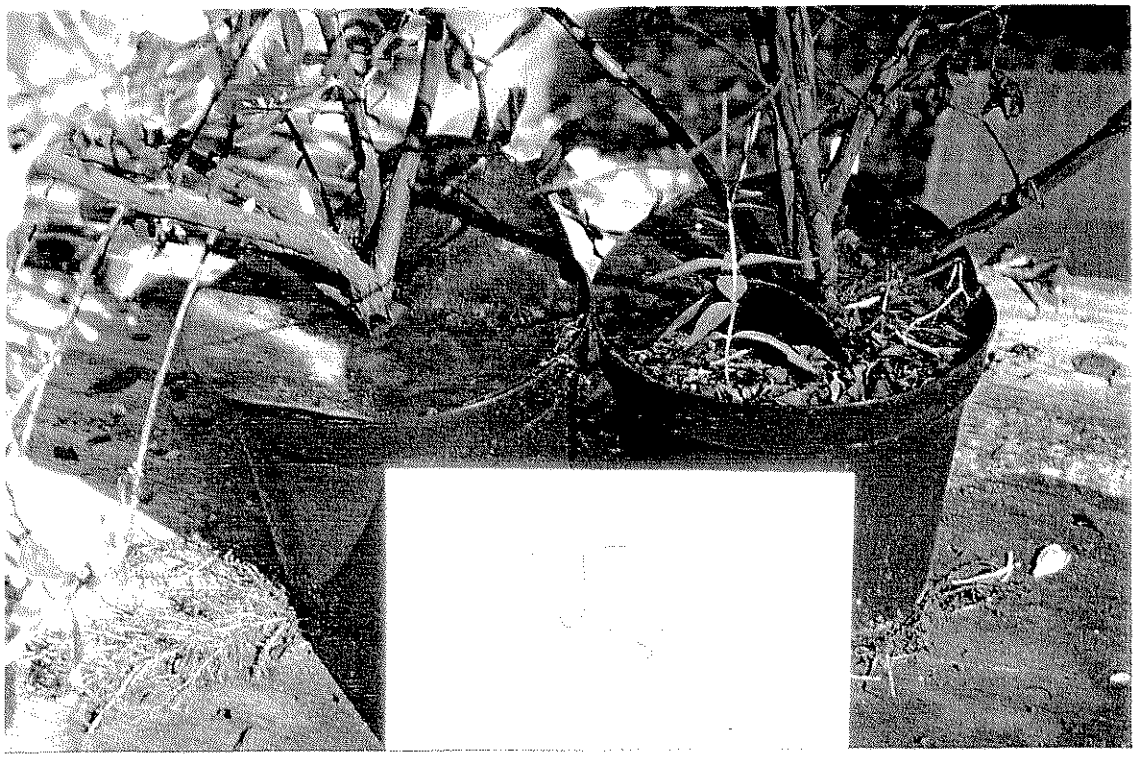
Plate 7

Wool pot topper (sandbed), final assessment, July 1996

Plate 8

Hadodisc pot topper (overhead irrigation), final assessment, July 1996

Plate 9

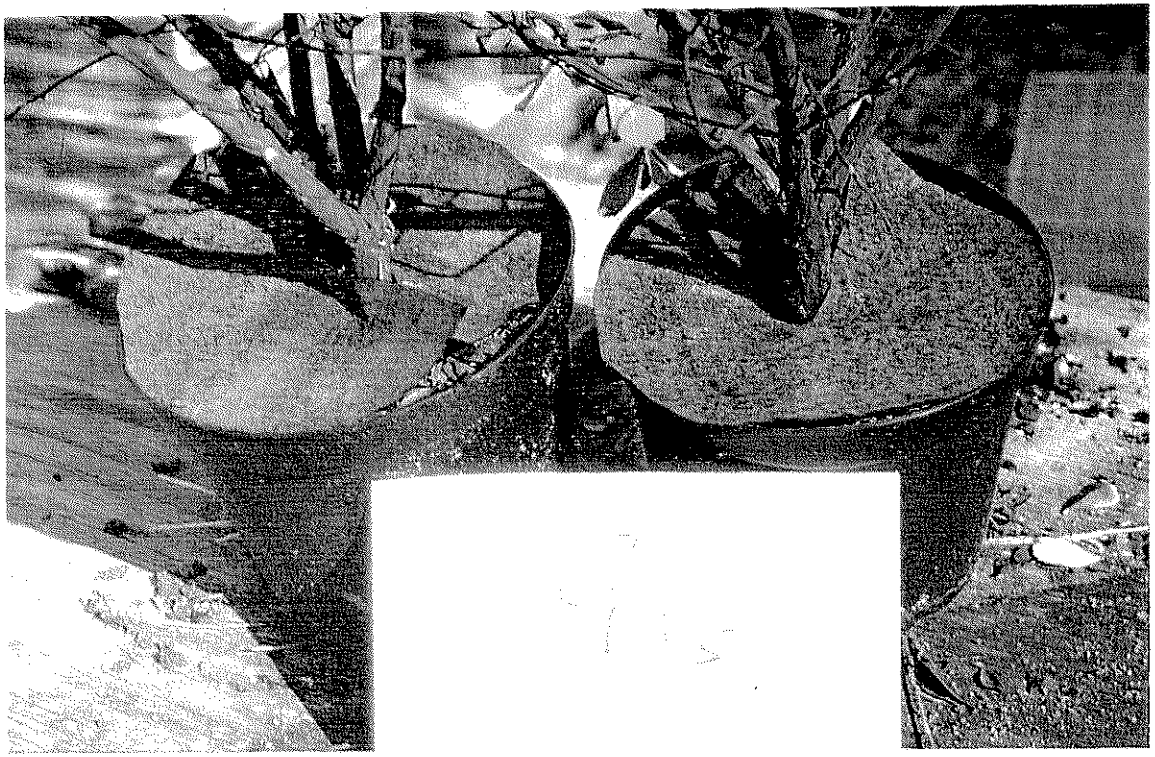


Hadodisc (sandbed), final assessment, July 1996

Plate 10

Spin-Out treated pot topper (overhead irrigation), final assessment, July 1996

Plate 11



Spin-Out treated pot topper (sandbed), final assessment, July 1996

Plate 12

Bark mulch (sandbed), final assessment, July 1996

Plate 13

Untreated control (overhead irrigation), final assessment, July 1998

Plate 14

Herbicide treatment on *Spireae* & *Jasminum* (overhead irrigation), final assessment, July 1998

Plate 15

Coir pot topper on *Spireae* (overhead irrigation), final assessment, July 1998

Plate 16

Coir pot topper on *Astilbe* (overhead irrigation), final assessment, July 1998

Plate 17

Wool pot topper on *Spireae* & *Jasminum* (overhead irrigation), final assessment, July 1998

Plate 18

Wool pot topper on *Jasminum* (overhead irrigation), final assessment, July 1998

APPENDIX II

Summary of statistical analysis, first year trial

***** Analysis of variance *****

Variate: WC_CAP%

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block.Wplot stratum					
Block	2	4517.2	2258.6	4.06	0.038
Treat	8	16743.0	2092.9	3.76	0.012
Residual	16	8905.9	556.6		
Total	26	30166.1			

***** Tables of means *****

Variate: WC_CAP%

Grand mean 74.1

Block	1	2	3
	92.2	67.2	62.9

Treat	HERBICIDE	WDI_PW	WDI_WPT	Mel_BM	W_HPCPT	S_PT	HY_TEX
	98.5	19.2	90.0	57.4	98.3	79.0	97.7

Treat	PLANTEX	HADODISC
	67.9	58.8

*** Standard errors of differences of means ***

Table	Block	Treat
rep.	9	3
s.e.d.	11.12	19.26

***** Stratum standard errors and coefficients of variation *****

Variate: WC_CAP%

Stratum	d.f.	s.e.	cv%
Block.Wplot	16	23.59	31.8

***** Analysis of variance *****

Variate: WC_OVER%

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block.Wplot stratum					
Block	2	6842.	3421.	2.66	0.101
Treat	8	27705.	3463.	2.69	0.044
Residual	16	20608.	1288.		
Total	26	55155.			

***** Tables of means *****

Variate: WC_OVER%

Grand mean 67.4

Block	1	2	3
	45.0	80.7	76.5

Treat	HERBICIDE	WDI_PW	WDI_WPT	Mel_BM	W_HPCPT	S_PT	HY_TEX
	100.0	15.8	86.7	6.1	92.5	75.1	93.2

Treat	PLANTEX	HADODISC
	64.7	72.0

*** Standard errors of differences of means ***

Table	Block	Treat
rep.	9	3
s.e.d.	16.92	29.30

***** Stratum standard errors and coefficients of variation *****

Variate: WC_OVER%

Stratum	d.f.	s.e.	cv%
Block.Wplot	16	35.89	53.3

Summary 1.

Analysis of the data revealed non-random residuals and this will influence the interpretation of the data. The results demonstrate a statistically significant block effect(p=0.038) and a treatment effect(p=0.012) for the capillary irrigation data and only a treatment effect for the overhead irrigation (p=0.044). It also appeared that two or three outlying data were present and these were rejected. Various transformations were evaluated and the square of the data was the one chosen to be adequate for a valid analysis of variance to be undertaken.

****

ANALYSIS AFTER 'OUTLIER' REJECTION.

***** Analysis of variance *****

Variate: WC_CAP%

Source of variation	d.f.(m.v.)	s.s.	m.s.	v.r.	F pr.
Block.Wplot stratum					
Block	2	1625.84	812.92	10.53	0.002
Treat	8	9792.30	1224.04	15.86	<.001
Residual	13(3)	1003.50	77.19		
Total	23(3)	9510.34			

***** Tables of means *****

Variate: WC_CAP%

Grand mean 81.3

Block	1	2	3
	92.2	76.1	75.4

Treat	HERBICIDE	WDI_PW	WDI_WPT	Mel_BM	W_HPCPT	S_PT	HY_TEX
	98.5	35.2	90.0	79.0	98.3	79.0	97.7

Treat	PLANTEX	HADODISC
	67.9	85.7

*** Standard errors of differences of means ***

Table	Block	Treat
rep.	9	3
s.e.d.	4.14	7.17

(Not adjusted for missing values)

***** Stratum standard errors and coefficients of variation *****

Variate: WC_CAP%

Stratum	d.f.	s.e.	cv%
Block.Wplot	13	8.79	10.8

***** Missing values *****

Variate: WC_CAP%

Unit	estimate
18	80.6
20	29.4
22	73.1

Max. no. iterations 5

***** Analysis of variance *****

Variate: WC_OVER%

Source of variation	d.f.(m.v.)	s.s.	m.s.	v.r.	F pr.
Block.Wplot stratum					
Block	2	197.3	98.7	0.65	0.535
Treat	8	7818.6	977.3	6.49	0.001
Residual	14(2)	2109.4	150.7		
Total	24(2)	8435.7			

***** Tables of means *****

Variate: WC_OVER%

Grand mean 77.1

Block	1	2	3
	74.1	80.7	76.5

Treat	HERBICIDE	WDI_PW	WDI_WPT	Mel_BM	W_HPCPT	S_PT	HY_TEX
	100.0	67.0	86.7	42.4	92.5	75.1	93.2

Treat	PLANTEX	HADODISC
	64.7	72.0

*** Standard errors of differences of means ***

Table	Block	Treat
rep.	9	3
s.e.d.	5.79	10.02

(Not adjusted for missing values)

***** Stratum standard errors and coefficients of variation *****

Variate: WC_OVER%

Stratum	d.f.	s.e.	cv%
Block.Wplot	14	12.27	15.9

***** Missing values *****

Variate: WC_OVER%

Unit	estimate
2	64.1
4	39.4

Max. no. iterations 4

Summary 2.

Rejection of data for plots 26,12 and 6 for the capillary sandbed irrigation and plots 4 and 6 for the overhead irrigation improved matters. There was increased block(p=0.002) and treatment(<0.001) for the capillary sandbed irrigation and an increased treatment(p=0.001) effect for the overhead irrigation. The relative rankings of the means for capillary bed and overhead irrigation was comparable with some exchanging of ranking positions. However, the distribution of the residuals was still systematic and 'square' transformations were undertaken.

ANALYSIS OF DATA EXCLUDING OUTLIERS, AND WITH SQUARED TRANSFORMATIONS OF %WEED CONTROL DATA.

***** Analysis of variance *****

Variate: SWC_CAP%

Source of variation	d.f.(m.v.)	s.s.	m.s.	v.r.	F pr.
Block.Wplot stratum					
Block	2	3.659E+07	1.829E+07	12.33	<.001
Treat	8	1.830E+08	2.287E+07	15.42	<.001
Residual	13(3)	1.929E+07	1.484E+06		
Total	23(3)	1.868E+08			

***** Tables of means *****

Variate: SWC_CAP%

Grand mean 7061.

Block	1	2	3
	8687.	6469.	6027.

Treat	HERBICIDE	WDI_PW	WDI_WPT	Mel_BM	W_HPCPT	S_PT	HY_TEX
	9713.	1305.	8177.	6418.	9670.	6440.	9563.

Treat	PLANTEX	HADODISC
	4721.	7540.

*** Standard errors of differences of means ***

Table	Block	Treat
rep.	9	3
s.e.d.	574.2	994.5

(Not adjusted for missing values)

***** Stratum standard errors and coefficients of variation *****

Variate: SWC_CAP%

Stratum	d.f.	s.e.	cv%
Block.Wplot	13	1218.0	17.3

***** Missing values *****

Variate: SWC_CAP%

Unit	estimate
18	6947.
20	271.
22	5384.

Max. no. iterations 5

***** Analysis of variance *****

Variate: SWC_OVER

Source of variation	d.f.(m.v.)	s.s.	m.s.	v.r.	F pr.
Block.Wplot stratum					
Block	2	6.053E+06	3.027E+06	1.43	0.273
Treat	8	1.537E+08	1.921E+07	9.05	<.001
Residual	14(2)	2.974E+07	2.124E+06		
Total	24(2)	1.629E+08			

* MESSAGE: the following units have large residuals.

Block 2	Wplot 4	-2345.	s.e. 1049.
Block 3	Wplot 4	2345.	s.e. 1049.

***** Tables of means *****

Variate: SWC_OVER

Grand mean 6331.

Block	1	2	3
	5924.	6995.	6075.

Treat	HERBICIDE	WDI_PW	WDI_WPT	Mel_BM	W_HPCPT	S_PT	HY_TEX
	10000.	4713.	7525.	2181.	8587.	5811.	8693.

Treat	PLANTEX	HADODISC
	4243.	5228.

*** Standard errors of differences of means ***

Table	Block	Treat
rep.	9	3
s.e.d.	687.0	1190.0

(Not adjusted for missing values)

***** Stratum standard errors and coefficients of variation *****

Variate: SWC_OVER

Stratum	d.f.	s.e.	cv%
Block.Wplot	14	1457.4	23.0

***** Missing values *****

Variate: SWC_OVER

Unit	estimate
2	4306.
4	1775.

Max. no. iterations 4

Summary 3.

There was increased block(p=<0.001) and treatment(<0.001) for the capillary sandbed irrigation and an increased treatment(p=<0.001) effect for the overhead irrigation. The distribution of the residuals was more random and therefore the analysis is more valid. There has also been a modification of the Duncan indices for the overhead irrigation data.

****

Note on Duncan's Multiple Range Technique.

If the treatment effect is significant then treatments can be ranked according to their variate(%weed cover) mean and each and every pair of results compared statistically and indices (a-d) derived to show similar groupings from the treatment effect. This gives the experimenter a guide to the relative effect of each treatment but should not be taken as being absolute. The tables below are for the 3 sets of analysis, namely for the raw data, the raw data with outliers excluded and the latter with the data transformed by squaring the original data.

Duncan's multiple range tests (p=0.05) on treatment means of % weed control-raw data.

Capillary bed irrigation.			Overhead irrigation.		
Treat. No.	Mean	Indices	Treat. No.	Mean	Indices
2	19.228	a	4	6.136	a
4	57.41	ab	2	15.831	ab
9	58.834	ab	8	64.687	abc
8	67.917	b	9	72.015	abc
6	78.961	b	6	75.124	bc
3	90.046	b	3	86.713	c
7	97.74	b	5	92.526	c
5	98.305	b	7	93.228	c
1	98.546	b	1	100	c

The treatment codes are 1-9 for treatments B-J(relative to A) respectively.