Project Title	Survey of nutrient run from container beds of Hardy Nursery Stock Nurseries in England
Project number:	HNS 158
Project leader:	John Adlam, Dove Associates
Report:	Final Report, January 2009
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Location of project:	Dove Associates, Dickleburgh, Norfolk Four nursery sites in the UK (NE, NW, SE, SW and S)
Date project commenced:	1 November 2007
Date project completed:	31 January 2009
Key words:	Nutrient run-off, container nursery stock, phosphorus, nitrogen, water pollution, water framework directive

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GROWER SUMMARY

Headline

- Samples taken from nursery discharge water contained nitrogen concentrations below the thresholds set by the Water Framework Directive. However, some samples had phosphorus levels that could be viewed as undesirable in ‘at risk’ catchments.

Background and expected deliverables

Much of the need for this study comes from the criteria set out in the EU Water Framework Directive (WFD). The WFD highlights the need for a reduction in nutrient levels in water (rivers, aquifers, coasts and estuaries). This work will provide an initial study to establish the nutrient pollution risk from container nurseries.

§ From the results comparisons can be made with WFD standards, giving the nursery stock industry the opportunity to contribute to the reduction of water pollution and enhance its image as a green industry.

§ The work is intended to provide a basis for further work to ensure the industry is able to comply with the EU Directives on water pollution.

Summary of the project and main conclusions

The purpose of this project is to carry out a preliminary survey of potential pollution risk from container nurseries, through collecting a limited number of water samples from nursery drains. Five nursery sites were selected to represent a wide range of environmental conditions, growing media nutrient levels and working practices. The nutrient applications, growing media ingredients, irrigation application systems, cropping density and crop types were recorded for each site, in addition to site specific meteorological data.

Four sites had one-off water samples taken. One site had several monthly samples taken over the course of a full 12-month growing season. The water was analysed for total nitrogen (N), phosphorous (P), electrical conductivity (EC) and pH levels. The median value for each of the analysed aspects of the water from all sites is listed below:

pH	EC (µS)	NH_4-N (mg/l)	NO_3-N (mg/l)	P (mg/l)
7.34	709.00	0.22	9.30	0.77

The levels of nitrogen detected in all the samples are below the threshold set by the Water Framework Directive (>50 mg/l). However, the phosphorus levels were often above what would be deemed as acceptable in rivers classified as containing a high concentration of P (>0.1 mg/l).

Bed construction

On the sites where the drainage water passed through soil into under-drains, the nutrient levels of the discharge water were marginally lower. This shows the potential value of soil (through cation exchange capacity of the soils clay colloid) in reducing nutrient run-off. Nutrient run off from sand beds and those isolated by an impermeable membrane tended to have a higher level of nutrients.

Controlled release fertilizer rates and formulations

Sampling revealed no obvious trend between discharged nutrient levels and CRF rates, their formulations or longevity. However, it is possible that trends could have been detected if more samples were collected.

Potting dates

There was no indication that nutrient run-off levels increased at the time of standing out newly potted plants.

Liquid feeding

Where liquid feeding was carried out, the nutrient levels in discharge water were generally higher. However, none of the sites exceeded a total N level of 50 mg/l in discharge.

Rainfall and irrigation applications

Total water application to the bed did show a potential link with the levels of nutrient levels in discharged water. There would appear to be a slight trend of increasing nitrogen concentration with decreasing water application levels and an opposite trend in the case of phosphorus, with increasing phosphorus concentration with increasing water application rates.

Water recycling and rainwater harvesting

The nutrient levels detected in discharge waters on several of the nursery sites actually posed very little threat to the environment. This was due to the water being captured and recycled on the nursery and not discharged to the environment. Rainwater harvesting, where practiced, also enabled run-off to be diluted.

Financial benefits

The costs of water abstraction will go through a series of phased increases over the next few years to incorporate environmental safeguards under the changes brought in by the Water Act 2003. It makes provision for abstraction charges to be linked to surface and ground water pollution levels in river basins. Lower pollution levels will relate to lower water charges. By paying attention to nutrient levels in discharge water today, lower water costs will be preserved for the future.

Likewise OFWAT has authorised a similar range of price increases for mains water from the water companies. These measures will include features such as interruptible tariffs and a system where higher rather than lower charges will be imposed for the more water that is used.

This report highlights the dual benefits (both economic and environmental) resulting from the adoption of rainwater harvesting and water recycling systems:

1. Reduced reliance on abstracted water sources.
2. Captured and diluted nutrient run off from container beds.

Action points for growers

- When planning construction work consider incorporating water recycling and rainwater harvesting. Check the outflow location of drains and retain water in isolated channels and pipes, where possible.

- Monitor irrigation application rates to ensure watering rates are matched to crop requirements, as excessive watering increases the risk of nutrient leaching.

- Review CRF incorporation rates used in growing media. Group nutrient incorporation rates to plant growth rates.

- Review CRF longevity against crop production times. Use shorter-term fertilizer products for short term crops. Revise low start and high start product usage according to plant groups.

- Review CRF formulations to reduce nitrogen levels where possible.

- Review liquid feeding by overhead irrigations systems on container crops.

SCIENCE SECTION

INTRODUCTION

The EU Water Framework Directive (WFD) is being progressively implemented by the UK government and will have implications for the nursery stock industry. High levels of nitrates and phosphates leaching from agricultural soils have upset the natural balance of the waters and, when extracted for potable supplies, costly and complex cleaning processes are necessary. The main source of nitrate in UK freshwater is leaching from agricultural land, although treated sewage discharges are also a factor for rivers. The main phosphorus sources are outputs from sewage treatment works and diffuse pollution from agriculture. Run-off has increased as agriculture has intensified and an increased number of roads and houses have degraded the permeability and reduced its capacity to retain and filter water. In 2005, 32% of river lengths exceeded 50 mg N per litre, which are the maximum permitted levels set in the WFD and 57% of river lengths exceeded 0.1 mg P per litre.

A 2002 DEFRA Study[3] "Agriculture and Water: A Diffuse Pollution Review" suggested that nurseries contribute to pollution in drainage water. The levels varied according to the crop feeding method, bed construction and irrigation. This work was limited in its scope, as it was only conducted on conifers nurseries.

Work carried out on nutrient loss from container-grown nursery stock[4] showed that the nutrient loss was influenced by irrigation and rainfall rates as well as plant species and nutrient applications. Under normal growing conditions very little nutrient loss occurred.

The WFD states "Groundwater is considered to have a good chemical status when:

- measured or predicted nitrate levels do not exceed 50 mg/l, while those of active pesticide ingredients, their metabolites and reaction products do not exceed 0.1 g/l (a total of 0.5g/lt for all pesticides measured);
- the levels of certain high-risk substances are below the threshold values set by Member States; at the very least, this must include ammonium, arsenic, cadmium, chloride, lead, mercury, sulphate, trichloroethylene and tetrachloroethylene;
- the concentration of any other pollutants conforms to the definition of good chemical status as set out in Annex V to the Water Framework Directive.

Work was carried out at HRI Efford in 1995 on container-grown systems employing frequent irrigation and applications of nutrients. An experiment was established to examine the losses of nitrate and phosphorus from a peat-based growing medium for HONS. Concentrations of nitrate-N in water draining from the beds exceeded 200 mg l^{-1} and phosphorus (P) exceeded 20 mg l^{-1}. The use of sand beds irrigated by a sub-surface system did not noticeably reduce losses of either pesticides or nutrients, unless used in conjunction with a re-circulation system

At this time much of the information on the subject of pollution from container beds is based on various studies on the level of nutrients in drainage water near the crop. Little has been done at a nursery level from main nursery drains, most results having been taken from close crop studies in research establishments.

The purpose of this project is to carry out a preliminary survey of a series of nurseries in England and collect water from container production area main drains. The water was analysed for total nitrogen, phosphorous, EC and pH levels. The methods of nutrient applications, growing media nutrient and bulky ingredient formulas, irrigation application systems, cropping density and crop types would be recorded for each site, in addition to site specific meteorological data. This information would be used to identify environmental pollution risks associated with container plant production.

MATERIALS AND METHODS

Sampling

Sampling was carried out by collecting one litre of water directly from the drain outlet on each of the sites. The project allowed for only one sampling visit to each site, however as further visits to some sites were carried out for other reasons additional samples were taken at those times. The sample was collected into a sealed unused bottle and delivered to the laboratory within three days of collection. Sites 1, 2, 3 and 4 were sampled for month of May and Site 5 was sampled 12 times, each month for a full growing season. For the purposes of comparison with Sites 1 to 4, the May and June data from Site 5 was isolated.

Water analysis

The water samples were analysed as a single sample on each occasion. The analysis of the water was carried out by Alliance Technical Laboratories Ltd and used the following methods for the elements analysed.

pH	pH units	by pH electrode
Electrical Conductivity	micro S/cm	by conductivity meter
Ammoniacal Nitrogen as N	Mg/litre	by colorimetry (lange cuvette)
Ammoniacal Nitrogen as NH_4	Mg/litre	by calculation from ammoniacal N
Nitrate Nitrogen as N	Mg/litre	by colorimetry (lange cuvette)
Nitrate Nitrogen as NO_3	Mg/litre	by calculation from nitrate N
Phosphorus as P	Mg/litre	by ICP-OES

Rain Gauge

The rainfall and irrigation was measured by a Technoline Ltd, Rain Monitor logging rain gauge. The measurement was by traditional 0.2mm tipping bucket with a radio link to the logger. Daily totalised readings were recorded weekly onto a record sheet.

Air temperature

Air temperature was measured by Tiny Tag temperature logger mounted at crop height on the bed. Logging was set to every 4 hours through the day. The data was downloaded at the end of the trial period.

SITE 1

Description of site

A glasshouse nursery growing a range of pot bedding and pack bedding plants. The plants are all grown for a short period and marketed directly to garden centres. The glasshouses are all twin span Venlo structures of 3.2m per span.

Container beds

The area chosen is all under glass with Mypex Ground Cover laid onto 50mm of 6mm stone. The stone is laid directly onto the soil.

Drains

The drains are all located directly in the soil under the glasshouse floor. At the sample point, no rainfall or outdoor areas are connected to the drain system. The sample point has a catchment area of 1,996.8 m^2.

Irrigation system

The glasshouses are irrigated by overhead spray lines with a single line positioned under the ridge of each 3.2m span. Some hand watering is carried out as required.

Growing media

The growing media in the pots and trays stood on the glasshouse floor is 90% peat: 10% bark. This is an "open" mix allowing free drainage. The growing media has Osmocote Exact High K (5-6 months) incorporated at the rate of 1.5kg/m^3. PG mix is added at the rate of 0.5kg/m^3.

Liquid feeding

Liquid feeding is carried out once every two weeks with Sangral 1:1:1. A stock solution of 1 kg to 10 litres of water is made and injected at 1:100.

Sampling point

Discharge of glasshouse under drains into stream.

Table 1: Water analysis at sample point at Site 1

pH	EC	NH4-N	NO3-N	P
7.0	950µS	<0.02mg/l	31.7mg/l	0.77mg/l

Figure 1: Air temperature inside structures during test period at Site 1

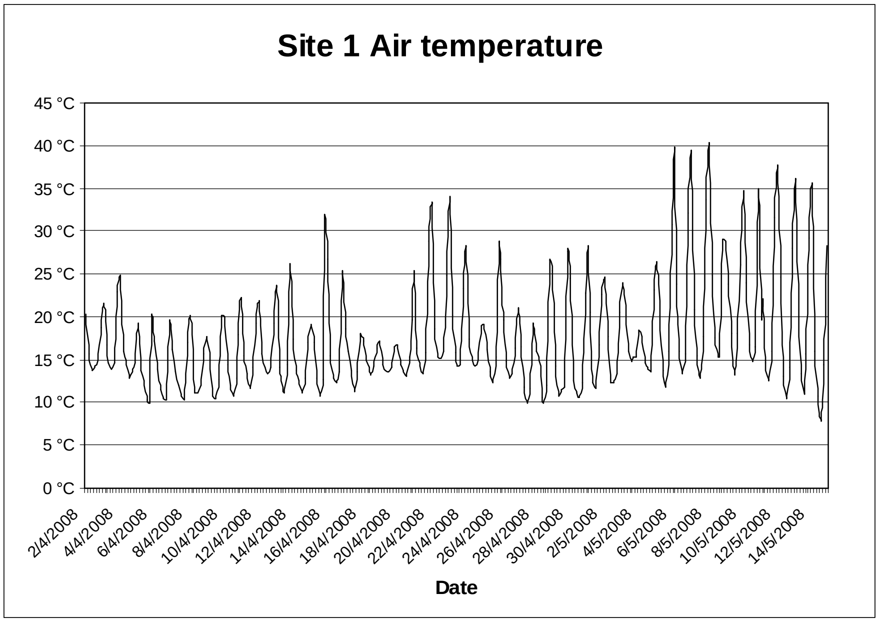
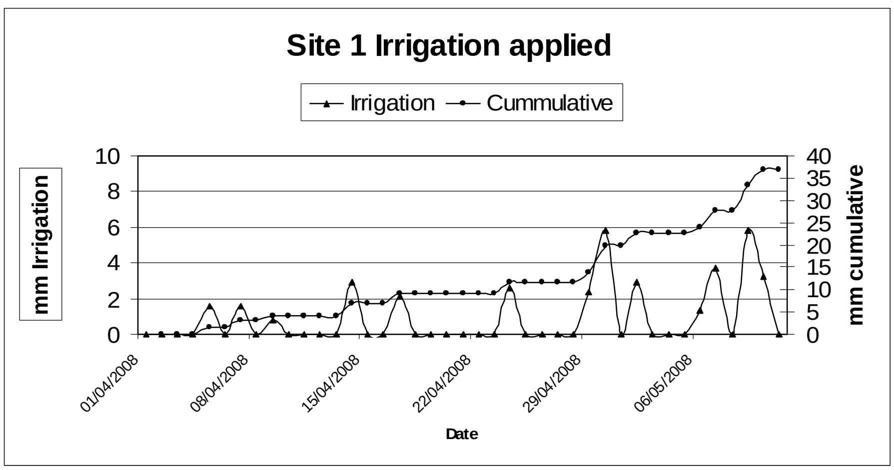


Figure 2: Irrigation applied on Site 1



SITE 2

Description of site

A hardy nursery stock nursery which grows a range of container grown shrubs. The plants are all grown for varying lengths of time according to the species and are mixed within any one bed area. Potting and despatch are also ongoing over long periods of time.

Container beds

The area chosen was an outdoor bed with Mypex laid directly onto the soil. The beds are constructed with a 2% slope to direct drainage water into the open drain network.

Drains

The drains are all open with the Mypex bed covering laid down into the drain. Some drains have paving slabs along the bottom. The drains for the whole bed area are directed to a common outlet. The sample point has a catchment area of 5,145m^2.

Irrigation system

The beds are irrigated by overhead sprinklers with a three rows of sprinklers down a 14m wide bed. The sprinklers are spaced at 5m intervals on a square pattern. The sprinklers are Dan Super 10 units with red jets.

Growing media

The growing media in the pots is 60% peat (50% medium + 50% medium/coarse) + 40% Toresa wood fibre. This is an 'open' mix allowing free drainage. Also incorporated is Sincrocell 12 (14+8+13) at the rate of 5.0kg/m^3, with additional nitrogen supplied as calcium nitrate at 0.3kg/m^3. Multimix (12-14-24) base fertilizer is added at the rate of 0.5kg/m^3.

Crops

Cropping of mixed nursery stock in 3 litre pots, spaced at 20cm x 18cm staggered. Plants stood out in the sampled area were potted between 1 month and 9 months.

Liquid feeding

No liquid feeding is carried out.

Sampling point

Discharge of open drain to soak-away area and channel to soak-away area.

Table 2: Water analysis at sample point 1 (drain discharge) at Site 2

pH	EC	NH_4-N	NO_3-N	P
8.6	900µS	1.03mg/l	12.30mg/l	0.85mg/l

Table 3: Water analysis at sample point 2 (channel) at Site 2

pH	EC	NH_4-N	NO_3-N	P
8.9	890µS	0.10mg/l	13.90mg/l	0.76mg/l

Figure 3: Outdoor air temperature during test period at Site 2

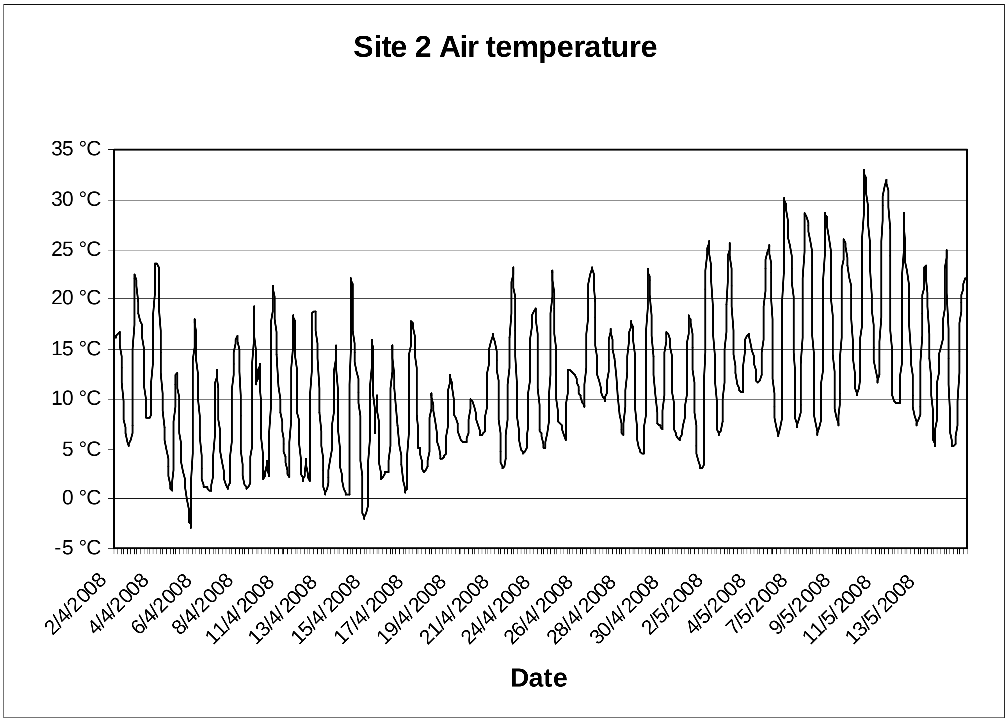
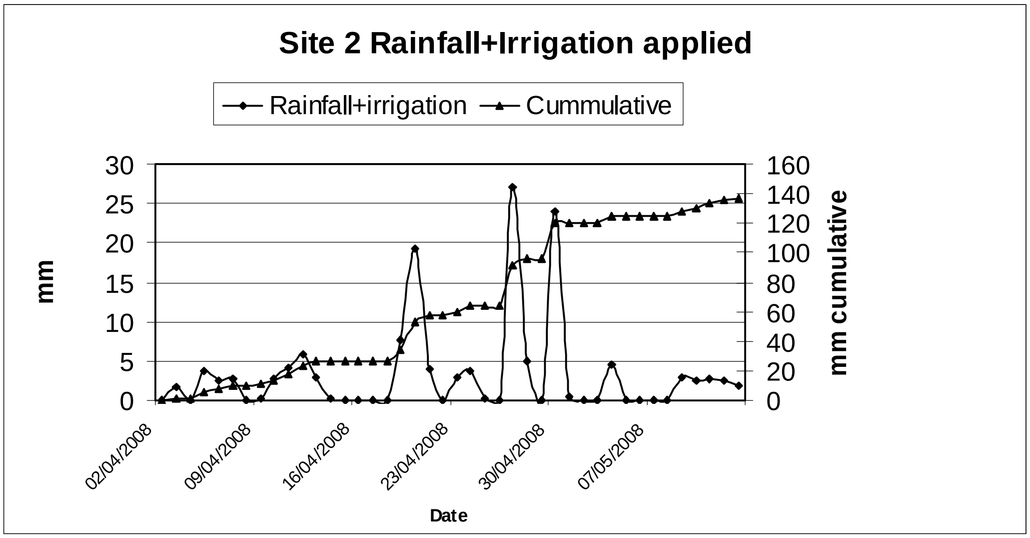


Figure 4: Rainfall + irrigation applied during test period at Site 2



SITE 3

Description of site

A hardy nursery stock nursery, growing a range of container-grown shrubs. The plants are all grown for varying lengths of time according to the species and are mixed within any one bed area. Potting and despatch are also ongoing over wide periods of time. The nursery operates a full rainwater harvesting and recycling system, with water collected from all areas into a reservoir. No one area is identifiable.

Container beds

The container beds are of varying construction ranging from Mypex over soil, to polythene lined and Mypex under protection.

Drains

The drains are all open with some beds having stone drains on the bed discharging into the open and others allowing natural run off from the bed to be directed into the drains. No run-off water is lost from the site. The water collection has a catchment area of 91,415m².

Irrigation system

The beds are irrigated by overhead sprinklers on most of the areas. Some glasshouse beds have spray lines and some have capillary sand beds. The sprinklers are spaced according to the manufactures recommendations.

Growing media

The growing media in the pots is 85% peat + 15% bark. This is an 'open' mix allowing free drainage. The growing media has Sincrocell 12 (14+8+13), incorporated at the rate of 4.0kg/m³.

Crops

Cropping is of mixed nursery stock in 2, 3, 4 and 5 litre pots. Potting and despatch of plants is carried out throughout the year.

Liquid feeding

Small areas of liquid feeding are periodically carried out.

Sampling point

Sampling was taken from water within a service channel and from the collection reservoir. Discharge of water from the site is only from the spillway of the reservoir, which occurs only during the winter period.

Table 4: Water analysis at sample point 1 (drain channel) at Site 3

pH	EC	NH_4-N	NO_3-N	P
7.93	168µS	0.10mg/l	2.80mg/l	0.60mg/l
7.10	250µS	0.06mg/l	5.50mg/l	1.86mg/l

Table 5: Water analysis at sample point 2 (reservoir) at Site 3

pH	EC	NH_4-N	NO_3-N	P
8.53	160µS	0.20mg/l	1.80mg/l	0.50mg/l
7.10	160µS	0.35mg/l	2.30mg/l	0.86mg/l

Figure 5: Outdoor air temperature during test period

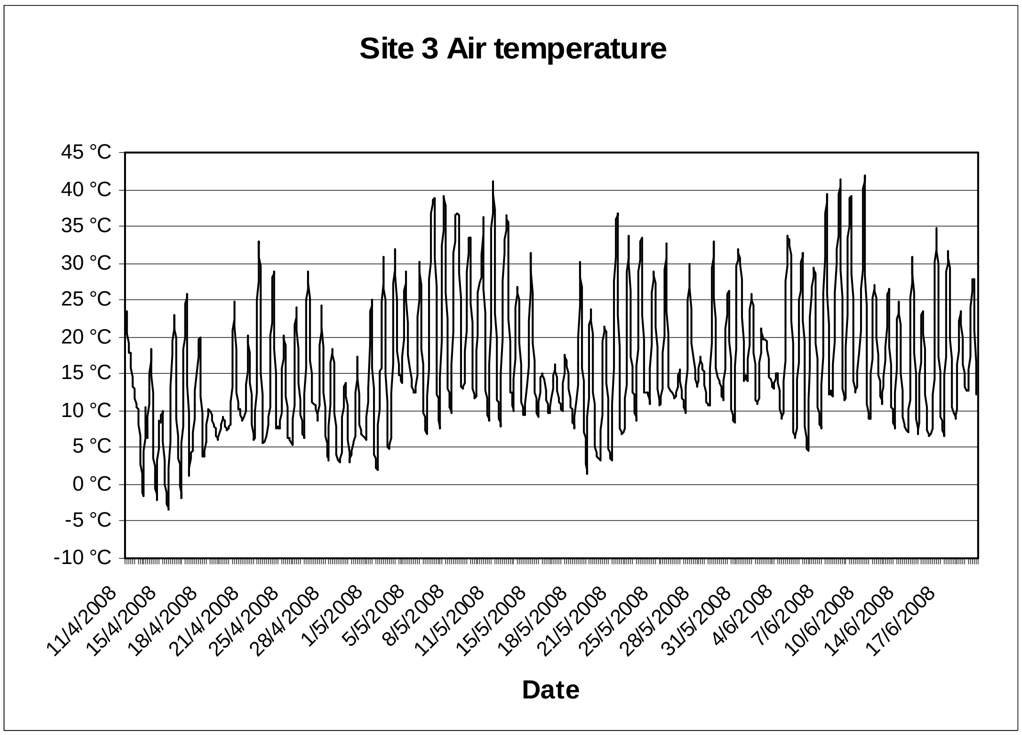
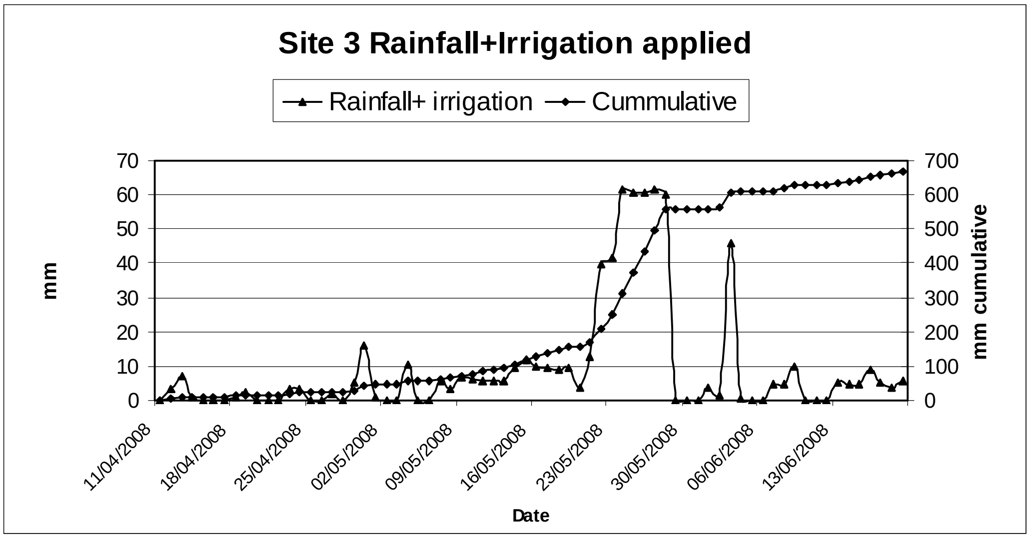


Figure 6: Rainfall + irrigation applied during the test period



SITE 4

Description of site

A hardy nursery stock nursery, growing a range of container-grown shrubs. The plants are all grown for varying lengths of time according to the species and are often mixed within any one bed area. Potting and despatch are also ongoing over wide periods of time. The nursery operates a full rainwater harvesting and re-cycling system on the beds selected for the water sampling.

Container beds

The container beds are made from LS Drain ground cover over sand, with polyethylene laid on the soil surface.

Drains

The drains are all open with the LS Drain bed covering laid down into the drain. The drain has paving slabs along the bottom. The drains for the bed are directed to a common outlet. A main collection channel runs along the southern end of the beds and acts as a collection pond from which the recycled water is taken, treated and used in the irrigation system. No run-off water is lost from the site. The water collection has a catchment area of 1,442m².

Irrigation system

The beds are irrigated by overhead sprinklers with a two rows of sprinklers down a 14m wide bed. The sprinklers are spaced at 6m intervals on a square pattern. The sprinklers are Rain Bird units with red jets.

Growing media

The growing media in the pots is 66% peat + 33% bark. This is an "open" mix allowing free drainage. The growing media has Osmocote (18+11+10), incorporated at the rate of 4.5kg/m³.

Crops

Cropping of the sample area is *Prunus laurocerasus* in 5 litre pots. Pots are stood out at 16/m². Potting was carried out on the first week of April (week 15).

Liquid feeding

No liquid feeding was carried out.

Sampling point

Sampling was taken from water draining from the centre channel drain.

Table 6: Water analysis at sample point (channel drain)

pH	EC	NH_4-N	NO_3-N	P
7.25	316µS	0.58g/l	22.00mg/l	6.60mg/l
7.40	300µS	0.12mg/l	9.30mg/l	3.40mg/l

Figure 7: Outdoor air temperature during test period

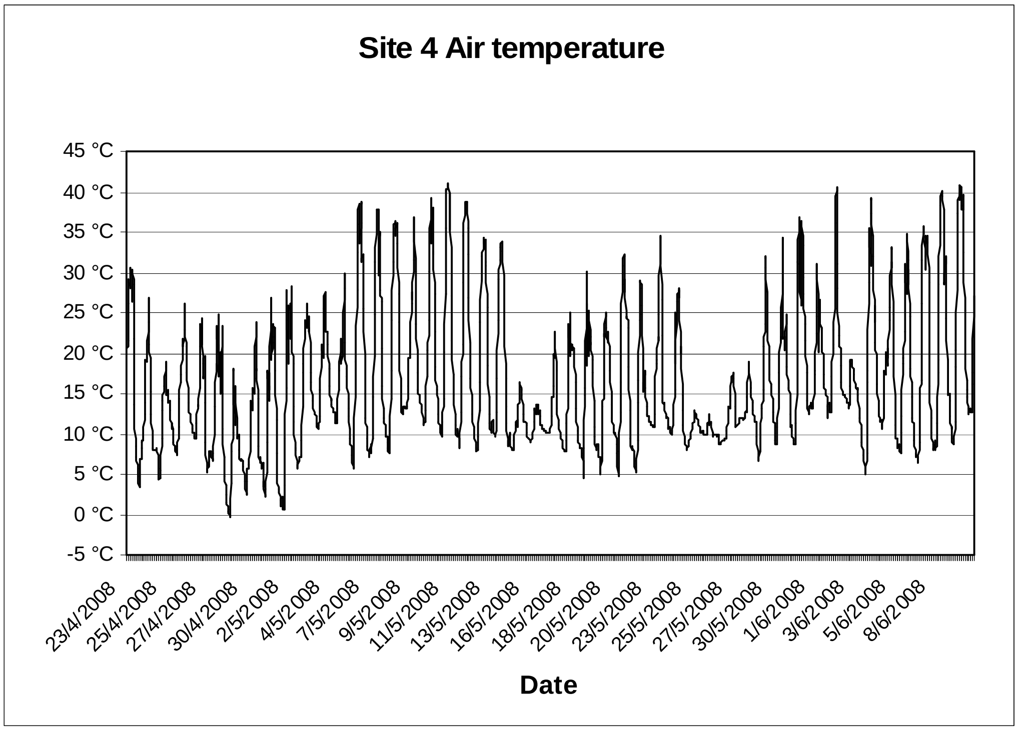
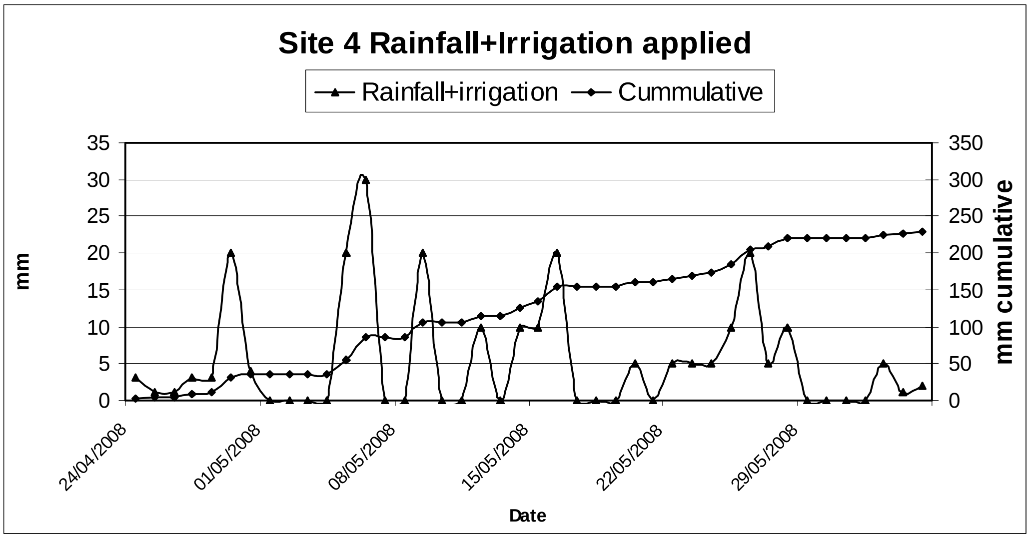


Figure 8: Rainfall + irrigation applied during the test period



Site 5

Description of site

Hardy nursery stock nursery, growing a range of field-grown roses; container-grown roses, herbaceous perennials and herbs. Plants are grown for varying lengths of time according to species. This site has a closed circuit for water and recycles drainage water from the container beds through a series of drains and a 4,800 m^3 reservoir, where it is reused for irrigation.

Container beds

The container beds are standard Efford Sand beds with polythene isolation from the soil with a central drain into a collecting tank.

Drains

Fibre wrapped central drain in each bed connected to a header tank. Header tank connected to main underground drain.

Irrigation system

Under drain irrigation with additional sprinkler for plant establishment and liquid feeding.

Growing media

The roses are grown in 75% peat: 15% composted forestry residues: 10% bark (5-12mm). Herbaceous perennials are grown in 75% peat: 10% composted forestry residues: 15% bark (5-12mm). The growing media has Osmocote Exact Standard (15+9+11), incorporated at the rate of 3.5kg/m^3.

Crops

Despatch of plants is carried out throughout the year. The test site pots around 6,000 roses into 5 litre pots in January/February and over 100,000 herbaceous perennials in 2 litre pots from September through to the beginning of March.

Liquid feeding

Peter's Professional 12:0:43 is applied to crops via overhead irrigation, once a week from the end of April onwards.

Sampling point

Sampling was taken from the main drain which took water from the whole site.

This site had water samples taken monthly from December 2007. Analyses continued until November 2008 to give a full growing season's recording.

Table 7: Water analysis at sample point until November 2008

Sample date	pH	EC	NH_4-N	NO_3-N	P
Dec 07	7.88	708µS	0.42mg/l	3.70mg/l	0.76mg/l
Jan 08	7.39	258µS	<0.02mg/l	1.80mg/l	0.51mg/l
Feb 08	7.19	649µS	0.51mg/l	1.60mg/l	0.24mg/l
Mar 08	7.40	646µS	0.11mg/l	8.80mg/l	0.60mg/l
Apr 08	7.27	709µS	0.12mg/l	8.30mg/l	0.30mg/l
May 08	7.34	810µS	0.83mg/l	21.00mg/l	3.60mg/l
Jun 08	7.30	850µS	0.22mg/l	16.50mg/l	2.70mg/l
Jul 08	7.40	970µS	4.70mg/l	28.00mg/l	6.80mg/l
Aug 08	7.30	490µS	0.02mg/l	4.50mg/l	0.80mg/l
Sep 08	7.30	870µS	0.04mg/l	17.00mg/l	1.10mg/l
Oct 08	7.50	890µS	0.37mg/l	14.00mg/l	0.10m/l
Nov 08	6.90	490µS	0.29mg/l	2.90mg/l	0.50mg/l

Figure 9: Cumulative rainfall onto sand beds for 12 month full growing season at Site 5

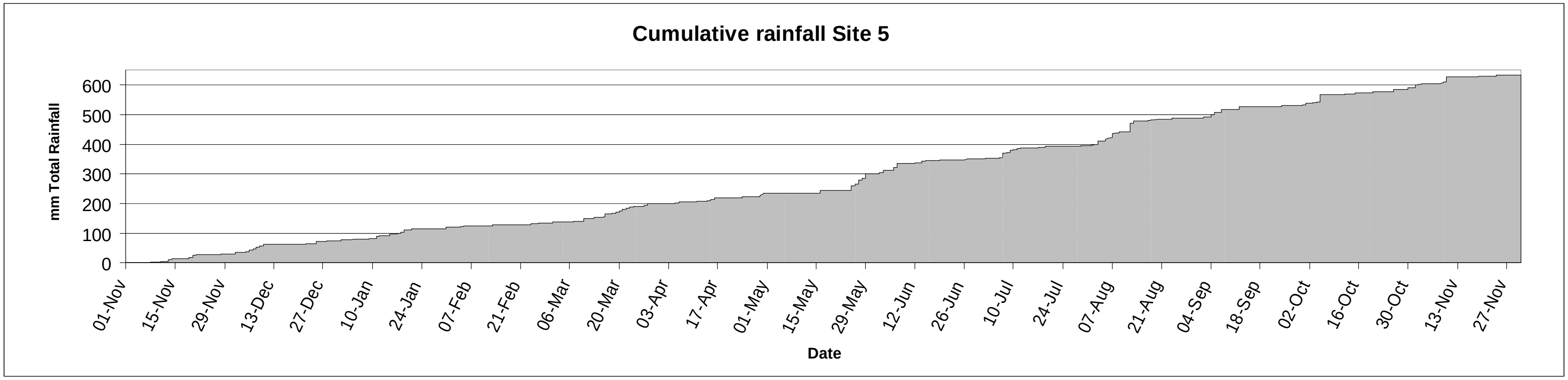


Figure 10: Rainfall onto sand beds for 12 month full growing season at Site 5

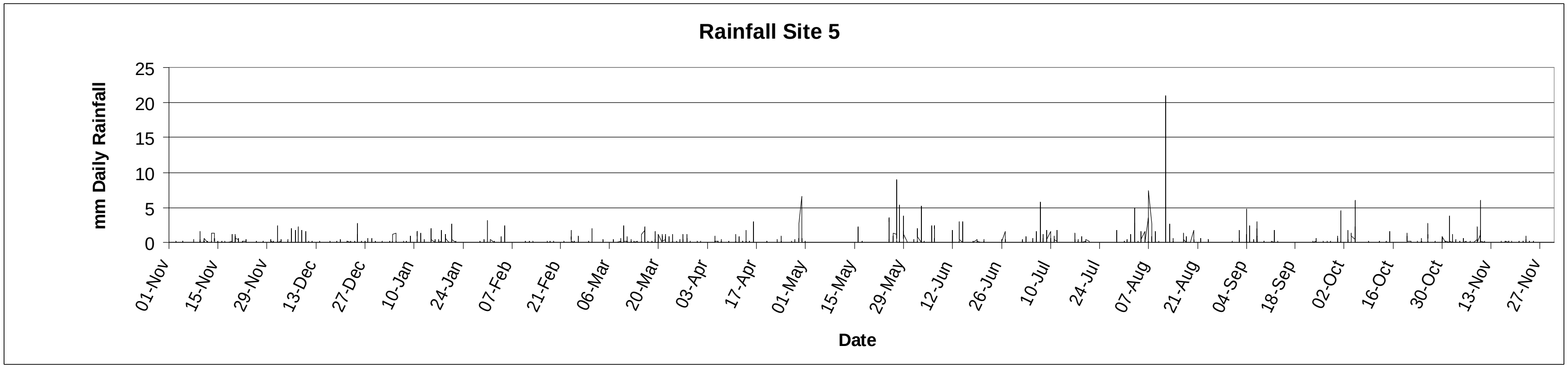


Figure 11: Air temperature at sand beds for 12 months full growing season at Site 5

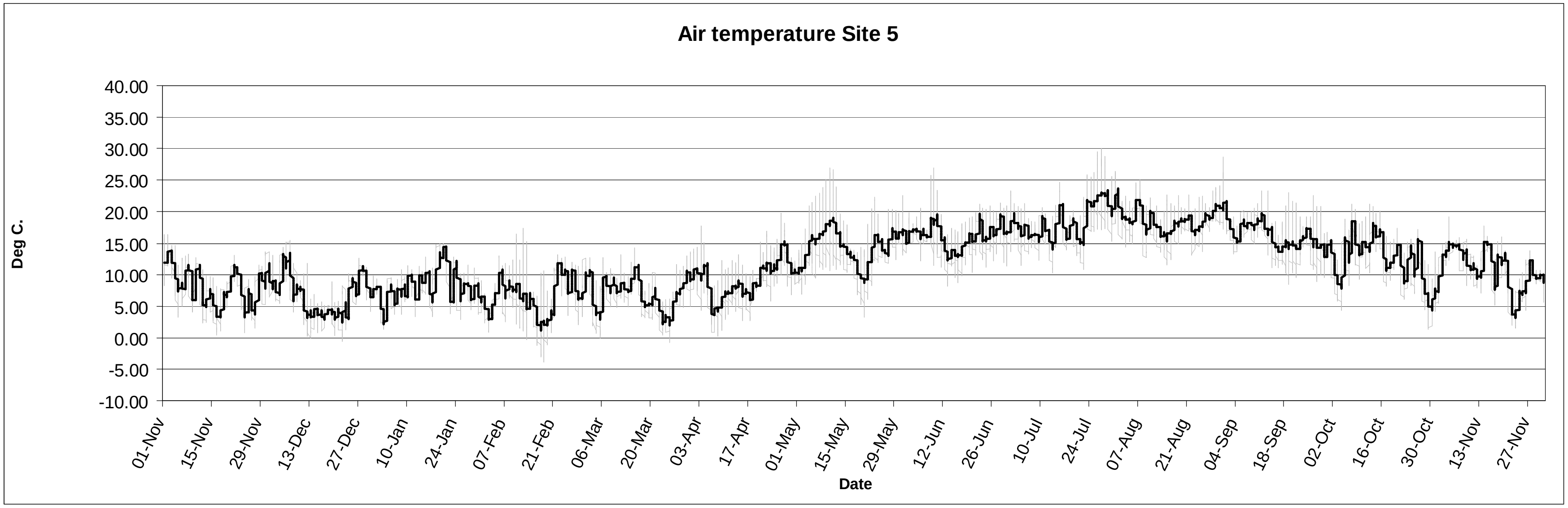


Figure 12: Relationship between drainage water conductivity and air temperature at Site 5.

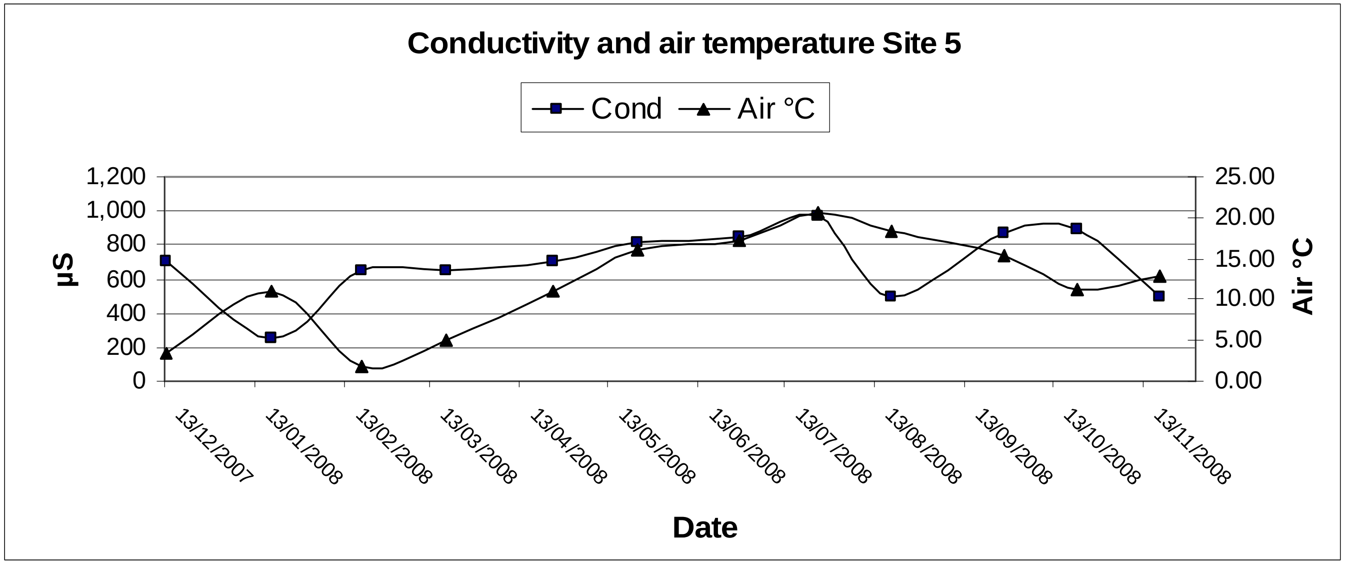
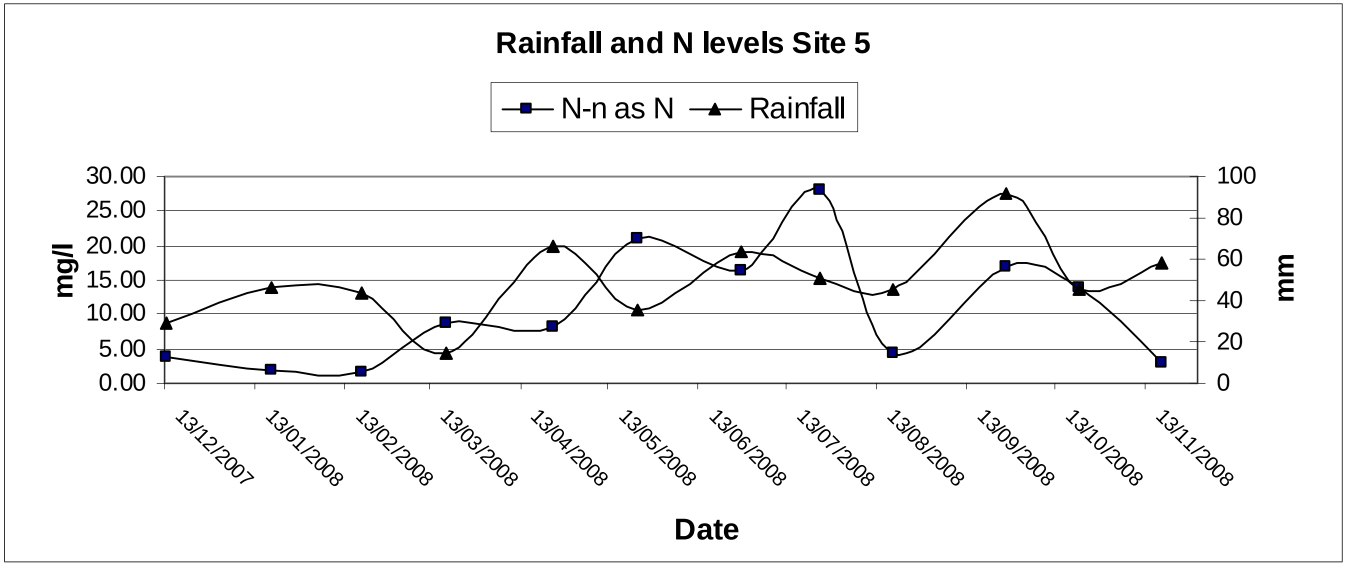


Figure 13: Relationship between rainfall and discharge nutrient levels at Site 5.



RESULTS AND DISCUSSION

The five sites were selected to represent a wide range of environmental conditions, growing media nutrient levels, crop types and working practices. The water samples reflect the level of nutrients in the water that is draining from the container beds. In three cases this water was collected and recycled directly as irrigation water and in two cases was discharged to the environment; one of those discharged directly into a fast flowing stream and one into adjacent grassland soak-away. As conditions were highly diverse and sampling limited, the results are only intended to produce an initial indication of the potential extent of pollution from the nursery stock sector.

The level of nitrogen and phosphorus in the discharge water was variable and was influenced to a degree by the use of supplementary liquid feeding. In Site 1 where feeding was carried out somewhere on the nursery everyday the levels of nitrogen discharges were higher than the other sites. Site 5 also carried out periodic liquid feeding and over the 12 month period of sampling the discharge rates were extremely variable. Site 4 recycled the irrigation water and had higher phosphorus levels, but this trend was not seen in the other sites that recycled water. Taking the outline data of all sites for each of the various analysed aspects of the water the overall data is as follows:

Table 8. Median, maximum and minimum water results.

	pH	µS	NH_4-N	NO_3-N	P
Median	7.34	709.00	0.20	13.90	0.77
Maximum	8.90	1,030.00	0.10	31.70	6.60
Minimum	6.90	160.00	0.02	1.80	0.20

Bed construction

On the sites where the drainage water passed through soil into under-drains the nutrient level of the discharge tended to be marginally lower. In the case of phosphorus, where the levels in discharge water collected from ground cover laid over soil were 0.2 mg/l (Site 2) to 1.86 mg/l (Site 3), when water was collected through sand, isolated from the ground by polythene the maximum level was 6.60 mg/l (Site 4), with all but one level greater than 2.70 mg/l. This shows the potential value of the cation exchange capacity of the clay colloid in reducing nutrient run-off.

Controlled release fertilizer rates and formulations

There was very little correlation between CRF rates, formulations or even longevity that could be identified from the limited data. Total N discharges varied for a 12-month CRF product (Sites 2, 3 and 4) from 2.78 mg/l (Site 3) to 16.00 mg/l (Site 4) and the 9 month product having a level of 12.57 mg/l (Site 5). A 6 month product had a total N reading of 31.72 mg/l (Site 1)

Regarding formulations, the highest reading (Site 1) was from a 10:11:18 product (31.72mg/l) and the lowest figure (Site 3) from a 14:8:13 product (2.78mg/l).

CRF incorporation rates ranged from 1.5kg/m³ to 5kg/m³, with the higher total nitrogen discharges of 31.72mg/l from 1.5kg/m³ (Site 1) and the lowest level 2.78mg/l (Site 3) from a 4kg/m. Several sites had a CRF rate of 4kg/m³ to 5kg/m³ and the total nitrogen discharges varied from 2.80mg/l (Site 3) to 16.00mg/l (Site 4), suggesting there is potentially very little relationship between incorporation rate of CRF and nutrient discharges.

Liquid feeding

Where liquid feeding was carried out the nutrient levels in discharge water had a tendency to be higher. Two sites carried out significant liquid feeding. On Site 1 a low level of CRF, 1.5kg/m³ was added to the growing media and liquid feeding carried out twice weekly. Due to the mixed nature of the cropping this resulted in liquid feeding being carried out most days somewhere on the site. The under-drains for the glasshouse beds are buried in the soil and this is reflected in the higher nitrogen discharge levels, which is very mobile in the soil, but a relatively low phosphorus discharge level which is very immobile in the soil.

Site 5 used liquid feeding as a supplementary feeding system to improve leaf and flower colour and it was applied only as and when crop conditions required it. Several applications were made to the crops during the period of the trial. No correlation was seen between the highest nutrient levels in the drainage water and the periodic liquid feeding programme.

Site 2 carried out periodic liquid feeding but none was applied before or during the period of the trial.

Discharge to surface waters

Site 1 discharged directly into a fast flowing stream. The stream had a width at the point of discharge of 3.8m and a slope, taken from map contours of 0.5% (1:250). With a water depth of 100mm the flow is calculated to be 1,364m^3/h and the discharge of the drain was 62l/h (0.062m^3/h), which is a dilution of the discharge from the nursery of 1:22,000. This would be a point source discharge and would have resulted in an increase in the stream of 0.0014mg/l N.

Sampling area

The water catchment area used for sampling shows no obvious relationship to the nutrient discharge results. Site 2 had an area of 5,145 m^2 with total N levels of 14.00mg/l and a smaller area of 1,442 m^2 (Site 4) had total N levels of 16.00mg/l. The largest area of 91,415m^2 (Site 3) had an N level of 2.78mg/l.

Rainfall and irrigation applications

The one set of data that did show some potential trend in relation to nutrient discharges, albeit seemingly weak, was the amount of rainfall and irrigation on the catchment area. Rainfall and irrigation applications were not identified separately and total water applications were measured on a 24-hour basis. Each site rainfall was expressed as mm per day based on the collected rainfall apportioned over the number of collected days.

Table 9. Influence of rainfall and irrigation on nutrient (N) discharge.

	Site 1	**Site 2**	**Site 3**	**Site 4**	**Site 5**
mm/day	1.09	3.27	4.04	5.56	2.03
Total N mg/l	31.72	14.00	2.78	16.00	12.57

Figure 14. Trend between rainfall and irrigation and nutrient (N) discharge.

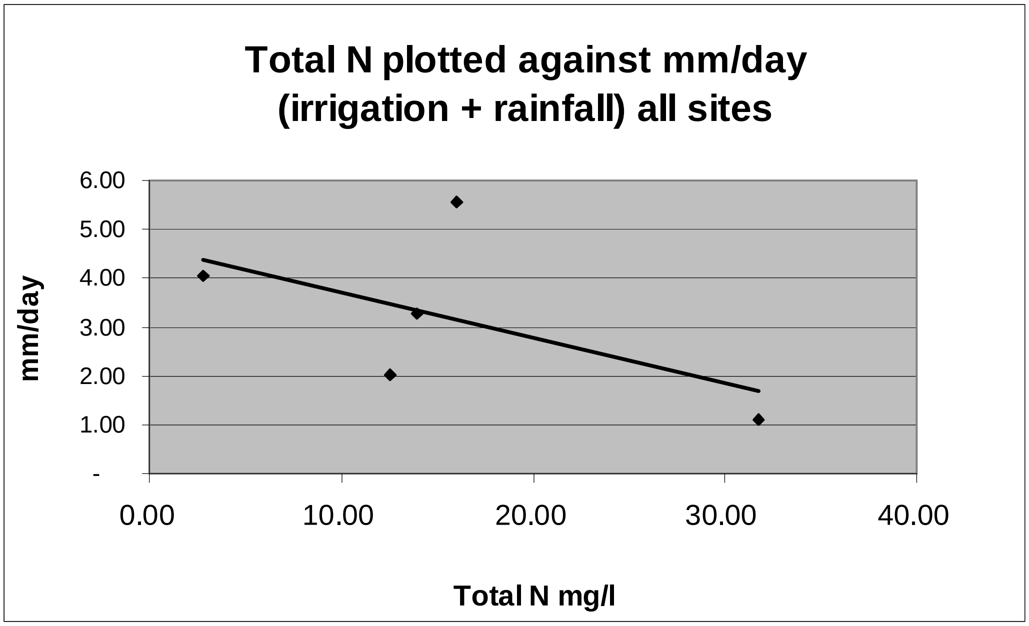
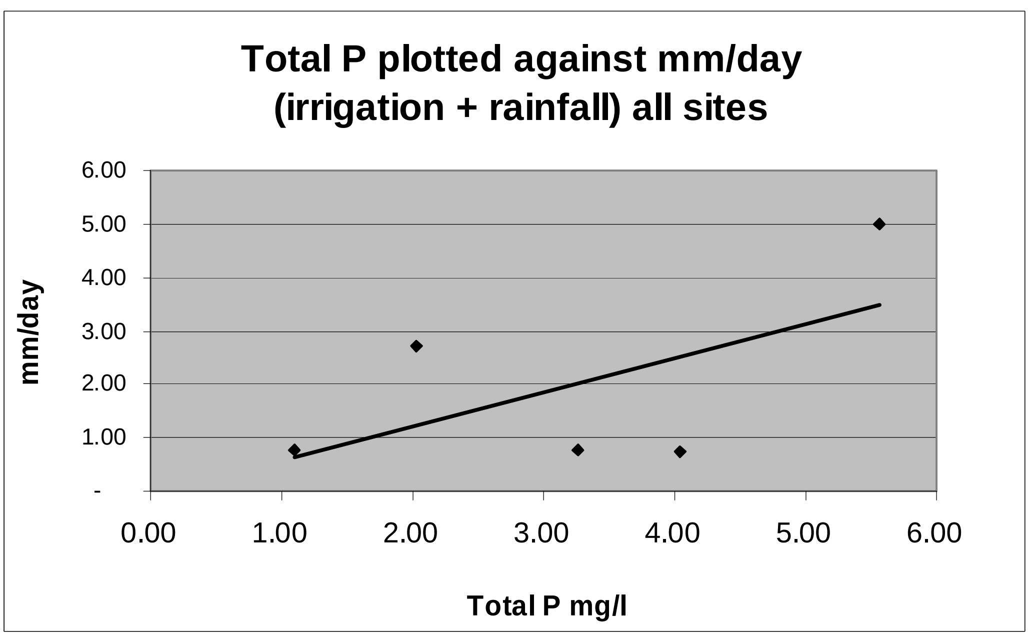


Table 10. Influence of rainfall and irrigation on nutrient (P) discharge.

	Site 1	Site 2	Site 3	Site 4	Site 5
mm/day	1.09	3.27	4.04	5.56	2.03
Total P mg/l	0.77	0.76	0.73	5.00	2.70

Figure 15. Trend between rainfall and irrigation and nutrient (P) discharge.



There would appear to be a slight trend of increasing nitrogen concentration with decreasing water application levels (Table 9 and Figure 14) and an opposite trend in the case of phosphorus, with increasing concentration with increasing water application rates (Table 10 and Figure 15).

CONCLUSIONS

The five sites were selected to represent a wide range of environmental conditions, growing media nutrient levels and working practices. The water samples reflect the level of nutrients in the water that is draining from the container beds. Although, the number of samples were extremely limited in this preliminary study, the results have provided an indication of the potential level of nutrient pollution from UK nurseries.

Table 11. Median, maximum and minimum nutrient levels (mg/l)

	pH	EC	NH_4-N	NO_3-N	P
Median	7.40	709µS.	0.22	9.30	0.77
Maximum	8.90	1,030µS	4.70	31.70	6.80
Minimum	7.00	160µS	0.02	1.60	0.10

Ammoniacal nitrogen (NH_4) expressed as N had a measured maximum level of 4.70 mg/l. Phosphorus had a measured maximum level of 6.80 mg/l (Table 11). When these figures are compared to the discharges from a domestic sewage water discharge, the normal levels reported by the Environment Agency are 15-20 mg/l of ammoniacal nitrogen and 8-10 mg/l of Phosphorus. The levels of nutrients in the discharge water measured in this trial are below these figures and the threshold set for N by the Water Framework Directive, but nevertheless requires attention and monitoring for good environmental management. At this present time no universally specific thresholds have been set for phosphorous, each site threshold being set according to the site specific soil and environmental conditions. However, rivers in England and Wales are often classified as having a high concentration of phosphorus when levels are in excess of 0.1 mg P/l. Therefore, it is clear to see that the values for P presented in Table 11 could be considered an unacceptable discharge, particularly if such water is not harvested and flows into catchments that have been identified at risk from diffuse sources of phosphorus pollution. It should however be remembered that some of those levels relate to closed circuit systems with no discharge to the wider environment.

Bed construction

On the sites where the drainage water passed through soil into under-drains the phosphorus nutrient level of the discharge was lower than the beds where water was re-cycled. This shows the potential value of the cation exchange capacity of the clay colloid in reducing nutrient run-off. The highest level of collected nutrients was detected in nurseries which recycled water, so, in these situations the drainage water did not enter the wider environment. The use of the nutrients by plant material, and the collection of rainwater which would dilute the nutrient content of the recycled water, is likely to ensure that the nutrient levels do not reach either toxic levels for plants or exceed environmentally acceptable levels.

Controlled release fertilizer rates and formulations

There was very little correlation between CRF rates, nutrient formulations or CRF longevity that could be identified (Table 12) from the limited number of samples.

Table 12. Table showing the lack of detectable trends in CRF relationships

Site	CRF formulation					Rainfall/irrigation	Bed	Total nutrients	
	kg/m³	Month	N	P	K	mm/day	construction	N	P
1	1.5	6	10	11	18	1.09	Mypex over soil	31.72	0.77
2	5	12	14	8	13	3.27	Mypex over soil	14.00	0.76
3	4	12	14	8	13	4.04	Mypex over soil	2.78	0.73
4	4.5	12	18	11	10	5.56	Mypex over sand/poly	16.00	5.00
5	4	9	15	9	9	2.03	Sand/poly	12.57	2.70

Liquid feeding

Where supplementary liquid feeding was carried out on a regular basis the N level in the discharge water tended to be higher. The discharge levels of N at Site 1 were almost double those of the other sites (Table 13).

	Site 1	Site 2	Site 3	Site 4	Site 5

Total N mg/l	31.72	14.00	2.78	16.00	12.57

Table 13. Total N levels of the various sites

This shows the need for care in the use of liquid feeding and the advantages of water recycling schemes. The construction of the container bed, crop spacing and drainage layout are also an important aspect to consider, to avoid the discharge of drainage water with nutrients going into the environment.

Rainfall and irrigation applications

Total water application to the bed did indicate a potential relationship with nutrient levels. There would appear to be a slight trend of increasing nitrogen concentration with decreasing water application levels and an opposite trend in the case of phosphorus, with increasing phosphorus concentration with increasing water application rates.

Water recycling schemes, that harvest rainwater and collect drainage water back to a reservoir, present the ideal situation. Such schemes do not permit the discharge of nutrients in the environment, but are captured on the nursery. This illustrates the potential environmental, as well as economic benefits, that water recycling schemes bring.

FINANCIAL BENEFITS

The costs of water abstraction will go through a series of phased increases over the next few years to incorporate environmental safeguards under the changes brought in by the Water Act 2003. At present there is no environmental element reflected in the abstraction charges levied by the Environment Agency. As a result of a consultation a new environmental multiplier will be incorporated into the water abstraction charging scheme called an Environmental Improvement Unit Charge (EIUC). This will be set each year and will vary according to the source factor and the type of abstraction. It makes provision for abstraction charges to be linked to surface and ground water pollution levels in river basins. Lower pollution levels will relate to lower water charges. By paying attention to nutrient levels in discharge water now, growers can influence the maintenance of lower water costs in the future.

Likewise OFWAT has authorised a similar range of price increases for mains water from the water companies over the next five years. These measures will include features such as interruptible tariffs and higher charges as more water is used. This report highlights the environmental and hence financial benefits from rainwater harvesting and re-cycling over the use of mains water.

TECHNOLOGY TRANSFER

There is relevant information from this report to produce a Factsheet outlining the information and detailing the various steps that a grower can take to minimise nutrient discharges to the environment. The following points would aid a reduction in nutrient run-off and could be incorporated into a Factsheet:

- Scheduling of irrigation to a specific crop needs,
- Scheduling of irrigation according to crop growth and canopy size,
- Grouping plants with similar water requirements, by matching size, spread and pot size
- Potting into a common growing media with common water holding characteristics, under one irrigation regime.

A Water Recycling handbook similar to the Slow Sand filter handbook would also incorporate many of the important aspects of this report.

The main points of this report should be broadcast through the HDC News and Trade Press articles.

We would like to thank the five nurseries who allowed us to take the water samples and site details in the preparation of this report.

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