Project Title:	Evaluating the risk of Run-off during Irrigation and Pesticide Application in Module Raised Vegetable Propagation Nurseries
Project Number:	CP 34
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Report:	Final Report, September 2006
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Location:	Variety of Propagation Nurseries in Yorkshire and Lincolnshire
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Date Commenced:	1st October 2005
Completion date:	30th September 2006
Key Words:	Water, run-off, irrigation, module, spraying vegetable, propagation, nurseries, gantry, overhead, pesticide, contamination, surface water, ground-water.

The results and conclusions in this report are based on data collected from a series of visits to several vegetable propagation nurseries over a period of 12 months. The conditions under which the investigations were carried out and the results generated 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 interpretation of the results especially if they are used as the basis for commercial recommendations.

AUTHENTICATION

I declare that the work was done under my supervision 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

Run-off from five propagation nurseries during irrigation and spray events found to be low at 0.6m^3/ha to 1.96 m^3/ha (1mm rainfall/ha = 10 m^3/ha) and unlikely to present a risk to groundwater.

Background and Expected Deliverables

The adoption of the Water Framework Directive by Defra in 2000 could potentially have fairly wide reaching implications for the horticultural and agricultural industries. Defra will need to produce data from detailed monitoring of many sites to enable them to draw conclusions and implement policy to ensure the "all inland and coastal waters reach 'good status' by 2015". It will do this by "establishing a river basin district structure within which demanding environmental objectives will be set, including ecological targets for surface waters". Depending on the outcome of these studies it is possible that remediation measures may be required in terms of changes to current practice to ensure that no breaches or exceedances occur which could potentially impact on surface or ground-water quality. Areas of specific concern for the horticultural industry include the leaching of fertiliser, particularly nitrates and phosphates, following irrigation and the potential for contamination via run-off containing pesticide residues from treated crops.

At present there are no risk assessments in place for individual nurseries regarding run-off from propagation crops and therefore there is no evidence on which to base the appropriateness or otherwise of current practices. As a result of the increased concern in this area the brassica propagators, through the Plant Propagators Association, considered it appropriate to try and gather independent run-off data from a range of randomly selected nurseries via a HDC-funded project conducted over 1 season. Depending on the outcome of these preliminary studies, the data could be used to form the framework of an effective 'due diligence' defence should issues relating to surface and/or ground-water contamination arise in the future.

The aim of the project therefore was to survey a selection of different propagation nurseries to determine the level of run-off following conventional 'commercial' irrigation and pesticide application deployed by different nurseries using a variety of different application techniques and equipment. It is expected that this project would deliver important information and data to re-assure members of the Plant Propagators Association and help provide accurate data from independent monitoring of module raised brassicas across a cross-section of nurseries to enable the industry to draw conclusions as to whether they need to alter of adjust their current commercial practice.

Summary of the Project and Main Conclusions

Five brassica propagators in Lincolnshire and Yorkshire were selected at random to participate in the study. Each nursery was visited on two separate occasions, once in November 2005 and again in March 2006. During each visit 2 discrete crops in different propagation units or glasshouses were identified endeavouring to ensure a range of different cultivars, sowing dates/crop sizes and module sizes were used wherever possible. Full details of the specific crops and the method of irrigation were collected. Examples of gantry and conventional overhead irrigation systems used commercially on these nurseries are shown in Figs 1 and 2 respectively.

Figure 1: Brassica modules being irrigated using a gantry system. The yellow canes mark the position of the collection trays below the crop

Figure 2: Brassica modules being irrigated using an overhead irrigation system. The yellow canes (just visible) mark the position of the collection trays below the crop

Numerous irrigation/spray collection trays (25.5cm x 34cm) were positioned under each crop to capture any run-off during irrigation and/or spray events. Following placement the irrigation and/or spray events were then triggered as per normal commercial practice. After 30 minutes the run-off collection trays were retrieved and any liquid contained was measured and recorded. It was observed during the first monitoring exercise in November 2005 that both the gantry and overhead irrigation systems allowed some water to fall on the pathways on either side of the crop. As this could potentially increase the run-off volume and potential for surface-water contamination, particularly in the event of a pesticide application, collection trays were positioned in the pathways adjacent to the crop being irrigated to allow a record of the amount of run-off falling on these areas to be made. Using the captured run-off data and the surface area of the collection trays it was possible to determine the run-off volume/unit area of both the crop and adjacent pathways.

The data demonstrated that the actual volume of run-off/m^2 from module trays was quite small (Mean of 0.16 and 0.37 m^3/ha in November 2005 and March 2006 respectively), though surprisingly variable both between different crops and nurseries. Run-off volumes, particularly at one nursery (Nursery B), appeared to be much higher during the March 2006 monitoring compared to the earlier visits in November 2005. This could potentially be a reflection of the dryness or otherwise of the compost, the water holding capacity of the growing medium being used, the frequency of watering prior to and during the monitoring periods, the total volume and duration of each irrigation event or simply the attention to detail in laying out the trays (to avoid sloping trays and spaces between them). The two crops which were irrigated using the overhead system (D 2 in November 2005 and D 1 in March 2006) showed slightly higher levels of run-off than many of the gantry-irrigated crops, but were by no means the highest overall in the March 2006 monitoring. A moderate level of run-off was recorded on one crop at Nursery B during the November 2005 monitoring though the run-off volume at this site increased significantly in both crops monitored in March 2006. Whilst it has not been possible to pin-point the precise reasons for the increased run-off recorded at this site it is perhaps possible to speculate as to a possible cause based on the fact that the two crops involved were both over-wintered having been sown in October 2005. As such it is likely that seedlings were effectively 'pot-bound' and this, together with the dense foliage could have prevented water uptake and hence increased run-off. Yet, to counter this argument, there was at least one other crop (Nursery A crop 2) that was also over-wintered and yet this crop recorded one of the lowest run-off figures when monitored in March 2006.

Where run-off was collected in the pathways during the March 2006 monitoring period a higher level of run-off was recorded (Mean of $18.1 m^3/ha$). It is, however, important to put the level of run-off captured in some sort of perspective. Firstly the area of pathway involved in run-off capture represents approximately 1% of the cropped area and therefore it could be argued that, even though the level of run-off was higher, the actual significance of this run-off is lower than that of the cropped areas. Secondly, 1mm rainfall over an area of 1ha is equivalent to $10 m^3$ water/ha; therefore, even assuming a 'worst-case' cropping scenario using a cumulative run-off figure from the March 2006 monitoring period i.e. $0.37 m^3/ha$ (cropped area) plus $0.18 m^3/ha$ (pathway : 1% of $18.1 m^3/ha$) and allowing a 10-fold safety factor (which gives a maximum run-off figure of $5.5 m^3$ run-off/ha) this still only equates to <u>0.1mm rainfall over a 1ha area</u>.

Whilst the project conducted here has attempted to address the issue of diffuse pollution through an independent assessment of run-off from propagation nurseries it has not specifically considered the various components of run-off e.g. nitrates, phosphates and pesticides, considered as potential threats to surface and ground-waters around the UK. Depending on whether the various government agencies consider the run-off volumes reported here as significant or not further work may be necessary to look in more detail at specific sites to measure the actual quantities of nutrients and pesticides leached out during irrigation and spray events.

- Five vegetable propagation nurseries were monitored during the period November 2005 to March 2006. The volume of run-off during both irrigation and spray events was determined on two occasions on a range of different crops and scenarios reflecting standard commercial practice.

- Baseline information relevant to each nursery and crop location was captured using a standardised questionnaire. This information was interrogated to aid interpretation of the run-off data.

- Only one of the randomly selected nurseries (in Lincolnshire & Yorkshire), based on the address details provided, during a review of the information contained within the Water framework Directive, proved to be located within an NVZ (Nitrate Vulnerable Zone). Whether glasshouses and potential run-off from such structures are regarded to be significant in such areas remains in some doubt.

- The level of run-off collected during the first monitoring in November was very low ($< 0.6 m^3/ha$) and this was irrespective of the irrigation or spraying technique, the growth stage or time of year the monitoring was undertaken. To put this in perspective, 1mm rain falling over an area of 1 ha is equivalent to 10 m^3/ha. Therefore the maximum level of run-off recorded equates to 0.06mm rainfall/irrigation or spray event.

- During the second monitoring period in March 2006 a higher level of run-off (up to 1.96 m^3/ha) was detected, particularly on one nursery (B). However, to put this in perspective again, this rate of run-off still only equates to 0.2mm rainfall/irrigation or spray event.

- It is also pertinent here to note that the brassica crops monitored were only irrigated occasionally and for very short durations of time, especially for the gantry systems which predominated in this study; though naturally this would be dictated by the prevailing weather conditions. On average, based on the data collected during the study, crops were watered at approximately weekly intervals in November 2005 but more frequently in March 2006 when it was approximately every 2 days.

- The run-off levels captured from the crops monitored were considered to be consistent with general nursery practice and regarded to be of negligible significance with respect to surface and/or ground water contamination, especially as much of the run-off solution will be adequately contained either by the overlying plastic mulch or in the soil which is likely to be well below field capacity, beneath the crops.

- However, at the second visit in March 2006 where run-off was captured from pathways adjacent to the cropped areas it was evident that on some nurseries that, perhaps not surprisingly, this increased the risk of run-off markedly relative to the cropped areas (maximum of 45m3/ha). It is important to note though that the actual areas involved, relative to the cropped areas, are relatively small and estimated to be less than 1.0% of the total irrigated and/or sprayed cropping areas. It is also relevant here that on several nurseries polythene was used beneath the crop and this prevented any run-off into the soil and the excess water applied subsequently evaporated during the day.

- In conclusion, the level of run-off from the cropped areas was, in most cases, insignificant and this ought to be of considerable assistance in preparing an effective 'due diligence' defence in the event of future concerns regarding run-off from commercial vegetable nurseries. However, the level of run-off from non-cropped areas e.g. pathways during irrigation events was higher and this suggests that there is perhaps room for slight improvement in terms of overall water management on these nurseries. There could, of course, be greater interest in the outcome of the run-off from the glasshouse roof and other standing areas rather than the crop itself, especially during high rainfall periods.

- Whilst this project focused broadly on determining the potential for run-off following irrigation & spray events it has not attempted to address the issue of pesticide residues or their breakdown products in the run-off solution or their potential for surface and ground-water contamination. Further discussion with the environment agency and other regulatory agencies e.g. PSD would be necessary to determine whether further studies would be appropriate given the levels of run-off reported in the current study.

Financial Benefits

There are no immediate financial benefits to be gained from this initial study. However, given the increased legislative requirements facing the industry the information is still of significant value in terms of identifying whether brassica propagators, and the propagation industry more widely, are compliant with current requirements in respect of the Water Framework Directive and other government legislation. The variability in run-off identified between individual nurseries is also of interest as it suggests perhaps that with improved irrigation management some nurseries could make significant cost-savings in terms of overall water use.

Finally, the data generated is now available to the propagation industry and can, where appropriate, be used to help provide a 'due diligence' defence in the event of a challenge from legislators with regard to diffuse pollution via run-off from propagation nurseries around the UK.

Action Points for Growers

- Growers need to be aware of their requirements with regard to surface and ground water from fertilisers, especially nitrates and phosphates but also pesticides and other chemicals that may accidentally be present as contaminants from run-off in surface.

- For more information growers are urged to check with the environment agency locally and/or via the web-site (www.environment-agency.gov.uk/).

- Growers should ensure they are fully conversant with the Water Framework Directive and Nitrate Vulnerable Zones (NVZ's). Eor those growers with access to a PC the following links should be useful:-
  - http://www.defra.gov.uk/environment/water/wfd/index.htm
  - http://www.defra.gov.uk/environment/water/quality/nitrate/default.htm

- Based on the information generated from this study it would appear that the likelihood of surface- and/or ground-water contamination from run-off is very small. The majority of growers are therefore unlikely to need to change existing practices. However, it would be advisable for propagators to review their own nursery irrigation practice to ensure their specific nursery is broadly in line with those monitored in this study with respect to irrigation run-off. Subject to further discussion with the environment agency (via the plant propagators association) the situation may change and therefore it is important that growers keep abreast of developments in this regard.

- Irrespective of the likelihood of run-off growers need to consider the fate of applied products and especially pesticides as there is potential for them to persist in some situations. A risk assessment would be advisable especially in situations where staff are employed on the nursery. Where appropriate soil and other samples can be submitted for multi-residue analysis and this should provide an indication of the overall pesticide levels around the nursery.

SCIENCE SECTION

Introduction

The Water Framework Directive, adopted by Defra in 2000 has the potential to have fairly wide reaching consequences for the UK agricultural and horticultural industry. The government, through Defra, will need to produce data from detailed monitoring of many sites to enable them to draw conclusions and implement policy to ensure that "all inland and coastal waters reach 'good status' by the year 2015". The current aim is to do this by "establishing a river basin district structure within which demanding environmental objectives will be set, including ecological targets for surface waters". Depending on the outcome of these studies it is possible that remediation measures may be required of specific businesses in terms of changes to current practice to ensure that no breaches or exceedances occur which could potentially impact on surface or ground-water quality. Areas of specific concern for the horticultural industry include the leaching of fertiliser, particularly nitrates and phosphates, following irrigation and the potential for contamination via run-off containing pesticide residues from treated crops.

At present there are no risk assessments in place for individual nurseries, including propagators, regarding run-off from crops and therefore there is no evidence on which to base the appropriateness or otherwise of current practices. As a result of the increased concern in this area the brassica propagators, through the Plant Propagators Association, considered it appropriate to try and gather independent run-off data from a range of randomly selected nurseries via a HDC-funded project conducted over one season. Depending on the outcome of these preliminary studies, the data could be used to inform the industry of the situation regarding run-off and assist in future risk assessments on nurseries. It could also potentially form the framework of an effective 'due diligence' defence should issues relating to surface and/or ground-water contamination arise in the future.

The primary aim of the project therefore was to survey a selection of different propagation nurseries to determine the level of run-off following conventional 'commercial' irrigation and pesticide application deployed by different nurseries using a variety of different application techniques and equipment. The project should deliver important information and data to re-assure or inform members of the Plant Propagators Association and help provide accurate data from independent monitoring of module raised brassicas across a cross-section of nurseries to enable the industry to draw conclusions as to whether they need to alter or adjust their current commercial practice.

Materials & Methods

(i) Trial site location

A representative selection of five geographically separate vegetable propagation nurseries in Lincolnshire and Yorkshire were chosen for the study following consultation with the HDC project co-ordinator. The nurseries were selected to represent the full range of irrigation and pesticide application practices currently used in the industry. The location of the five nurseries which participated in the study has been kept confidential in this report and are identified only by letters A-E. Individual nurseries have been made aware of their own data set for comparative purposes with the full data-set.

(ii) Nursery questionnaire

Following nursery agreement for participation in the study an initial monitoring visit was conducted at which time a detailed questionnaire (Appendix 1) was completed by each nursery to gather relevant information on the growing regime, irrigation technology and pesticide application methods employed at the nursery.

(iii) Nursery visits

Two visits were carried out to each site to measure run-off in November 2005 and again in March 2006. During each site visit two separate propagation areas were identified in consultation with the individual growers. The sites chosen for study differed, where possible, in watering method (gantry, overhead etc.), module size, crop/cultivar, plant age e.g. over-wintered or recently sown and overall management style. A total of 10 collection trays (25.5cm x 34cm) were positioned under each crop during the visits in November 2005 and their position logged on the grid diagram shown overleaf. For greater accuracy the number of trays/site was increased to 20 (beneath each crop) for the visits conducted in March 2006 together with a further 4 trays/crop in the adjacent pathways.

Figure 3: Example of monitoring grid used at each site. Each square represents a single module tray containing between 84-504 cells or seedlings.

Evaluating the risk of Run-off during Irrigation Events

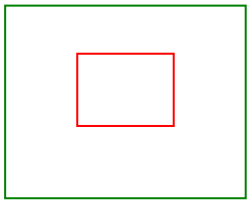
Nursery ……………………………. Date ………………………

Crop ………………..………..… Variety……………………

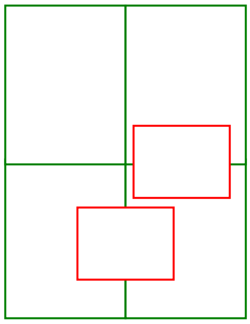
Module size ………………………… Sown……………………..

20										
19										
18										
17										
16										
15										
14										
13										
12										
11										
10										
9										
8										
7										
6										
5										
4										
3										
2										
1										
	1	2	3	4	5	6	7	8	9	10

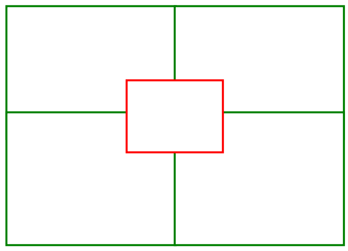
Where possible the trays were placed in a variety of positions under the crop, for example, some trays were positioned directly and fully below a module tray (position 1), others were positioned below two adjacent trays (position 2), and where tray supports allowed, others were positioned at the point where the corners of four trays met (position 3). The green lines represent the propagation tray, whilst the collection tray is shown in red.



Position 1



Position 2
(2 alternatives)



Position 3

Following the positioning of the trays the irrigation event was initiated as normal using typical durations and flow rates as was normal practice on that crop at that time of year. Following the irrigation event the crop was left undisturbed for 30 minutes to allow any drainage from the trays to occur. Full details of crop, cultivar, irrigation method, nozzle size, flow rate/volume were collected for each site where monitoring was carried out.

Site layout varied considerably from nursery to nursery and within nurseries depending on the crop and the glass house. Some of the monitored sites had pathways along side the trays which had a variety of surfaces e.g. mypex, soil, sand etc. It was decided that during the March monitoring visits collection trays would also be placed within the pathway (Position 4) to catch whatever irrigation water was incident on these areas as this was potential run-off.

(iv) Crop Diary

07.11.05	1^{st} visit to Nursery A
15.11.05	1^{st} visit to Nurseries B and C
23.11.05	1^{st} visit to Nurseries D & E
17.03.06	2^{nd} visit to Nursery A
23.03.06	2^{nd} visit to Nurseries E & D
28.03.06	2^{nd} visit to Nurseries B & C

Results

Table 1 below shows the collated details from the questionnaires used at each nursery. The majority of the nurseries were positioned on sites with little or no elevation, largely a reflection of their location in Lincolnshire. Three of the five nurseries provided details regarding their proximity to local water courses or drainage ditches and where these ultimately emptied out. A variety of methods for carrying out pesticide applications were used. Some nurseries applied all crop protection products via their irrigation gantries (or overhead spray lines), whilst a few used a mixture of gantry and barrow sprayers. No monitoring of a pesticide application using a barrow sprayer was possible during the period of this study. It is perhaps reasonable to assume that whilst this method of application is likely to be less even across the crop area and, depending on the operator, might result in variable levels of run-off across the crop though the volumes involved are likely to be much lower than during irrigation events.

Table 2 provides details of each of the trial sites monitored during the 1st set of visits carried out in November 2005. Details of the sites monitored in the second set of visits is presented in Table 3. The majority of the sites visited used gantry irrigation systems and only 2 crops were found which were irrigated by overhead spray lines. It is interesting to note that at the November 2005 visits irrigation events were, on average, applied every 7-8 days. However, in March 2006 the frequency of irrigation events was increased to every 2-3 days. This is likely to be a reflection of the active growing condition of the monitored crops relative to the prevailing solar radiation levels at the time of the visits.

Tables 4 & 5 provide details of the run-off collected under each crop on each visit during the two monitoring periods in November 2005 and March 2006 respectively. As described in the Methods and Materials section, 10 collection trays were positioned below each crop during the visits carried out in November 2005. At this time, trays were not placed in the pathways between or around the edges of the crop. It was also only possible to position any collection trays in position 3 (at the central point of 4 adjacent trays) at one nursery (A). This was due to the methods of supporting the module trays used at other nurseries. At the second monitoring period 20 collection trays were used per crop and they were also put in the pathways (4/crop). The results from these are presented in Table 6.

1st Nursery Visit : November 2005

Volumes of run-off collected during these visits were mostly very low. Six out of the ten crops monitored had a recorded run-off of < 3ml/m^2 (equivalent to 0.03m^3 water/ha) The highest level of run-off recorded (63.4ml/m^2) was in crop No. 2 at Nursery D in November 2005, which was irrigated using an overhead, rather than a gantry system. However, it should be noted that all the collection trays at this monitoring visit were positioned between 2 adjacent trays (position 2) which is likely to give a slightly higher run-off than the average as, generally speaking, a greater level of run-off was recorded from trays in position 2 than position 1. This run-off volume is equivalent to 0.63m^3/ha (634 litres water/ha). Crop 2 at Site B (a gantry system) during the evaluation period in November 2005 also showed a relatively high level of run-off compared to the other crops monitored; the run-off volume being equivalent to 0.48 m^3/ha (484 litres water/ha). The mean run-off volume/irrigation event was calculated to be 0.16m^3water/ha. It is also worth noting that at this time of year irrigation was applied to these crops on average once every 7-8 days therefore the overall quantity of water applied is very low and the run-off minimal especially if you consider the fact that the underlying soil under glass tends to be very dry, well below field capacity and in some cases covered in polythene or Mypex. Moreover the higher temperatures under protection lead to a higher level of evaporation from surfaces particularly during periods of high solar radiation and this will further reduce the risk of any run-off.

2nd Nursery Visits : March 2006

Generally, the level of run-off from crops was higher during the second monitoring period compared to that conducted earlier during November 2005, though the run-off in some crops remained very low and 5 of the nurseries still had a recorded run-off of < 3ml/ m^2. A maximum of 196.1ml/m^2 (1.96 m^3 water/ha) was captured from crop 1 at Site B (irrigated by gantry). The second crop at Site B also had an elevated level of run-off volume (0.84 m^3water/ha) relative to the other crops monitored. Overall, the mean run-off volume from the monitored crops was 0.37 m^3water/ha at this time. It may be relevant that the frequency of irrigation was much greater during the second monitoring period and was estimated to be occurring at 1-2 day intervals. The increased irrigation frequency could potentially account for the higher run-off volumes due to the modules being closer to field capacity. The highest run-off recorded during this study was equivalent to ca. 0.2mm rainfall over the same area.

During the first monitoring period it was noted that a proportion of the applied irrigation fell either in the narrow pathways or at the edges of crops. For the second monitoring period capture trays were also placed in these areas to estimate the run-off from un-cropped areas. The data in Table 6 shows the estimated run-off from un-cropped areas. The data here must however be treated with caution as whilst the run-off figures are much higher they can, potentially, be misrepresented. Whilst the highest figure of 44.9m^3 water/ha (Crop 1 Nursery C) appears very high it needs to be appreciated that the un-cropped areas on nurseries represent an estimated 1% relative to the cropped area. Therefore, a more accurate figure for the actual run-off from the un-cropped area in a 1ha block of modules would be 0.45m^3 water/ha.

Table 1: Collated data from Nursery Questionnaires

Nursery	Aspect	Elevation	Proximity to water courses	Method of Irrigation	Soil type	Compost used	No. crops/year	Method of Pesticide Application	Ground cover in Glasshouse
A	E/W	None	None	Gantry	Sand	Humax Standard	3	Gantry	Soil below crop, Mypex in paths
B		None	40' Dyke, Clay Dyke Bank	Gantry	Clay – Heavy	Bulrush Standard	3	Gantry	Mypex usually, Polythene beneath Calabrese
C		Slopes to W	Trader River 0.5 Miles away, ditches And drains emptying Into river	Gantry	Clay – Heavy	Bulrush Standard	3	Barrow Sprayer	Mypex
D	N/W Facing	None	Localised drainage Ditches	Overhead & Gantry	Mainly Silt/loam	Basic Peat	3	Basilex via OH Aliette via barrow Sprayer	Plastic under beds Mypex between be
E	N-S	Approx 2m	None	Gantry	Very fine Sandy Loam	Bulrush Modular	3	Drench via Gantry Otherwise via barrow Sprayer	Mypex

Table 2: Details of the sites monitored during the first set of nursery visits carried out in November 2005.

Nursery	Site	Monitoring Date	Crop	Variety	Sowing date	Module size	No. days Since last Irrigation	Type of irrigation	Nozzle size	Volume of Water/min
A	1	7.11.05	Cabbage	Premius	21.10.05	126	7	Gantry	XR Teejet 110 08 VP	2.4l/msq
A	2	7.11.05	Calabrese		3.10.05	216	7	Gantry	XR Teejet 110 08 VP	2.4l/msq
B	1	15.11.05	Calabrese	Ironman CB1	23.9.05	345	7	Gantry	Cone Full Jet S.S.CO FL-6.5VS	1.5l/min/nozzle
B	2	15.11.05	Calabrese	Marathon	23.9.05	216	7	Gantry	Cone Full Jet S.S.CO FL-6.5VS	1.5l/min/nozzle
C	1	15.11.05	Calabrese	Iron	28.9.05	336	11	Gantry	Blue Lurmark 10 F110 + 15 F110 at RH Edge	4.3l/min/nozzle
C	2	15.11.05	Calabrese	Iron	28.9.05	216	11	Gantry	Blue Lurmark 10 F110 + 15 F110 at RH Edge	4.3l/min/nozzle
D	1	23.11.05	Cauliflower	Valtos 23G	26.10.05	345	1	Gantry	Lurmark	50l/min
D	2	23.1.05	Calabrese	Marathon	24.9.05	216	1	Overhead	Lurmark	50l/min
E	1	12.12.05	Cauliflower	Mayflower	6.10.05	84	19	Gantry		4l/min/nozzle
E	2	12.12.05	Cauliflower	Durham Elf	12.10.05	345	19	Gantry		4l/min/nozzle

Table 3: Details of the sites monitored during the second set of nursery visits carried out in March 2006.

Nursery	Site	Monitoring Date	Crop	Variety	Sowing date	Module size	No. days Since last Irrigation	Type of irrigation	Nozzle size	Volume of Water
A	1	17.03.06	B. Sprout	Camus	01.03.06	345	2	Gantry	Teejet XR 110 08 VP	400l/bay
A	2	17.03.06	Calabrese	Olympia	20.09.05	216	2	Gantry	Teejet XR 110 08 VP	400l/bay
B	1	28.03.06	Cauliflower	Valtos	24.10.05	345	2	Gantry	Teejet F110 01 FL 6.5V	1.5l/min/nozzle
B	2	28.03.06	B. Sprout	Adagio	24.10.05	216	2	Gantry	Teejet F110 01 FL 6.5V	1.5l/min/nozzle
C	1	28.03.06	B. Sprout	Cumulus & Thalassa	07.03.06	336	3	Gantry	Blue Lurmark 10 F110 + 15 F110 at RH Edge	4.3l/min/nozzle
C	2	28.03.06	B. Sprout	Cumulus	07.03.06	336	3	Gantry	Blue Lurmark 10 F110 + 15 F110 at RH Edge	4.3l/min/nozzle
D	1	23.03.06	B. Sprout	Revenge	07.03.06	345	1	Overhead	Blue 2mm Coarse	4.54l/min/nozzle
D	2*	23.03.06	B. Sprout	Cumulus	07.03.06	345	1	Gantry	Yellow 02 Fine	0.92l/min/nozzle
E	1	23.03.06	Calabrese	Iron	09.03.06	336	0	Gantry		4.5l/min/nozzle
E	2	23.03.06	Leek	Harston	05.03.06	504	0	Gantry		4.5l/min/nozzle

* Fungicide Application

Table 4: Run-off volume collected from each site monitored in November 2005 during a specific irrigation or spray event

Nursery	Site No.	Total water volume collected from trays (ml)			Type of irrigation	Total run-off volume collected in catchment trays+ (ml)	Mean run-off volume (ml/m^{2}) *	Mean run-off volume (litres/ha)*	Mean run-off volume (m^3/ha)#
		Position 1	Position 2	Position 3					
A	1	0.0	1.0	1.0	G	2.0	2.3	23.1	0.02
A	2	0.0	0.0	0.5	G	0.5	0.6	5.8	<0.01
B	1	0.0	2.0	-^	G	2.0	2.3	23.1	0.02
B	2	3.0	39.0	-^	G	42.0	48.4	484.4	0.48
C	1	0.0	0.0	-^	G	0.0	0.0	0.0	0.0
C	2	0.0	14.5	-^	G	14.5	16.7	167.2	0.17
D	1	0.0	0.0	-^	G	0.0	0.0	0.0	0.0
D	2	-^	55.0	-^	O	55.0	63.4	634.4	0.63
E	1	12.0$	4.0	-^	G	16.0	18.5	184.5	0.18
E	2	0.5	0.0	-^	G	0.5	0.6	5.8	0.06
MEAN	**-**	**1.7**	**11.6**	**0.8**	**-**	**13.3**	**15.3**	**152.8**	**0.16**

^ No trays in this position
$ Possible gap between two trays
+ Run-off calculated from total volume collected in 10 trays/crop.
# 1mm of rainfall in 1 ha is equivalent to 10,000 litres water or 10m^3. The highest volume of run-off recorded here from one irrigation event is therefore equivalent to **0.06mm rainfall**.

* Example of calculation:
Collection tray area = 25.5cm x 34cm = 867cm^2≡ 0.0867m^2

$$\frac{\text{Total run-off volume (ml)}}{\text{No. of replicate trays (10)}} \div 0.0867 = \text{Average volume of run-off (ml/m}^2\text{). Multiply x10 to convert to litres/ha}$$

Table 5: Run-off volume collected from each site monitored in March 2006 during a specific irrigation or spray event

Nursery	Site No.	Total water volume collected from trays (ml)			Type of irrigation	Total run-off volume collected in catchment trays+ (ml)	Mean run-off volume (ml/m²) *	Mean run-off volume (litres/ha)*	Mean run-off volume (m³/ha)#
		Position 1	Position 2	Position 3					
A	1	0.0	1.0	0.0	G	1.0	0.6	5.8	<0.01
A	2	0.0	2.5	0.0	G	2.5	1.4	14.4	0.01
B	1	252.0	88.0	-^	G	340.0	196.1	1,960.8	1.96
B	2	79.5	65.5	-^	G	145.0	83.6	836.2	0.84
C	1	30.0	22.0	-^	G	52.0	30.0	300.0	0.30
C	2	11.5	12.0	-^	G	23.5	13.5	135.5	0.14
D	1	43.0	24.8	-^	O	67.8	39.1	391.0	0.39
D	2	1.0	3.0	-^	G	4.0	2.3	23.1	0.02
E	1	0.0	0.0	-^	G	0.0	0.0	0.0	0.00
E	2	0.0	4.8	-^	G	4.8	2.8	27.7	0.03
MEAN	**-**	**41.7**	**22.4**	**0.0**	**-**	**64.1**	**36.9**	**369.5**	**0.37**

^ No trays in this position
$ possible gap between two trays
+ Run-off calculated from total volume collected in 20 trays/crop.
# 1mm of rainfall in 1 ha is equivalent to 10,000 litres water or $10m^3$. The highest volume of run-off recorded here from one irrigation event is therefore equivalent to **0.2mm rainfall**.

* Example of calculation:

Collection tray area = 25.5cm x 34cm = $867cm^2 \equiv 0.0867m^2$

$$\frac{\text{Total run-off volume (ml)}}{\text{No. of replicate trays (20)}} \div 0.0867 = \text{Average volume of run-off } (ml/m^2)$$

Multiply x10 to convert to litres/ha.

Table 6: Run-off volume from adjacent pathways and crop edges in the monitoring period March 2006 during a specific irrigation or spray event

Nursery	Site No.	Total run-off volume collected from catchment trays in pathways (ml)	Mean run-off volume from pathways (ml/m^2)*	Mean run-off volume from pathways (litres/ha)*	Mean run-off volume (m^3/ha)#
A	1	483	1,393	13,927	13.9
A	2	435	1,254	12,543	12.5
B	1	696	2,006	20,069	20.1
B	2	672	1,937	19,377	19.4
C	1	1556	4,487	44,867	44.9
C	2	1510	4,354	43,541	43.5
D	1	183	528	5,277	5.3
D	2	83	239	2,393	2.4
E	1	250	721	7,209	7.2
E	2	405	1,168	11,678	11.7
MEAN	**-**	**627.3**	**1,809**	**15,484**	**18.1**

Note : Pathway monitoring not conducted in November 2005

+ Pathway run-off calculated from mean volume collected in 4 trays/crop.
# 1mm of rainfall in 1 ha is equivalent to 10,000 litres water or 10m^3. The highest volume of run-off recorded here from one irrigation event is therefore equivalent to **4.5mm rainfall**.

* Example of calculation:
Collection tray area = 25.5cm x 34cm = 867cm^2≡ 0.0867m^2

Total run-off volume (ml) ÷ 0.0867 = Average volume of run-off (ml/m^2). Multiply x10 to convert
No. of replicate trays (4) to litres/ha

Discussion & Conclusions

It is evident from the figures generated in this relatively small-scale study that the potential for run-off from module-raised crops under protection is very small. Indeed, anecdotal reports suggest that when glasshouse drains are monitored during irrigation or spray events run-off is usually not observed. It is considered that the generally efficient irrigation practice adopted by nurseries keeps run-off from the modules to a minimum and the data captured here supports this. The maximum run-off volume from cropped areas was during March 2006 using a gantry system where nearly 2m^3 water/ha was recorded. However, whilst this was the highest volume during an active growing period in brassica modules it is only equivalent to 0.2mm rainfall over the same area and it is perhaps therefore not surprising that run-off is reported not to occur from glasshouse drains.

The observation that a proportion of the applied irrigation and/or sprays does not contact the crop but falls on the pathways in or around the crop is interesting, especially as the level of capture is equivalent to 4-5mm rainfall over the same area; a significant increase compared to capture from the crop itself. If this level of run-off occurred over a large area it could potentially be of considerable significance, especially if the run-off contained pesticides, nitrates, phosphates etc. However, such un-cropped areas only represent approximately 1% of the cropped areas and therefore the total volume of run-off on a specific nursery via this means is usually going to be small. In most cases in these areas the run-off is further captured by the polythene covering the soil surface; and this is subsequently lost by transpiration. However, it would be good nursery practice for growers to monitor such un-cropped areas and keep them to an absolute minimum for both economic and environmental reasons.

In conclusion, therefore, from the data captured in this study there would appear to be minimal run-off from brassica propagation nurseries in a ‘worst-case’ scenario and this would appear to be irrespective of the nature or the type of irrigation event. It is also likely to the case with other module-raised ‘plug’ plants under protection e.g. bedding plants though this could perhaps require similar validation studies for confirmation.

Technology Transfer

The primary purpose of this study was to determine whether there is a risk of environmental contamination from irrigation run-off from propagation nurseries. The data generated indicates that the likelihood of run-off is very small and this is of considerable relevance to both the glasshouse industry and various government agencies. It is for the industry to determine at which point they use the data presented in support of a 'due diligence' defence and in this respect it is not appropriate to publicise the data through open technology transfer events at this time.

References

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Acknowledgements

We would like to acknowledge the support of the various brassica propagation nurseries who agreed to participate in this study though, for a variety of reasons, they cannot be identified here. Thanks also to the HDC Project Co-ordinator for devoting considerable time to ensure this project remained focused and addressed the industries key concerns.

Appendices

Appendix 1 Copy of questionnaire sent to nurseries involved in this project.

Propagator Questionnaire

Nursery Name ……………………………………………………………………………………

Contact Name ……………………………………………………………………………………

Address ……………………………………………………...…………………………………

Tel: ……………………………………………….. Mobile: ………..…………………………

Area of Nursery ……………………… Area of Glass …………………………………...

Aspect of Site (Plan if available)……………………………………………………………

Elevation …………………………………………………………………………………………

Water courses close to site ………………………………………………………………..

How are crops irrigated …………………………………………………………………….

Soil type ………………………………… Compost Used ……………………………….

Details of module cell sizes used …………………………………………………………..

No. of crops/rotations/year ……………………………………………………………………

……………………………………………………………………………………………………

Details of Pesticides applied ………………………………………………………………..

……………………………………………………………………………………………………

Method of Pesticide application …………………………………………………………….

Nutritional regime Autumn …………………………………………………..……………

Spring ………………………………………………………………….

Ground cover material in glass ……………………………………………………………..

How are trays elevated ……………………………………………………………………..