Project title: **The Environmental Impact of Run-off from Protected Ornamental Crops**

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PRACTICAL SECTION FOR GROWERS

Objectives and Background

Agriculture has continually come under scrutiny from governments and environmentalists as it seeks to use fertiliser and pesticides on the land. The European Union has developed, and will continue to develop directives and policies relating to these issues. As the EU issues these directives so the member countries must develop strategies to comply with the standards set. The most relevant directives to this study are the '1980 EU Drinking Water Directive' and the 'Nitrate Directive'. The Drinking Water Directive has set maximum permissible levels for components of fertilisers and pesticides. The most well known is the level set for nitrates in water courses which must not exceed 11.3 mg/l NO_3-N (50 mg/l NO_3). The MAC (maximum allowable concentration) for a single pesticide is 0.1 μ/l and 0.5 μg/l for total pesticides.

These can be difficult targets to achieve and in an attempt to keep below these levels the UK government has developed new legislation and schemes. In accordance with the Nitrate Directive, Nitrate Vulnerable Zones (NVZs) have been highlighted across England and Wales. Within these zones the authorities monitor, very strictly, the use of nitrates in fertilisers and general agricultural practices. The Nitrate Sensitive Areas scheme, now closed to further entry, was set up as a voluntary scheme for farmers to reduce their usage of nitrates in return for area payments. There are also sections in the codes of Good Agricultural Practice for Water and Soil which cover the sensible use of nitrates.

On the whole these schemes and any new legislation have not significantly impacted on ornamental growers and especially those growing under protection. However pressure from Europe, to reduce contamination of waters, is increasing and the government, through the Environment Agency, will be looking more closely at all uses of potentially polluting substances.

This project reports on how legislation, both existing and proposed, will effect protected ornamental nurseries. It also, through the use of a questionnaire sent to growers, identifies the main production systems used by protected ornamental growers today. The potential effect, of these systems, on the environment is considered and an assessment is made of how the industry may need to change to conform to new legislation and other pressures, for example from customers. The pros and cons of 'open' and 'closed' production methods are considered with particular reference to the use of ebb and flow flood benching systems. For those that cannot change from an open production system other methods of minimising run-off are discussed.

Environmental impact of run-off

Nitrate is extremely soluble and is found, to some extent, in most natural waters above and below the ground. Soil type effects the degree of movement of nitrate through the soil with more open structured soils enabling leaching down to the water table below. Phosphate is another fertiliser which is applied in significant amounts as a fertiliser in agricultural and horticultural situations. Once in the soil, these substances will gradually move towards the water table and may find their way into water courses. As levels increase in waters, a process called eutrophication can occur. Eutrophication is a nutrient enrichment which typically leads to an increased growth of algae and causes fluctuations in oxygen and pH levels of the water. These reduced oxygen levels upset the ecological balance of the waters and can lead to the death of many organisms in the waters. Levels of nitrate in UK rivers have been gradually increasing over recent decades as nutrients applied to land in years gone by, gradually reach water courses.

Protected ornamental production covers an insignificant land area, compared to agriculture, but despite this is a relatively large user of fertiliser and pesticide. Fertiliser is most often applied as a liquid feed which can very quickly leach through the open structured, peat based, growing media widely used today. This means that run-off of nutrients can be considerable over a relatively small area and if run-off is high in nutrient or pesticide it could be termed a 'point source' for pollution. Protected ornamental production may not have a noticeable effect on the national state of waters, but may have considerable effect on waters in the immediate local area and may contribute to some waters exceeding the EU levels.

Pesticides are widely used in protected horticulture, although this is decreasing with the increased use of biological control methods. From a 1991 survey none of the 10 pesticides, applied in greatest quantity to protected ornamentals, were detected in drinking water in England and Wales in 1995. Of these 10 pesticides applied in greatest quantity, it is estimated that aldicarb, bromide, dazomet and fosetyl aluminium are at greatest risk of leaching to cause water pollution. Any pesticides applied without care may result in water pollution, including those with a low leaching risk, if there is direct entry to a water course.

Legislation

The basis of legislation was outlined above as the UK seeks to comply with EU targets. Growers found to be causing EU levels to be exceeded in 'controlled waters' are liable to be fined under Section 85 of the 1991 Water Resources Act. Pollution offences are regarded seriously and can carry penalties up to £20,000 in the Magistrates Court. Section 97 of the Act has lead to the production of Codes of Good Agricultural Practice for which growers are obliged to adhere to. A new CoGAP is being developed for water which is due for release in October 1998. This will contain a section on 'Specialised horticulture' which will apply to horticultural growers.

Under this Act new Groundwater Regulations are being drawn up which are due to come into force from 1 April 1999. These require those discharging listed substances to groundwaters to have authorisation to do so. Ammonia, nitrites and phosphorus are among those substances listed. Run-off from protected ornamental production could potentially be high in these substances and if run-off drains to a ditch or accumulates at any specific point then it may require authorisation from the Environment Agency. Authorisation will also be required for any disposal of these substances to land. Authorisation follows investigation by the EA and will be at the grower's expense.

Other Acts may also impinge on growers and these include the Urban Waste Water Treatment Directive, EC directive on water quality for freshwater fish, Food and Environment Protection Act 1985, Environmental Protection Act 1990, Environment Act 1995 and the Environmental Assessment directive.

Questionnaire

A questionnaire, consisting of 23 questions was sent to protected ornamental growers in the summer of 1997. The results were grouped into categories for pot plants, bedding plants, pot and bedding, and cut flowers. The results showed that many protected growers have a heavy reliance on liquid feed and by far the majority use overhead irrigation. This overhead irrigation with open structured growing media presents a high leaching risk. Very few collect any run-off and for most it just drains into some form of stream or ditch. The major concern is that if this run-off is contaminated with nutrients then it may well require authorisation before it can be permitted to drain into the ground.

Environmental Impact Comparisons with edible crops and HONS

Leaching losses vary considerably with different land uses. Unfertilised grass alone will lose between 0 - 10 kg N/ha/year and intensive grazing land will lose 70 -130 kg. Potatoes will lose about 100 kg and HONS will lose between 80 - 360 kg; rockwool grown tomatoes can loose between 500 - 1500 kg and NFT tomatoes will lose between 100 - 300 kg (Vaughan, 1994). Protected ornamentals are expected to lose between 100 and 200 kg (unpublished ADAS research), but this is merely an estimate and further study is required before firmer estimates can be given.

Comparisons between 'open' and 'closed' production systems

Previous research has been analysed to give detailed comparisons on the economics and environmental differences between open and closed systems. A flood benching system in a glasshouse will cost approximately £42/m^2 to set up as compared to £3-4/m^2 for a basic open system (using March 1998 costs and exchange rates). Growers should consider the long term implications of changing to a closed production system and not just the short term costs. For example an increase in throughput can be achieved between 15 and 30% on ebb and flow systems. All the issues of ebb and flow production are considered which include: greater manipulation of the crop, humidity control, speed of supplying and removing water, watering frequency, pest and disease, growing media, recirculation and temperature.

A report is made of research comparing nutrient losses from different systems in the USA. This found that far more run-off was produced from microtube and handwatering than from ebb and flow although the run-off produced was less concentrated. Results from experiments comparing leaching fractions have shown that reducing leaching fractions (volume of solution leached ÷ total solution applied) by altering irrigation management will reduce the movement of nitrate through the profile.

Situation in Holland and Germany

In Holland protected ornamental growers have faced stiff, and vigorously enforced, legislation which enforces the reduction of run-off. An environmental action plan was developed which set a target for the year 2000. This target stated that glasshouse horticulture must have achieved a totally, or almost totally, closed operating system with no emissions. These controls are governed by the Surface Water Pollution Act and the Soil Protection Act.

Local water authorities have been set up to implement the legislation and ensure the targets are reached. Every grower must register monthly the volume of water coming in to the nursery and the amount not used. Fertiliser use must be registered to calculate nutrient uptake by the crop. Growers must collect rainwater from glasshouse roofs and must store a minimum of 500m^3/ha. Growers must record amounts of pesticide brought onto the nursery and amounts used, this is regularly inspected. The Multi Year Crop Protection Plan aims to reduce pesticide usage and is progressing well.

In Germany nurseries within water conservation areas must convert to some form of closed irrigation system. Surplus water must be collected, stored and recycled. Some growers of container HONS have managed to convince the government that with the use of controlled release fertilisers there is virtually no run-off.

Minimising Run-off

In many situations it may not be economically viable to convert to a completely closed production system. In these cases other means need to be found to reduce the amounts of run-off being produced. A number of methods can be considered and a selection could be used or adapted to individual nurseries. Some of the methods will require more research before being put into practice. The methods are as follows:

1. Accurate irrigation scheduling considering environmental conditions and plant requirements.
2. Developing a production system to cope with media with a higher water holding capacity.
3. More frequent analysis of growing media so fertiliser inputs can be adjusted to plant needs.
4. Uniform irrigation.
5. Use of controlled release fertilisers.
6. Collect run-off and recycle.

Practical and Financial anticipated benefits

Growers that are aware of the environmental impact of their operations will be able to act to reduce their contribution to any pollution of ground or surface waters. Growers that are aware of existing and proposed legislation will be able to adapt practices in order to conform and therefore avoid potential fines. An understanding of the situation in Holland and Germany will enable growers to see how environmental pressures have lead to changes in these countries and therefore give some idea of what we may expect in the UK.

Growers need to be ready to adapt to customer pressures for plants produced without damage to the environment. At present Holland, Denmark and Germany are far more prepared to meet these demands than UK growers.

Closed systems, such as ebb and flow flood benching, must be considered with its long term benefits including increased throughput and ability to mechanise as well as reduced contamination to the environment.

1. INTRODUCTION

This project was initiated following a recommendation given by Jill Vaughan in her previous project entitled 'Environmental impact of waste solutions from hydroponic systems for the production of edible crops' (PC 59). PC 59a addresses the same issues but for protected ornamentals.

Market forces, domestic and EU legislation are putting increasing pressure on horticulture to reduce or eliminate losses of nitrate, phosphorus and pesticides. Holland and Denmark have designated the whole of their territories as Nitrate Vulnerable Zones (NVZs) and are requiring growers to conform to action programmes designed to reduce nitrate levels in water. The NVZs in England and Wales are less extensive but more are added at each four year review. These zones focus on agricultural production but legislation is increasingly considering the role of horticulture in environmental pollution.

Horticulture has been added to the Code of Good Agricultural Practice for the use of Water, which is due for release in October 1998, giving recommendations for production systems. The proposed new Groundwater regulations may also have a significant impact on ornamental plant producers.

Even though nitrogen and phosphorus output from protected crops is small in national terms compared with other agricultural sources, discharges from nurseries could be significant, local, point sources of pollution. These could become the dominant source of nitrate in some surface waters during the summer months when inputs from other sources are small.

The objective of this review is to provide growers with the necessary information to enable them to make informed decisions regarding future investments in growing systems and how to modify current practices to comply with legislation. It will also give an overview of the situation in Holland and Germany as well as details on the financial implications of changing to different open or closed systems of production.

2. ENVIRONMENTAL IMPACT OF WASTE SOLUTION FROM PROTECTED ORNAMENTAL NURSERIES ON GROUND AND SURFACE WATER

2.1 Nitrate and Phosphate

Nitrate is extremely soluble: 1 kg calcium nitrate will dissolve in 1 litre (i.e. 1 kg) of water. Nitrate is found in most natural waters, both surface and underground. Concentrations in these waters have been increasing steadily for the past thirty years. At the same time, quantities of nitrate fertiliser applied to crops have also been increasing. The two trends are well correlated, but this does not imply a cause and effect relationship. Nitrate levels in the soil can also be a result of natural processes. The rise in nitrate concentration in aquifers and drinking water has increased in line with population and farm intensification as the more people on the earth are fed (Addiscott *et al.*, 1991).

After the second world war food production had to be increased to meet the shortfall made obvious during the war. The British government introduced a subsidy on the use of fertilisers that lasted until 1966. There was also a significant national change from pasture and rough grazing to arable cropping during the period 1939 to 1946, mostly in the south of England and East Anglia and there has been no substantial reversion to grassland since that time. There is evidence that nitrate release from ploughed up pasture can be from 200 to 400 kg N/ha (Young, 1986), or up to 4 t/ha over twenty years (Addiscott *et al.*, 1991).

There are two main pathways for nitrate to leave the soil. Firstly it may travel in solution to an underdrainage system and thence to an outfall. It may then affect surface waters such as dykes or rivers, depending on the position of the outfall. Secondly, nitrate may percolate down through the soil towards the water table.

The way nitrate moves through a soil depends on several soil properties.

Water normally moves much more freely through sand or gravelly soils than through clay soils, unless there are large cracks. Silt soils are intermediate but they have the capacity to hold much more water than sandy soils. Organic and peaty soils are very moisture retentive. The more water a soil can hold, the more has to be displaced for losses of nitrate to occur, so the capacity of the soil to hold water is important for slowing down nitrate loss.

Soil is made up of about 50% by volume solid particles, the rest is air and water. Water can normally percolate easily down through the soil. The speed at which it moves depends on factors such as soil particle sizes and the degree of cracking. Channels in soils are known as 'pores'. The flow of water in a pore of 1mm diameter is 10,000 times greater than that in a 0.1mm pore. If there are very large and continuous pores or cracks water flows rapidly down through the soil without any appreciable interaction with water and nitrate held within soil aggregates.

Soils with only slowly permeable subsoils usually have underdrainage systems. Water moves laterally on top of any permeable layer as well as into and through the drains. Drainflow can be collected, measured and analysed, but this does not necessarily collect all the drainage water. A lot of the drainflow will be flowing laterally and how the drainage collection points are set up will determine the amount of lateral flow collected in addition to the vertical drainflow.

In the protected cropping situation, ornamental crops are often grown in peat based growing media or with some crops, e.g. cut flowers, directly into the soil. In both cases if all drainage is not collected then it will eventually find its way into the soil beneath. As soils of different textures and porosities have different retentive properties so also growing media comes in many different forms. There has been an increasing move in the past decades to more open structured growing media which are more freely draining. This well drained media makes crops easier to grow with less risk of overwatering. It is designed to fit in with the systems of high levels of fertiliser and irrigation which have evolved in modern glasshouse crop production (Biernbaum, 1992).

Growing media components, like peat and vermiculite, appear to have a high cation exchange capacity (CEC), but in reality the CEC of field soil is far greater. CEC in simple terms is the ability of the media to hold nutrients, it is often expressed per unit of weight. Growing media tends to hold more nutrients per unit weight than soil, but has a low bulk density. Therefore when equal volumes of media and field soil are compared there is twice the nutrient capacity in soil than media (Biernbaum, 1992).

This all means that nutrients are lost far more easily from growing media than from field soil, and nitrate will quickly move through it when flushed through with the high levels of water which are typically applied in protected cropping situations.

But why should these issues concern growers anyway? The issues of nitrate pollution have already become a big problem for agriculture and are increasingly likely to reach ornamental growers as the problem gets worse. The whole issue is of concern mainly as a result of the EC Drinking Water Directive and the Nitrate Directive (see Section 3). This legislation came about because of the human health risks and environmental problems associated with nitrate. These are outlined briefly below.

Health Risks Associated with Nitrate

Nitrate itself is not toxic; it only becomes a potential hazard when it is converted into nitrite.

Two health problems have been linked with nitrite in the diet:

1. blue-baby syndrome or methaemoglobinaemia
2. stomach cancer

The last death due to blue baby syndrome in the UK was in 1950 and the last confirmed non-fatal case in 1972. The available literature was reviewed by

Addiscott *et al.*, 1991, who found no cases of blue-baby syndrome associated with tap water from the mains supply. The majority of cases have occurred when the water contained in excess of 22 mg/l N and was often contaminated with bacteria as well.

Stomach cancer has also been linked with the concentration of nitrate in drinking water. The mechanism suggested is that nitrite produced from nitrate could react in the stomach with an organic compound coming from the breakdown of meat to form an N-nitroso compound. These compounds are known carcinogens (Anon., 1981).

However, while nitrate concentrations in water have been increasing during the past thirty years the incidence of stomach cancer has been declining (Addiscott *et al.*, 1991). Of the substantial proportion of the nitrate we consume, often at least half, comes from food rather than water. Although leafy vegetables such as lettuce and spinach contain nitrate, they also contain vitamin C, which is reputed to be an anti-cancer agent. A lower incidence of cancer has been associated with a high daily intake of green/yellow vegetables by Hirayama (1982).

The evidence to link stomach cancer with nitrate in water is very limited although there may be a time lag between exposure to nitrate and diagnosis of cancer. Blue- baby syndrome is also clearly not a current problem in the UK. Despite all this Europe has set the standards and the UK must comply.

Environmental Effects of Nitrate and Phosphate

Eutrophication can be described as nutrient enrichment typically leading to increased algal growth and periodic wide fluctuations in parameters such as dissolved oxygen and pH. In fresh waters, phosphate is the principal limiting nutrient whereas in estuarine and coastal waters it is nitrate (Anon.,1992). The long term subtle effects of eutrophication in water courses are poorly documented, although it is likely that habitats and animal communities will be significantly altered (Anon., 1992). Surplus nitrogen causes many aquatic plants, such as reeds, to take their nitrate from the water rather than the bank and thus put down feeble root systems that are not strong enough to anchor the plant when water flow increases. River banks may become eroded as the reeds are washed away, loosening the soil and probably bringing more nitrate (and phosphate) into the water from eroded organic matter in the eroded soil. Alternatively, reeds may grow to excess thus narrowing waterways and possibly overloading and damaging banks. Water supply conduits become clogged and machinery damaged.

Estuaries are categorised into four quality classes ranging from "good" (class A) to "bad" (class D) based on the biological, aesthetic and chemical quality of the water (Anon., 1993a). Between 1958 and 1980 there was a steady improvement in the quality of estuaries in England and Wales. Since 1980, there has been a gradual deterioration, mainly explained by three factors in roughly equal proportions: changes in survey methodology, the effect of some hot, dry summers and discharges from sewage works, industry and farms (Anon., 1993a). Some of these factors mean that the solution is less dilute with the reduced rainfall and more concentrated by the increased discharge.

Coastal waters are also covered by the Nitrate Directive. Waste products and effluents containing contaminants reach the marine environment, principally from direct pipeline discharges. (The UK will cease the disposal of sewage sludge at sea by the end of 1998). Nitrate discharged into the sea can cause excess growth of marine algae.

Phosphate is most often the limiting nutrient for algal growth in fresh water ecosystems (Anon., 1992). Much of the phosphate "load" present in rivers and lakes comes from domestic sewage, but agricultural inputs may be significant. Fish cage-rearing adds large amounts of phosphate and can be locally very polluting. Pig slurry makes up another important source of phosphates.

Increasing and high levels of phosphates often result in algal blooms, especially in still waters such as lakes and reservoirs. The limiting concentration is about 10μg/l (1 μ = 0.001 mg). Algal blooms are unsightly and if water from contaminated lakes is required for drinking it has to be given expensive treatment to remove the algae. Large variations in dissolved oxygen and pH caused by algae photosynthesising during the day and respiring at night have been known to kill fish. Toxins may be produced by blue-green algae. These have caused illnesses in people using reservoirs for recreation and severe illness and death to animals. Phosphorus in lake and river sediments can be remobilised and recycled causing increased algal growth after the pollution has ceased.

Nitrate Trends in Rivers

In 1986 the DoE's Nitrate Co-ordination Group reviewed long term data from 25 rivers and shorter term data from 149 sites. It was concluded that nitrate concentrations had increased at varying rates, being generally higher in central and south eastern areas, although there were indications that trends were levelling off from the mid 1970's (Anon., 1992). Crude assessments of annual rates of increase are shown in table 2.1.

Table 2.1 Geographical variations in the rates of increase of nitrate concentration in rivers

Area	Increase in nitrate concentration mg/l per year
Scotland, Wales, North West	0.1-0.4
North East	0.1-0.7
Yorkshire, Severn Trent, Thames, Southern, Wessex	0.3-0.8
Anglian	0.7-1.1

(After Anon., 1992)

Many rivers exhibit winter peaks of nitrate, which are probably associated with surface run-off from the land and not from sewage effluents, which would be diluted in high river flows. The implication is that rising nitrate levels in the monitored rivers are due to agricultural practices; rivers exhibiting positive trends are not restricted to principally arable areas.

The mean quarterly nitrate concentration at Walton on the River Thames has increased from about 2.5 mg/l N in 1929 to over 7.0 mg/l in 1979. Modelling has been used to explain the observed trend (Onstand and Blake, 1980). Data on land use, inorganic fertiliser use, animal production and crop yields were used to generate estimates of the amount of nitrate available on the land over the period 1922 to 1975. Despite some gross assumptions, this accounted for 78% of the observed variance. The effects of a number of plausible options in agricultural trends were also assessed to the year 2000 and river nitrate levels were expected to rise still further.

River and canal water quality has been monitored in a series of national surveys (Anon., 1993a). Rivers and canals are classed as ‘Good’ (1A and 1B), ‘Fair’ (2), ‘Poor’ (3) and ‘Bad’ (4). About 15% of the total river length in England and Wales was downgraded and about 11% upgraded in 1990 compared with 1985. Overall the estimate net downgrading of river length in England and Wales since 1985 (about 4%) is mostly explained by the same three factors that affected estuary quality: improved monitoring; the effect of hot, dry summers and increased discharges from sewage works, industry and farms. It is estimated that the contribution of each of these factors to the overall net deterioration in river water quality was about the same (Anon., 1993a).

Substantial amounts of data are also collected regularly on a number of parameters at river locations all over Great Britain. These include BOD (Biological Oxygen Demand), phosphate, nitrate, zinc and certain pesticides. This is part of the Harmonised Monitoring Scheme (HMS), which covers 230 sampling points in Great Britain. Most of these sites are situated at tidal limits of major rivers or points of confluence of significant tributaries. Some of these data are summarised in Table 2.2.

Table 2.2 River water quality: distribution of annual mean concentrations of selected parameters across monitoring sites (whole of Great Britain)

	Average % distribution over 5 year periods		
	1977-81	**1982-86**	**1987-91**
Nitrate mg/l N Over 4.0	36	36	37
Over 1.6 up to 4.0	34	33	30
1.6 or below	30	31	33
Orthophosphate mg/l P, Over 0.36	32	34	37
Over 0.06 up to 0.36	35	34	29
0.06 or below	33	32	34

(after Anon., 1993a)

Causes of Rising Nitrate Trends in Rivers

Water may become polluted by discharges, run-off, leaching from soil, acid deposition or because of pollution incidents.

One important and perhaps surprising piece of information is that all the land in the UK, whether in agricultural production or not, receives up to **40 kg N/ha each year** from the atmosphere, in rain, aerosols and dust. If this amount dissolved as nitrate in the average amount of water draining from arable land in East Anglia it would give a concentration exceeding the EC limit of 11.3 mg/l NO_3-N! (Addiscott *et al.*, 1991).

Earlier in the 1990's about 8% of discharge consents were given to sewage treatment works and some of these were in breach of their discharge consent conditions. In 1996 there were 20,158 substantiated water pollution incidents; this was 14% less than 1995 indicating that pollution prevention measures are having some effect despite the fact that the general public are increasingly willing to report incidents (Anon., 1997). In 1991 13% of the substantiated incidents came from a "farm" source (Anon., 1993a). The Environment Agency had 229 successful convictions against water polluters in 1996/97 but these were by no means all farmers and heavy industry and water companies are bearing much of the blame for many pollution incidents.

Harris (1991) attempted to estimate the effect of discharges from HONS container units on nitrate levels in surface water. The importance of point source inputs of waters with high nitrate concentration will depend on many factors which include the quantity of water being discharged, the background N level and the volume of water in the surface waters. Inputs of water with high N levels will cause a problem when river discharges are low and the point of entry of the pollution is close to an abstraction point (Harris, 1991).

Effective rainfall is highest in the winter months, with sub-surface drainage contributing to catchment run-off typically between December and March. As a result, catchment flows tend to be highest between November and May with particularly low baseflows often in the period late June through to early September (Harris, 1991).

Muscutt *et al.*, (1991 and 1993) found that nitrate leaching was highest in the UK in late autumn / early winter following a flush of nitrate from the soil. During winter N concentrations fell, before rising again through the spring following inorganic fertiliser applications. Nitrate leaching in the summer was usually very low. However, under drought conditions, very low river flows provide little opportunity for dilution of point source inputs such as the recognised high nutrient discharges from sewage treatment plant outfalls. Under the extreme conditions experienced in 1976, it is well known that problems were experienced with summer nitrate concentrations in many southern England rivers (Harris, 1991).

Harris describes the "worst case scenario" as follows:-

- Summer discharges resulting from overhead irrigation to HONS container beds or from similar circumstances in glasshouses.

- A catchment with above average area of HONS containers or glasshouses.

- A catchment with low baseflows either due to established intensive under-drainage (causing lower water tables and potentially less groundwater/spring inputs) or due to periodic drought conditions.

- Background river N concentrations already near to the EC limit - more likely under drought conditions.

Under dry conditions, experienced in many parts of the UK during recent summers, surface run-off has been almost exclusively confined to "paved" areas. As a result the opportunities for dilution of high N water from horticultural holdings will depend upon the catchment and the proximity of an urban area upstream of the potable water intake. As high N leaching has been related to intensive agricultural production, and in the summer months, drainflow is likely to cease, horticultural discharge may become the dominant N source in many surface waters (Harris, 1991).

Water supplies stored in porous rocks (aquifers) are used and replenished over long time scales and much of the nitrate from changed farming practices has not yet reached underground water. This has been described as a "nitrate time-bomb".

In some areas where soil overlies chalk, water remains in aquifers for a long time (50 years or more) while, for example, in fissured limestone or sandstone the residence time is much less, perhaps five years or so. This means that any changes in agricultural practice will not necessarily make any difference to nitrate concentrations in bore hole water for many years to come. By boring into the aquifer rock and measuring nitrate in the water, hydrogeologists found that most water moves downwards through chalk at a rate somewhere between 0.5 and 1.5m in a year with a small proportion moving much faster (Addiscott *et al.*, 1991). The proportion moving faster through fissured limestone is much greater. The response time can be a few years or, in extreme cases, one season.

Long term data exists for many public supply boreholes, but these are imperfect indicators of trends in aquifer quality (Anon., 1992). Water from boreholes consists of a mixture from different depths and its quality is influenced by borehole construction, flow and pumping regime. Data from research boreholes are more reliable but are available for relatively short intervals. Of those sources with reliable data, some show little increase in nitrate since 1970, and a few have shown a decrease, but some display an overall rising trend. Analysis of pore water from the unsaturated zone can indicate whether nitrate levels will continue to rise, although predictions are difficult as there is a risk of recharge short circuiting the unsaturated zone during wet weather.

Nitrate migration in ground water appears to be highly variable; it is non-systematic in Norfolk Chalk, where there is also evidence of dispersion. Vertical stratification in the saturated zone is probably due to the aquifers not having reached an equilibrium with the "recharge" water's quality. In many cases, this is likely to take decades, or perhaps centuries (Anon., 1992).

A study on the Isle of Thanet, carried out by Southern Water (Anon., 1985), indicates that nitrate is moving vertically downwards at a rate of about 0.5

m/year. As the chalk is largely sterile, it is unlikely that biological processes will significantly reduce the nitrate content; its arrival at the saturated zone is thus irreversible and unavoidable. Concentrations of nitrate in the ground water are about 30mg/l beneath unfertilised permanent grass, although single ploughing events can cause peaks in excess of 50 mg/l. Trend analysis of the Thanet sources shows no clear upward or downward behaviour in the last thirty years. Nevertheless, future increases are expected as the effects of post-war ploughing and fertiliser usage eventually reach the saturated zone.

Some catchments need to use mathematical modelling to predict nitrate losses. It is probably the case that reductions in nitrate leaching cannot be achieved merely by improvements in the management of present land use, but that restrictions on land use are required which must involve a reduction in the intensity and area of arable cropping, and an extension of sympathetic grassland management practices.

De-nitrification

Microbes in the soil not only produce nitrate from organic matter, they can also change it to nitrogen gases. This process is known as de-nitrification. It occurs only if the microbes are starved of oxygen i.e. it is an anaerobic process. Nitrogen gas, N_2 or nitrous oxide, N_2O is produced.

Soil usually becomes anaerobic simply because it is wet. Oxygen diffuses about 10,000 times more slowly through water than through air. Wetness is not the only factor involved; the microbes demand for oxygen develops because there is organic material available which they can decompose. De-nitrification tends to be patchy, occurring in "hot spots" and this makes it extremely difficult to measure, especially in field experiments. The potential for de-nitrification to occur in soils is very great: waterlogged soils kept warm in the laboratory (at say 25°C) and supplied with plenty of easily decomposable organic matter will rapidly use up the supply of oxygen and the resulting de-nitrification may destroy nitrate at a rate equivalent to 30 kg/ha/day (Addiscott *et al.*, 1991). Rates of de-nitrification in soils in the field (i.e. outside) are more likely to be of the order of 3 kgN/ha/day.

Areas of soil in greenhouses under the plastic floor covering can be waterlogged and anaerobic where areas are low and water collects (in areas with dry cracked soils underneath, this will not be such a problem). If, alongside this anaerobic environment, there is also a source of organic matter then de-nitrification could occur. Whether this is a desirable process depends on the gas formed. Nitrogen gas, N_2, is no problem because it makes up 78% of the atmosphere, but nitrous oxide, N_2O, is implicated in global warming and the depletion of the ozone layer. The ratio of $N_2O:N_2$ in the gases formed during de-nitrification depends on a combination of soil factors and is difficult to predict with certainty. In general, non-acid soils in the temperate regions emit mainly nitrogen gas, except when there is a large concentration of nitrate in the soil. On a global scale the amount of nitrous oxide emitted from soils is twice the amount produced by burning fossil fuels and four times the amount evolved from the oceans (Jenkinson, 1990).

Drinking Water Quality

Water supply companies in Great Britain are responsible for assessing the quality of the water they supply through regular sampling of discrete "water supply zones" in which less than 50,000 people reside. Regulatory bodies also ensure that the water is good enough.

2.2 Pesticides

Pesticides applied to protected ornamental crops

By area

In 1991 the area of protected ornamentals in England and Wales, including plants in propagation, was estimated at 1,714 ha (Thomas *et al.*, 1992). The gross area treated with registered pesticides, including repeated applications, was 21,222 ha; ie an average of 12.4 treatments/ha/year. The most common types of pesticide used, according to treated area, were insecticides (44.7%) and fungicides (39.7%), with a smaller proportion treated with acaricides (6.5%), growth regulators (4.7%) and other products. The extent of pesticide usage varied greatly with each crop group. The use of insecticides was particularly common on chrysanthemums, carnations, alstroemenia and pot plants; the use of fungicides was particularly common on pinks, roses, pot plants and plants in propagation; the use of soil sterilants was particularly common in cut flower production.

By weight

The quantities of pesticide active ingredient applied are shown in Table 2.3. The 10 fungicides and insecticides used most (by weight) are listed, together with the most common acaricide, algicide, biological control agent, disinfectant, fungicide/insecticide, growth regulator, herbicide, molluscicide, repellent and soil sterilant. Fungicides, insecticides and soil sterilants jointly comprised 93% of the total weight of pesticides applied. The fungicide, insecticide and soil sterilant used most were propamocarb hydrochloride, tar oil and methyl bromide, respectively. The 10 pesticides of any type used most (by area and weight) are shown in Table 2.4.

The three fungicide active ingredients used in greatest quantity (propamocarb hydrochloride, etridiazole and fosetyl aluminium) are all applied principally as high volume sprays or drenches to the root zone for the control of root diseases.

Tar oil is used principally as a clean up insecticide prior to planting. Formaldehyde is used as a disinfectant to clean glass, shelving and trays, especially prior to propagation.

The two soil sterilants (methyl bromide and dazomet) account for 40% of the total weight of all pesticides active ingredients used on protected ornamentals in 1991. Both are widely used in chrysanthemum production, a crop which is traditionally grown in the soil.

Within the last two years growers have had the option of growing in compost containing imidacloprid granules. The amounts of this substance used does not bring it into the categories stated above but its use may increase. The weight of active ingredient used in treated compost is estimated at 280 kg/year for the 5% granule product and 140 kg/year for the 7% water dispersible granule product (E. Gotts, pers.comm.). It is considered, by the manufacturers, to be immobile and presenting a low risk of leaching. No figures were available for the new drench treatment of imidacloprid.

The use of pesticides in 1991 on protected ornamental crops compared with selected protected edible crops, is shown in Table 2.5. The greatest quantities of pesticides were applied to cut flowers (especially soil sterilants and insecticides) and to tomato (especially soil sterilants and disinfectants).

Table 2.3. Use of pesticides on ornamental glasshouse crops in England and Wales , 1991 (kg ai applied). Data from Thomas *et al.*, (1992)

Pesticide	kg ai
Fungicides	
Propamocarb hydrochloride	14,496
Etridiazole	5,573
Fosetyl-aluminium	3,836
Chlorothalonil	2,375
Tolclofos-methyl	2,114
Zineb	1,433
Furalaxyl	1,315
Iprodione	1,072
Thiram	773
Carbendazim	543
All fungicides	37,855
Insecticides	
Tar oil	19,350
Aldicarb	4,086
Chlorpyrifos	2,159
Nicotine	1,460
Fonofos	1,360
Malathion	1,256
Heptenphos	804
Dichlorvos	713
Diazinon	352
Endosulfan	328
All insecticides	34,142
Soil sterilants	
Chloropicrin/methyl bromide	40,630
Dazomet	13,150
All soil sterilants	53,812

Pesticide	kg ai
Acaricides	
Dienochlor	437
All acaricides	747
Algicides	
All algicides	80
Biological Control Agents	
Verticillium lecariu	12
All biological control agents	14
Disinfectants	
Formaldehyde	5,398
All disinfectants	5,461
Fungicide/Insecticides	
Permethrin/thiram	40
All fungicides/insecticides	42
Growth regulators	
Daminozide	1,054
All growth regulators	1,290
Herbicides	
Diphenamid	521
All herbicides	1,290
Molluscides	
Methiocarb	75
All molluscides	131
All pesticides	**134,868**

Table 2.4. The ten pesticide active ingredients used most on protected ornamentals in England and Wales, by area and quantity - 1991.

Active ingredient	By area treated (ha)	Active ingredient	By amount used (kg a.i.)
1. Deltamethrin	1,496	1. Chloropicrin/methyl bromide	40,630
2. Chlorothalonil	1,246	2. Tar oil	19,350
3. Cypermethrin	1,178	3. Propamocarb hydrochloride	14,496
4. Iprodione	1,135	4. Dazomet	13,150
5. Heptenphos	1,057	5. Etridiazole	5,573
6. Benomyl	984	6. Formaldehyde	5,398
7. Encarsia formosa	804	7. Aldicarb	4,086
8. Dienochlor	758	8. Fosetyl-aluminium	3,836
9. Daminozide	744	9. Chlorothalonil	2,375
10. Aldicarb	743	10. Chlorpyrifos	2,159
Total	10,145		111,053

Data from Thomas *et al.* (1992).

Table 2.5. A comparison of the use of pesticides on ornamental and edible glasshouse crops in England and Wales - 1991 (kg a.i. applied)

Pesticide	Cut Flowers	Pot plants	Plants in propagation	Total ornamental crops	Tomato	Cucumber	Lettuce	Total edible crops
Fungicides	4,604	6,474	26,257	37,336	3,508	2,128	9,653	16,515
Insecticides	12,444	3,373	18,326	34,142	801	1,451	480	3,017
Acaricides	417	193	135	747	530	604	-	1,235
Disinfectants	270	633	5,076	5,980	10,950	2,082	2,039	15,418
Soil sterilants	47,272	409	6,130	53,812	42,295	862	57,761	112,078
Total	65,007	11,082	55,924	132,017	58,084	7,127	69,843	148,263
Crop area (ha)	499	252	961	-	422	239	1,040	-
kg a.i./ha	130	44	58	-	138	30	67	-

Data from Thomas *et al.*, (1992)

The fate of pesticides

For pesticides applied to a crop or the growing medium, plant uptake and metabolism will remove a small amount of pesticide. Some may also be lost as vapour (volatilisation). A further proportion of the pesticide may be broken down by sunlight (photodegradation) or by chemical breakdown on reaction with water or oxygen. The remainder is potentially available for movement into soil and possibly leaching through the soil into water. Pesticide persistence and movement in soil depends on many factors including:

1. *The half-life of the chemical (DT_{50}).*

   This is the typical length of time needed for one half of the total amount applied to break down to non-toxic substances. In the UK, pesticides are classified into four persistence categories on the basis of DT_{50} by the Pesticides Safety Directorate:

Laboratory DT_{50} (days) at 25°C		
<5	Impersistent	- (eg malathion)
5-21	Slightly persistent	- (eg pirimicarb)
22-60	Moderately persistent	- (eg chlorothalonil)
>60	Very persistent	- (eg carbendazim)

   It must be borne in mind, however, that half-lives can vary greatly depending on factors such as soil type, soil moisture content and temperature.

2. *Solubility in water*

   This is usually expressed in grams per litre (g/l). Pesticides can differ greatly in solubility, for example, propamocarb hydrochloride is very soluble (867 g/l) while carbendazim is relatively insoluble (0.008 g/l).

3. *Degradation*

   Pesticides are broken down by microbial and chemical degradation. Microbial degradation occurs when fungi, bacteria and other soil organisms use pesticides as a food or energy source. Microbial activity is generally greater in warm, moist soils.

4. *Adsorption to soil*

   High K_{oc} indicates greater adsorption by the soil. For most pesticides, soil organic matter accounts for most of the sorption and this can be measured as K_{oc}. Pesticides with a relatively low adsorption to soil include metalaxyl and oxamyl. By contrast, propamocarb hydrochloride is virtually immobile in soil. Pesticide half-lives, solubility in water and adsorption to soil are given in Table 2.6 for the 10 pesticides use in greatest quantity on protected ornamental crops. Water solubility does not always relate well to movement in soil; adsorption is a much better indicator.

Pollution of soil and water from pesticides applied to protected ornamental crops

The greatest risk of soil and water pollution is likely to arise when pesticides are applied:

- directly to the soil
- to the structure of an empty greenhouse
- as a high volume (eg drench) application

Pesticides which are applied in this manner to protected ornamental crops, include:

chloropicrin/methyl bromide	) soil sterilants
dazomet	
formaldehyde	) greenhouse clean-up between crops
tar oil	)
propamocarb hydrochloride	) fungicide drenches/
etridiazole	) compost incorporation
fosetyl-aluminium	)
tolclofos-methyl	)
carbendazin	)
aldicarb	) insecticide drench

All of these products, with the exceptions of carbendazim, were also used in relatively large quantities in 1991 (Table 2.3).

Table 2.6. Chemical properties of ten pesticide active ingredients commonly used in the production of greenhouse ornamental crops.

Active ingredient	Product (example)	DT_{50} (days) at 25°C	K_{oc}	Solubility in water (g/litre)
Methyl bromide	Methyl bromide	-	-	13.4 g/litre at 25°C
Dazomet	Basamid	7	10	3 g/litre at 20°C
Formaldehyde	Formalin	-	-	'very soluble'
Tar oil		-	-	
Etridiazole	Aaterra	12	392	50 mg/litre
Fosetyl-Al	Aliette	-	-	122 g/litre (room temp.)
Furalaxyl	Fongarid	70	158	230 mg/litre (20°C)
Propamocarb	Filex	30	10^6	867 g/litre
Tolclofos-methyl	Basilex	30	2258	0.4 mg/litre (23°C)
Aldicarb	Temik	30	17	6 g/litre (room temp.)

DT_{50} Time for 50% loss
K_{oc} Distribution co-efficient between soil organic matter (expressed as carbon) and water

Data from Tomlin (1994) and Wauchope R D *et al.*, (1992) Groundwater contamination occurs when pesticides move down through the soil to the water table. The closer the water table is to the surface, the greater the potential for contamination by leaching. Pesticides that have a long half-life and are not readily adsorbed by soil (usually a low K_{oc}) have the greatest potential to be leached. These include benomyl (Benlate), metalaxyl (eg in Fubol) and triforine (eg Saprol) (Jenkins and Smith, 1992). The amount of a pesticide used is also important, with leaching risk likely to increase with rate of application. The leaching risk of 7 of the 10 pesticides applied in greatest quantity to protected ornamental crops is shown in Table 2.7 (information provided by S Bailey, Soil Scientist, ADAS Wolverhampton). No information was available on the half-life or adsorption for four products; methyl bromide, formaldehyde, tar oils and fosetyl aluminium. However, it is considered that bromide (released from methyl bromide), and fosetyl aluminium have a relatively high leaching risk, whilst formaldehyde and tar oils have a relatively low leaching risk (see footnotes to Table 2.7).

Pesticides found in drinking water

Water companies are required to monitor for pesticides at specified frequencies in samples taken from consumers' taps in each water supply zone. The standard sampling frequency is four samples for each pesticide in each zone. The pesticides to be included in the monitoring programme are not specified. Each company is required to develop a monitoring strategy for pesticides based on the likely risk of particular pesticides being present in the water source serving the zone (Hydes *et al.*, 1992).

During 1995, 27 pesticides were detected above 0.1 µg/l (0.03 µg/l for aldrin and dieldrin) in drinking water supply zones in England and Wales (Table 2.8) (Anon., 1996). Some of these detections were made on only one occasion and were not confirmed or repeated. Atrazine, chlorotoluron, diuron, isoproturon, mecoprop and simazine were detected most frequently (Table 2.8); these substances are all herbicides. The list of individual pesticides shown in Table 2.8 are those which exceeded the prescribed concentration in any of the three years 1995, 1994 and 1993. This list includes two pesticides (carbendazim and iprodione) commonly used on ornamentals; neither was detected in 1995.

Weakly absorbed herbicides are the most commonly reported pesticides found above 0.1 µg/l in water sources (Foster *et al.*, 1991). Atrazine and simazine, the two most commonly reported pesticides in drinking water, have limited use in agriculture but are widely used to control weeds in non-agricultural situations.

In a report on pesticides, chemicals and health by the British Medical Association (Anon., 1990), evidence is quoted of 298 water sources or supplies exceeding the EC Drinking Water MAC for single pesticide (0.1 µg/l) and of 76 breaches of the MAC for total pesticides (0.5 µg/l). The detected breaches occurred in six out of ten of the former National Rivers Authority (NRA) regions. It was considered that absence of reported breaches elsewhere may reflect inadequate investigations of water in these areas. In the fifth report on the quality of drinking water in England and Wales (Anon., 1996) individual pesticide concentrations above the prescribed standard were found in 0.8% of 925,666 determinations, and total pesticides above the prescribed standard (0.5 mg/l) were found in 3.2% of 44,256 determinations. For both individual and total pesticides, the proportion of determination exceeding the prescribed standards were less than those reported in 1994 (1.2 and 4.7% respectively).

As well as the water companies, the Environment Agency routinely analyses for about 50 pesticide active ingredients in fresh water, but could extend this list relatively easily. However, there will remain some pesticides for which there are no routine methods of detection (Anon., 1992).

An instance of careless use of a pesticide in a glasshouse causing a major drinking water problem was described at the National Cucumber Conference in 1996 by a representative of the Environment Agency. Waste solution of a phenolic product used as a clean up insecticide prior to planting a greenhouse directly entered a stream and resulted in taint in the local drinking water supply, necessitating closure of that source and supply of water from elsewhere.

Risk to the aquatic environment

As well as the possible contamination of drinking water sources, pesticide pollution from run-off could damage the aquatic environment. Few pesticides are "target specific" and hence affect a range of organisms; the full extent of their toxicity to a range of aquatic life is usually unknown (Anon., 1992).

Pesticide contamination of watercourses largely depends on pesticide mobility in soil, solubility and rate of degradation. Although many pesticides decompose quickly in the soil, it is likely that they will be more persistent once in the ground water because this tends to be less biologically active than soil (Anon., 1992). Pesticide degradation in surface water occurs by direct sunlight-induced reactions or reactions with photochemical produced reactive chemical transients eg OH-, superoxide or carbonate (Zepp, 1991). Pesticides may also bind to suspended and settled sediment.

Discharge from point sources (eg into dykes or streams) can result in fish and invertebrates mortalities.

Risks to the aquatic environment also arise from the storage of pesticides. The disposal of even small amounts of unused or surplus pesticide to foul sewers is another area of concern to the EA. The pesticide may pass through the sewage treatment process unaltered and enter the river where it may kill aquatic life. In addition, the toxicity of some compounds is such that a relatively small amount could impair or incapacitate the biological sewage treatment process, and the discharge of inadequately treated sewage might then also pollute the river (Anon., 1992). The Code of Practice for the Safe Use of Pesticides on Farms and Holdings (1998) gives guidance on pesticide use and precautions to be taken to prevent water pollution.

The toxicity to trout, where available, of ten pesticides widely used in the production of protected ornamentals is shown in Table 2.7. Dazomet is the most toxic, with an LC_{50} of 0.37 mg/litre.

Conclusion

None of the 10 pesticides applied in greatest quantity to protected ornamentals (1991 survey data) was detected in drinking water in England and Wales in 1995. Of these 10 pesticides applied in greatest quantity, it is estimated that aldicarb, bromide, dazomet and fosetyl aluminium are at greatest risk of leaching to cause water pollution. Any pesticides applied without care may result in water pollution, including those with a low leaching risk, if there is direct entry to a water course.

It is possible that local contamination of water close to a grower's holding may occur. This may have dissipated to non-detectable levels by the time the water reaches a water-treatment works, but the contamination could still have damaging effects on the aquatic environment near to the holding.

Table 2.7. List of pesticides applied directly to soil, to the structure of an empty greenhouse or to plants at a high volume (drench), their risk of movement through soil to water (leaching risk) and their toxicity to trout

Active Ingredient	Product (example)	Quantity used (kg a.i./ year) (1991)	Leaching risk (1 = highest risk)	Toxicity to trout[†] (or carp) LC_{50} 96 hour (mg/l)[††]
Soil sterilants				
1. Chloropicrin/methyl bromide	Methyl bromide	40,630	-[a]	2,200 (5 days)
2. Dazomet	Basamid	13,150	1	0.37
Greenhouse disinfectants				
1. Formaldehyde	Formalin	5,398	-[b]	'Toxic to fish'
2. Tar oil	Tar oil	19,350	-[c]	-
Fungicides				
1. Propamocarb hydrochloride	Filex	14,496	>> 5	410-616
2. Etridiazole	Aaterra	5,573	3	> 2.66
3. Fosetyl Al	Aliette	3,836	-[d]	428
4. Furalaxyl	Fongarid	1,315	4	32.5
5. Tolclofos-methyl	Basilex	2,114	5	2.13 (carp)
Insecticides				
1. Aldicarb	Temik	4,086	2	8.8

[†] Low values indicate greater toxicity

[††] Data from Tomlin (1994) and Flury and Papritz (1993)

[a] Methyl bromide is converted in the soil to inorganic bromide (Br^-) which presents the main leaching risk. Bromide is very weakly adsorbed to soil and cannot be broken down further in soil. Roughan (1980) reported that up to 70% of MeBr was lost to the atmosphere following application. Sheeting materials have improved since then and losses now are probably much lower. Assuming 40% is lost to the atmosphere, the input of methyl bromide to the soil would be approximately 16,252 kg/year. This is equivalent to 13,683 kg Br^-/year. Hence methyl bromide presents a high risk of leaching with respect to Br^-.

[b] Formaldehyde is unlikely to persist in soil; there is probably rapid oxidation to formic acid and subsequent metabolism. Leaching risk is therefore estimated to be low, unless it is transported directly to surface water by by-pass flow (ie through cracks and fissures and underdrainage systems).

[c] Tar oils are stated to be insoluble in water (Tomlin, 1992). They are probably degraded in soil fairly slowly relative to pesticides, as with other oils. They are probably bound by soil tightly. Leaching risk is probably low or moderate, unless transported rapidly by by-pass flow.

[d] Fosetyl-aluminium.rapidly breaks down in the soil to fosetyl, which is probably very mobile and at least moderately persistent. Taking into account the amount used, this results in high relative leaching risk, possibly similar to aldicarb.

Table 2.8. Detection of individual pesticides[a] in drinking water supply zones in England and Wales - 1995[b]

Pesticide[c]	No. of determinations	No. exceeding PCV[d]	% exceeding PCV
Fungicides			
Carbendazim	2601	0	0
Fenpropimorph	609	2	0.3
Fentin	320	0	0
Flutriafol	917	41	4.5
Iprodione	595	0	0
Oxadixyl	602	0	0
Insecticides			
Azinphos-methyl	36	0	0
Chlorfenvinphos	1990	3	0.2
Clopyralid	1292	9	0.7
Dieldrin	336	0	0
Dimethoate	2837	22	0.8
Gamma HCH	2034	0	0
Herbicides			
Asulam	851	1	0.1
Atrazine	34,779	567	1.6
Bentazone	260	0	0
Carbetamide	878	0	0
Carbofenothion	9	1	11.1
Carbofuran	372	0	0
Chlortoluron	29,152	335	1.1
Cyanazine	884	0	0
Dalapon	266	43	16.2
Dicamba	432	0	0
Dichlobenil	678	0	0
Dichlorprop	2,097	1	<0.1
Diuron	31,829	311	1.0
op-DDD	315	2	0.6
pp-DDD	315	2	0.6
pp-DDE	1,043	1	0.1
EPTC	306	0	0
Fluroxpyr	3,020	1	<0.1
Glyphosate	1,274	3	0.2
Imazapyr	1,726	0	0
Ioxynil	260	0	0
Isoproturon	32,373	4,098	12.7
Linuron	8,172	51	0.6

Table 2.8. Detection of individual pesticides[a] in drinking water supply zones in England and Wales - 1995[b] Cont-d .....

Pesticide[c]	No. of determinations	No. exceeding PCV[d]	% exceeding PCV
Methabenzthiazuron	3,692	17	0.5
MCPA	19,794	21	0.1
MCPB	4,755	0	0
MCPP	1,741	26	1.5
Mecoprop	25,021	278	1.1
Propazine	4,242	0	0
Propham	389	0	0
Propyzamide	61	1	1.6
Propetamos	307	0	0
Simazine	33,069	1,216	3.7
TCA	437	120	27.5
Terbutryn	15,624	0	0
Triclorpyr	417	0	0
Trietazine	946	2	0.2
Trifluralin	1,881	0	0
2, 4-D	10,627	0	0
2, 4, 5-T	136	0	0

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[a] Individual pesticides monitored by different water companies varies; companies establish those pesticides used within their catchment areas and which could reach water sources.

[b] Data from Anon (1996).

[c] Pesticides tabulated are those for which the prescribed concentration was exceeded in any of the three years 1995, 1994 and 1993.

[d] Prescribed concentration or value (maximum legal concentration).

Protected Ornamentals

This title covers a broad area of plants produced for the horticultural market. It encompasses many and varied growing systems developed by crop experience or scientific research. Protected crop production is distinct from almost every other type of crop production by the way in which fertiliser is frequently and repeatedly applied. Such production will never produce the huge areas of fertiliser application, as seen in agricultural situations, but it will produce small areas of highly concentrated application.

For this reason protected cropping is not considered significant enough to be covered by nitrate, phosphate and pesticide restrictions, yet. However, as can be seen by the examples of Holland and parts of the USA (see Section 7) environmental legislation may come to embrace even these small scale uses of pesticide and fertiliser. It may be that soon these highly concentrated, localised applications of fertiliser will not be tolerated unless they can be contained, as a closed system, within the protected environment or the amounts reaching the soil significantly reduced.

The protected ornamental sector includes growers of pot plants, bedding plants, HONS and cut flowers. Losses of nitrates applied to pot and bedding plants are estimated at between 100 and 200 kg/ha (100-300 mg/l NO_3) and phosphate losses at 2/5 of the nitrogen (unpublished ADAS research). Impact on ground water depends mainly on mean concentration and total loss rather than the timing of the loss. The large water loss means that in most cases N from intensive horticulture would move down to ground water faster than N from agriculture, thus increasing the impact. Phosphate and pesticide concentrations will be attenuated but some pesticides will survive in quantities sufficient to breach the EU limit for drinking water (unpublished ADAS research). The comparisons of this with other crops are considered in Section 6.

3. EXISTING AND PROPOSED LEGISLATION

This section outlines some of the existing and proposed legislation which could affect growers. However, expert advice should be sought before taking any action which could result in pollution, or if there is any doubt about the legality of current practice.

Laws controlling pollution

Water Resources Act (WRA) 1991

Water pollution control is mainly governed by the Water Resources Act (WRA) 1991. It works in two ways:

1. allows people to be prosecuted if pollution occurs.

2. contains measures designed to prevent pollution happening in the first place. The Environment Agency (EA) is responsible for most of this work.

Section 85 of the Water Resources Act 1991 makes it an offence to cause or knowingly to permit a discharge of poisonous, noxious or polluting matter or any solid waste matter to enter controlled waters. It is also an offence to allow matter to enter water so as to obstruct flow and aggravate pollution. "Controlled waters" means all ground water, coastal or inland waters including rivers, streams, ditches, land drains and most other passages through which water flows, and most lakes and ponds (Anon., 1992). One can "cause" pollution without acting intentionally or negligently.

A person does not, however, commit an offence under Section 85 if he/she has proper authority to make the discharge. This usually means a consent to discharge issued by the EA under Section 88 of the Act. In practice few farmers apply for discharge consents. The strengths of the wastes involved, the lack of dilution usually available, and the costs of treating the wastes to a form that might be acceptable to discharge, make it unlikely that an application for a discharge consent for most farm wastes would be acceptable to the EA (Anon., 1992). Situations where wastes may be discharged to controlled waters under a discharge consent include intensive livestock units, which may be able to justify the costs of a treatment plant; and where the polluting effect of the waste is relatively weak, e.g. with vegetable washings.

Consents to discharge may be reviewed; the EA has a duty to review them from time to time. This may result from circumstances in, for example, an individual river or by the Government responding to European Directives on water quality.

A consultation document was released earlier in 1998 for new groundwater legislation. The proposal is expected to be confirmed by parliament by late 1998 and would come into force from April 1999. These new regulations group chemicals into two lists; List I consists of the more harmful substances and List II lists others of concern. Ammonia, nitrites and phosphorus are in List II; these are substances which may be typically released from horticultural premises. The proposed regulations state that an authorisation to introduce these substances, into groundwater, shall not be granted in relation to:

1. Any direct discharge of any substance in List II.

2. Any disposal or tipping for the purpose of disposal of any substance in List II which might lead to an indirect discharge of that substance.

3. Any other activity on or in the ground which might lead to an indirect discharge of any substance in List II.

Such authorisation would not be given unless that activity has been subjected to prior investigation. This prior investigation will be the responsibility of the EA which will be given the powers to grant authorisations. This new legislation will undoubtedly impact on many horticultural producers including growers of protected ornamentals. The following areas where controls may be introduced are taken from the draft regulations, however growers should not assume that they do or do not fall into the categories described. The advice, in the first instance, is to contact the local office of the EA.

- The discharge of unused fertiliser solution (i.e. any solution containing List II substances), must be authorised by the EA. This may affect growers that use recirculating systems which need an annual cleaning out. Authorisation for this will be required unless the grower can demonstrate that the discharge of this solution onto land is of direct agricultural benefit.

- Where run-off collects in a drainage or ditch system, before draining into the ground or water courses (drainage into a mains should already have authorisation). This drain or collection system will require authorisation from the EA. This is of particular concern as any point source of discharge will require authorisation.

- General run-off (which is not collected) may also require authorisation. However, this gradual seepage of List II substances will be required to conform to a code of practice, which will be drawn up once the regulations are approved. This code will ensure that growers conform to practices which minimise such discharge. In all cases growers should contact local EA offices for clarification on particular circumstances.

The authorisation will be granted as long as the conditions are met. These conditions can be extensive and include precautionary measures, maximum quantities and arrangements for monitoring. The cost of this authorisation procedure will be borne by the one seeking to discharge (i.e. the grower); these charges are not, as yet determined, but could potentially be quite considerable. Growers should take these regulations seriously and aim to minimise the levels of these substances in run-off water.

Pollution offences are regarded very seriously and carry a penalty of up to £20,000 in the Magistrates court and an unlimited fine in the Crown court. It may also be necessary to pay for any damage caused by the pollution.

At present Section 85 of the Water Resources Act does not automatically cover all types of discharge, including discharges to land and certain lakes or ponds. However the EA can prohibit such discharges in particular cases by issuing so-called "relevant prohibitions" under Section 86. This power is limited to discharges "from a building or from any fixed plant" - a restrictive definition which raises complications in the case of certain farm waste disposal systems (Anon., 1992). The new groundwater regulations, described above, will extend the EA's powers in dealing with discharges to land.

Section 93 and schedule 11 contain powers to designate "Water Protection Zones". Activities likely to result in water pollution can be restricted in these areas. The EA is responsible for proposing designations to the Secretary of State. This would be in addition to the existing Nitrate Sensitive Areas and Vulnerable Zones (see below).

Section 161 allows the EA to carry out operations itself to prevent or clean up pollution and recover the costs from the person responsible (the "polluter pays" principle). Under Section 202 the EA can ask farmers and growers for information which will assist in carrying out its job preventing water pollution.

Section 97 provides for Ministers to approve Codes of Good Agricultural Practice (CoGAP). The CoGAP for water was published in 1991 and is a practical guide to help farmers and growers avoid causing water pollution. Non-compliance with the code does not necessarily give rise to civil or criminal liability but it could be taken into account in any legal action. Following the code is not a defence against a charge of causing pollution. At the time of writing this report, consultation documents were available for a revision of this code of practice. "Specialised horticulture" (and fish farming) were specifically excluded from the 1991 code (para 2) but provision is made for it in the revision due to be released in October 1998.

The revised code will contain a section on specialised horticulture and covers soil-grown protected crops, hydroponic protected crops, container nursery stock, organic wastes, other wastes, mushrooms and watercress. It will mean that some growers would be advised to implement new pollution measures. For example, the revised code suggests that for non-recirculating hydroponic systems growers should be encouraged to measure water application rates to ensure that it does not exceed crop requirement plus a reasonable (<30%) excess. For these same systems, excessive run-off should be avoided by using the following techniques:

1. measure the quantity of run-off at a representative number of points in each cropping area (the code will give details on a method which can be used for measurement). Compare the measurement with standard figures, where available,

of run-off for your annual water use. Water application should be reduced if run-off is more than 30% of the water being applied.

2. Make sure the irrigation system is well designed, carefully installed, monitored closely and regularly maintained to ensure that the variability in the amount of water delivered by each nozzle or dripper is as low as possible.

3. The amount and frequency of applications should be adjusted according to the needs of the substrate and growing system. For example more frequent applications of smaller volumes are needed for less retentive substrates.

4. Addition of nutrients to the water for protected crops should be matched to the crop requirement, particularly stage of growth and time of year.

For hydroponic recirculating systems, the solution should be allowed to run down as much as possible before the end of cropping to prevent large discharges when the tanks are emptied

For containerised nursery stock, the revised code suggests minimising run-off wherever possible by using sub-irrigated sand beds if these can be afforded or if overhead irrigation is used, carefully design the system to match the cropped area and regularly maintain irrigation nozzles to ensure even water application.

The code suggests that new container areas should be planned with the possibility of water recirculation in mind. It also commends the use of controlled release fertilisers and suggests that the amount of nutrients added to both compost and water should be carefully matched to the production system to minimise the amount lost in run-off. Nutrient levels should be monitored to minimise costs and run-off loss.

The code revision does not specifically mention protected ornamental crops which are often not soil grown and not hydroponically grown. However, the conditions relating to containerised nursery stock and nutrient input would probably also cover protected ornamentals.

The Codes of Good Agricultural Practice written for air (1992) and soil (1993) have also been revised and are due for release in October 1998.

The Urban Waste Water Treatment Directive (91/271/EC)

This Directive was introduced to protect the environment from the adverse effects of discharges from sewage treatment works and from certain sectors of industry. It is implemented through the Urban Waste Water treatment (England and Wales) Regulations SI 1994/2841. These define the EA as the competent authority.

The Directive requires the identification of Sensitive Areas using indicative standards expressed in terms of nitrate (95% of samples taken should contain no more than 50 mg/l nitrate), phosphate, dissolved oxygen, plant biomass, clarity, retention time and biological effects; with different criteria applying to estuaries and coastal waters, still freshwaters and running freshwaters. Waters can only be identified as Sensitive Areas under the Directive, if a qualifying discharge is contributing to problems. In such cases nutrient removal is required, unless it can be shown that this is not the cause. So far, 33 areas have been accepted as Sensitive Areas which requires the installation of phosphorus removal equipment in 41 sewage treatment works by the end of 1998.

Whilst this Directive directly targets eutrophication, it is mainly targeted at large sewage works impacting in designated Sensitive Areas. It may come into effect against extreme agricultural polluting sources but does not provide the complete answer for controlling eutrophication. The EU is currently working towards a Framework Directive on Water Resources, which aims to integrate different aspects of policy. This will tie in many of the aspects of different legislation e.g., whereas this directive deals with sewage works and the Nitrate Directive deals with agriculture, the EU are aiming to draw it all together in one Framework Directive.

EC directive on water quality for freshwater fish (78/659/EEC)

This Directive sets water quality objectives for stretches of rivers and other fresh waters needing protection or improvement in order to support fish life. These objectives are to be achieved through pollution controls and reduction programmes.

Food and Environmental Protection Act (FEPA) 1985, Control of Pesticide regulations 1986, and Code of Practice for the Safe Use of Pesticides on Farms and Holdings (1990)

The regulations which have been issued under FEPA Part III set out detailed rules on the approval, supply, storage and use of pesticides. One of the basic conditions laid down for the use of pesticides is that users take all reasonable precautions to protect the environment and "in particular to avoid the pollution of water". People who use pesticides must be competent and have received proper instruction.

The Code of Practice for the Safe Use of Pesticides on Farms and Holdings (1990, revised April 1998) gives guidance on pesticide use and precautions to be taken to prevent water pollution. In particular, the Code contains advice on possible routes for disposing of dilute wastes and washings, highlighting the need to ask the EA for advice where disposal is to land. Similar advice is also contained in the 1991 CoGAP for water (revised version due October 1998). FEPA contains powers to control the levels of pesticide which may be left in any crop, feed or feeding stuff.

Environmental Protection Act (EPA) 1990

The Environmental Protection Act 1990 updates the UK's pollution control systems. It brings in a system of integrated pollution control for the disposal of wastes to land, water and air.

Part I establishes integrated pollution control and gives local authorities powers to control air pollution from a range of prescribed processes; Part II improves the rules for waste disposal; and Part III covers statutory nuisances and clean air. A new waste management licensing system was put in place by the Waste Management Licensing Regulations 1994, although most agricultural activities are exempt. The DETR (Department of Environment, Transport and the Regions) is expected to consult on the application of controls, to agricultural waste, later in 1998.

Environment Act 1995

This Act does not replace the EPA (1990) or the WRA (1992) acts, but was introduced for the main purpose of enabling the setting up of the Environment Agency. It also gives the EA new duties which overarch the EPA and WRA with relation to sustainable development and conservation. In real terms, this means there are no functional changes in legislation without the EPA and WRA now considering an extra tier, which includes development and conservation, in any decisions which are made.

Planning Law

Environmental Assessment Directive (85/337/EEC) and the Town and Country Planning (Assessment of Environmental Effects) Regulations 1988

These regulations set out the requirements for the Environmental Assessment of certain major developments for which planning permission is needed. Most agricultural projects are exempt from planning control and hence from the procedures established under the Directive requiring environmental assessment of projects likely significantly to affect the environment. Certain projects may, however, be subject to assessment: these include, for agriculture, projects which involve water management, poultry and pig rearing.

If a farmer plans a project which requires Environmental Assessment, he is responsible for carrying out the assessment. If a proposed project is likely to affect water quality or water resources, the EA is interested to see that there are likely to be no adverse effects (Anon., 1992). This applies to clean surface water as well as run-off; large volumes of water are collected from glasshouse and shed roofs and concrete areas during rainstorms and could overload ditches. The appropriate body may also be consulted if there are plans to build in an Environmentally Sensitive Area (ESA), National Park, on Sites of Special Scientific Interest (SSSI's) or on archaeological sites.

Control of the Use of Water

Water Act 1989

Water Resources Act 1991

Most people who need to abstract water from a "source of supply" need an abstraction licence. A source of supply can either be an inland water (e.g. river) or ground water. Abstractions of less than 20 m^3 per day, which fulfil certain requirements as to location, do not need a licence. Interestingly this could mean that some, efficient ebb and flow nurseries, could operate without a license. For example a typical ebb and flow system needs approximately 4 litres/m^2/day; as long as less than 20,000 litres was used per day then an ebb and flow system up to 5000 m^2 could be used without a license (N. Bragg, pers. comm.). It is an offence to abstract water without a licence or not to comply with the terms of a licence. The EA may impose temporary restrictions on abstraction of water for use for spray irrigation, if an exceptional shortage of rain or other emergency makes that necessary (without having to pay compensation). Such restrictions can only relate to groundwater abstractions where that is in turn likely to affect the flow of an inland (i.e. surface) water (Anon., 1992). At present glasshouse growers are exempt but nursery stock growers are not.

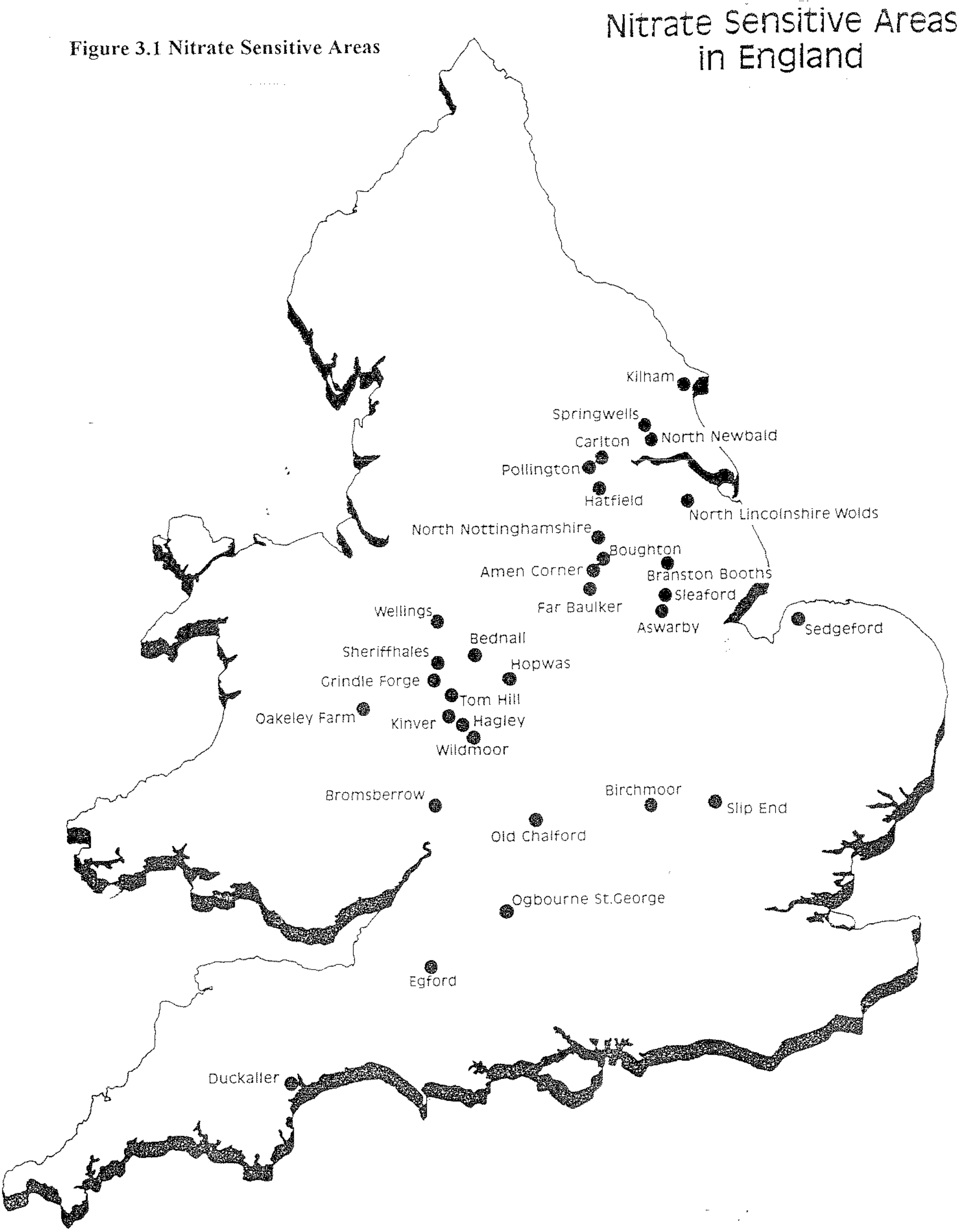
Nitrate Sensitive Areas Scheme

The NSA scheme provides an opportunity for farmers in certain, selected areas of England, to receive payments in return for voluntarily helping to protect valuable supplies of drinking water. A Nitrate Sensitive Area is an area where nitrate concentrations in sources of public drinking water exceed, or are at risk of exceeding, the limit of 50 mg NO_3/l laid down in the 1980 EU Drinking Water Directive and where voluntary, compensated agricultural measures have been introduced as a means of reducing those levels. The NSA scheme consists of 22 areas in England, covering about 35,000 ha, over 28 nitrate vulnerable groundwaters. These areas are shown on the map on Figure 3.1.

Farmers are invited to sign contracts for 5 years agreeing to comply with rules aimed at reducing nitrate loss. The rules include maintaining cover crops on land which would otherwise be bare over winter; and restrictions on manure and inorganic fertiliser use. Inorganic fertiliser use is restricted to 150 kg/ha N, with the option, at the lowest payment level, of applying up to 200 kg/ha N for 1 year in 5. Payments are made to farmers who join the scheme and the amounts paid vary depending on the level of the scheme that is chosen.

Arable farmers make use of this voluntary scheme, but there has been less uptake by the few intensive horticultural units within the area. This is mainly because the compensation payments offered would not make the changes, which most horticultural growers would have to make, financially worthwhile. The scheme does not provide for protected crops. The government has recently announced the NSA scheme to be closed to further entry, existing scheme members will be able to continue for the coming five years after which the scheme will not exist.

Figure 3.1 Nitrate Sensitive Areas



Laws Relating to Drinking Water Quality

Much of this legislation originates from the EU in the form of Directives. These are instructions to the UK Government, and other EU member states, to take steps in domestic law which will carry out the objectives of the Directive. Environmentally orientated Directives tend to operate by setting standards (e.g. for drinking water quality). The Government, through the EA, then has to meet these standards by taking whatever measures will achieve them.

EU Surface Water for Drinking Directive (75/440/EEC)
EU Sampling Surface Water for Drinking Directive (79/869/EEC)

The objective of the first of these Directives is to ensure that surface water abstracted for use as drinking water, prior to treatment, reaches certain standards and receives adequate treatment before being put into public supply; the second deals with quality measurements.

EU Drinking Water Directive (80/778/EEC)

This has been implemented under the Water Industry Act (1991) and the Water Supply (Water Quality) Regulations 1989 and amendments in 1989 and 1991. The Regulations incorporate all the standards (maximum admissible concentrations MACs and minimum required concentrations MRCs) set out in the EU Drinking Water Directive. They also include 11 national standards. In total, numerical standards are set for 55 parameters and descriptive standards for a further 2 parameters. In addition to these standards applying to water at the time of supply, a number of standards apply to water issuing from treatment works and to water held in service reservoirs within the distribution system.

Statutory responsibility is placed upon the Water Companies, but they are subject to checks by local authorities and by the Drinking Water Inspectorate. Monitoring information must be made publicly available.

The EU Drinking Water Directive (1980) sets standards for various substances in drinking water supplies. For nitrate, there is a "guide level" of 25 mg/l NO_3 and a MAC of 50 mg/l NO_3. The EU limit refers to *nitrate*. However, most growers are used to dealing in terms of nitrate-N.

To convert from a nitrate (NO_3) concentration to nitrogen (N) it is necessary to divide by 4.427. The EU limits thus become 5.6 and 11.3 mg/l, respectively. Values are quoted as nitrogen (N) throughout this report. Often the designation nitrate-N (NO_3-N) is used to distinguish from ammonium-N (NH_4-N).

The EU Drinking Water Directive also set standards for pesticides and related products in water at the time of supply of 0.5 µg/l for the total of the detected concentrations of individual substances and 0.1 µg/l for a single pesticide. Pesticides are defined as fungicides, herbicides and insecticides and the related products refer to polychlorinated biphenyls and terphenyls. The Directive's standards were set at the limit of detection for organochlorine insecticides in order to minimise the occurrence of pesticides in drinking water and they were not based on toxilogical evidence (Hydes *et al.*, 1992). The World Health Organisation adopts a different approach from that of the European Union. It considers the toxicology of individual substances and recommends a guideline concentration for each substance based on the assumption of lifelong consumption at that concentration.

Nitrate Directive

In December 1991 the European Union Nitrate Directive was adopted by member states; this may impact on intensive horticulture. The Nitrate Directive aims to limit nitrate contamination of drinking water and prevent nitrate limited eutrophication. ("Eutrophication" is the term used to describe what happens when the nutrient content of natural waters is artificially raised; there may be excessive growth of aquatic plants e.g. reeds and algae and periodic fluctuations in parameters such as dissolved oxygen and pH).

The Directive states that the application of nitrogen from animal manure should not exceed 170 kg/ha. This value includes nitrogen in manures and urine deposited while grazing. The legislation will impinge mainly on pig and poultry holdings, and on some intensive dairy farms with no other enterprise. It will impinge only within designated Nitrate Vulnerable Zones (NVZs).

The Directive includes diffuse losses of nitrate from agriculture and so excess nutrient allowed to drain into the soil would be covered. Both ground and surface waters are included.

The Directive required that by 1994, "vulnerable zones" were to be designated. These are areas of land draining directly or indirectly:

a) into drinking water sources (both ground and surface water) which contain or could contain more than 50 mg/l nitrate (11.3mg/l NO_3-N),

b) into waters which are, or may become, eutrophic (with nitrogen as the limiting factor).

Then by the end of 1995, action programmes were to be drawn up specifying what farmers in the vulnerable zones had to do to reduce nitrate losses. These programmes are set to be compulsory by the end of 1999, UK measures come into effect on 19 December 1998. The UK designated the first batch of NVZs and, at the time of writing the report, they were going through a review which takes place every four years. None of the previously designated areas are likely to be removed but new areas are being considered that have nitrate levels at or near the level of concern. The NVZs place no specific requirements on protected horticulture.

The UK has drawn up an action programme which has been released for consultation. The action programmes are based on "good agricultural practice", including rules on:

- The timing, rate and other conditions of fertiliser applications, both organic and inorganic, to ensure that the crop does not receive more nitrogen than is economically justifiable. e.g. organic manure application must not exceed 250 kg / ha /year of total N.
- Closed periods, e.g. for slurry spreading, and storage capacity to be sufficient to cover the longest period during which application is forbidden.
- The overall quantity of N per ha which may be supplied by animal manure including that deposited while grazing, (normally not more than 170 kg/ha with a higher limit of 210 kg N/ha for the first four years after the measures come into effect).

Legislation implications for protected ornamentals growers

As shown, there is a considerable amount of legislation relating to nitrates; most is in an agricultural context, with smaller scale horticultural enterprises being less affected. However, as these pressures increase and the public becomes more aware of nutrient and pesticide losses from horticulture, then it may not be long before the UK finds itself moving towards the Dutch system (see Section 7) and moving towards closed production systems.

Most of the legislation against water pollution either regulates large scale agriculture or large industry and sewage works. Figures are given in the Nitrate Directive for values of N per hectare which should not be exceeded, this covers direct application to soils and soil grown crops. However, no provision is currently made for protected ornamentals or containers as far as nutrient regulation is concerned.

Although fertilisers are rarely applied directly to soils in protected ornamental production, yet there can still be considerable run-off of nutrients to the ground. The area under protection can become a point source of pollution, possibly exceeding agricultural levels. Therefore, the following aspects of legislation should be borne in mind:

- Water Resources Act - follow the new horticulture sections in the CoGAP and be prepared for the new groundwater regulations.
- FEPA - Prevent water contamination by pesticides by following the regulations.
- Drinking Water Directive - Ensure run-off is not causing nitrate levels in adjoining watercourses to exceed the limit of 50 mg/l.

Horticultural enterprises should be seen to be minimising nutrient and pesticide run-off in order to prevent heavily enforced legislation being imposed in the future. However if it is, then we need to be ready and have a strategy to reduce our nutrient and pesticide waste.

4. QUESTIONNAIRE

Method

A questionnaire, consisting of 23 questions, was produced and sent to over 700 growers of protected ornamental plants. The questionnaire sought to gain data from growers which could be used to estimate fertiliser usage and run-off, on a nation-wide basis. The questionnaire, which was distributed during the summer of 1997, is shown in the Appendix.

Results

The number of questionnaires returned by growers was relatively few (only 72 could be used for any form of analysis). Many of the questionnaires contained data which had been filled in poorly and much information was not supplied by growers. This meant that a full statistical analysis could not be carried out on the results. The results shown here consist of the information which could be extracted from the completed questionnaires.

The growers responding to the questionnaire can best be divided into four categories:

1. Pot plant growers - 7 nurseries
2. Bedding plant growers - 13 nurseries
3. Growers of pot and bedding plants - 22 nurseries
4. Cut flower growers - 30 nurseries

These will be looked at individually. Questions which cover all sectors, i.e. numbers 13-16 and 18-22 will be analysed later.

Pot plant nurseries

The first question relating to pot plant growers is Question 3. This asks for growers to give details of the three most important crops in terms of crop area / year. It is important to bear in mind that the results (Table 4.1) only relate to the 7 nurseries that grow solely pot plants.

Table 4.1 Pot plant crops grown

Crop	Number of nurseries growing it	Area grown (ha)	% of total area
Begonia	4	2.0	16
Cyclamen	2	0.4	3
Foliage	0	0	0
Chrysanthemum	5	2.4	20
Poinsettia	5	4.6	38
Primrose	1	0.2	2
Other	4	2.6	21

Question 6 asked growers what grade of compost they used from coarse (free draining), through medium, to fine (moisture retentive). Of the pot plant growers, 3 (43%) used coarse and 4 (57%) used medium.

Questions 7 to 11 relate to fertiliser inputs into the crops. None of the pot plant growers surveyed used controlled release fertiliser; they all used liquid feed and most applied it in every watering. The fertiliser details completed by growers for Questions 8 and 10 were too varied and complex to give useful analysis.

Question 12 asked how often compost, plant and liquid feed samples were analysed (Table 4.2).

Table 4.2 Number of pot plant growers analysing and frequency of analysis

	Number of growers that sample ...				
	Before planting	Daily	Weekly	Monthly	Never
Compost	1	0	1	5	1
Plant	1	0	0	2	0
Feed	0	2	1	1	0

Question 17 asked growers to specify their methods of irrigation. The methods are grouped in categories as shown in Table 4.3.

Table 4.3 Irrigation methods used by pot plant growers

Irrigation type	Number of nurseries	% of nurseries using the system
Overhead	3	43
Low level	5	71
Capillary	7	100
Ebb and flood	0	0

Clearly some nurseries use more than one system or incorporate the different systems.

Question 23 asked about run-off; none of the pot plant growers measured run-off and few would estimate.

Bedding plant nurseries

The first question relating to bedding plant growers is Question 4. This asked for growers to give details of how they grow their plants (i.e. what container) and the cropped area (Table 4.4). The section on number of weeks was not accurately filled in. Obviously some crops are in place longer than others and some will overlap. This factor cannot be accounted for here. It is important to bear in mind that the following results relate to the 13 bedding plant nurseries that completed the survey.

Table 4.4 Containers used for bedding plant production

	Number of nurseries	Area grown (ha)	% of total bedding area
Pots	8	7.7	37
Pots (other than 9 cm)	6	5.3	26
Strip bedding and boxes	10	6.9	33
Baskets	7	0.3	1
Other	1	0.4	2

Question 6 asked growers what grade of compost they use. Results are shown in Table 4.5.

Table 4.5 Compost grade used by bedding plant growers

Grade	Number of nurseries using ...		
	Pots	Boxes	Baskets
Coarse	2	1	1
Medium	8	7	6
Fine	3	3	2

Questions 7 and 9 identify the methods of fertilisation used on the participating nurseries (Table 4.6).

Table 4.6 Methods of bedding plant fertilisation

	Number of nurseries	% of total bedding nurseries
CRFs only	4	31
Liquid feed only	1	8
CRF + Liquid feed	8	62

Question 12 relates to frequency of sampling in the 13 nurseries (see Table 4.7).

Table 4.7 Number of bedding plant growers sampling and frequency of analysis

	Number of growers that sample ...				
	Before planting	Daily	Weekly	Monthly	Never
Compost	1	0	1	4	6
Plant	0	0	1	1	6
Feed	0	2	1	0	5

Question 17 relates to irrigation (see Table 4.8).

Table 4.8 Types of irrigation system used by bedding plant growers

Irrigation type	**Pots**	**Boxes**	**Baskets**
Overhead	13	10	7
Low level (trickle and lay-flat)	1	0	3
Capillary	3	2	1

As with the pot plant nurseries, none of the bedding nurseries measured run-off. Five of the nurseries estimated the run-off, with an estimation average of 40% run-off.

Pot and bedding plant nurseries

These nurseries completed both the pot and bedding plant sections of the questionnaire. The nurseries produce both crops depending on demand and ensuring the greenhouses are full for as much of the year as possible.

The first question relates to crops and areas grown (see Table 4.9).

Table 4.9 Crops grown by producers of pot and bedding plants

Crop	**Number of nurseries growing it**	**Area grown (ha)**	**% of total area**
Pot plants			
Begonia	1	< 0.5	< 1
Cyclamen	17	3.2	7
Foliage	6	0.9	2
Chrysanthemum	0	0	0
Poinsettia	11	5.6	12
Primrose	15	4.2	9
Other	11	1.5	3
Bedding			
Pots	18	4.4	10
Pots (not 9 cm)	15	4.5	10
Strip bedding and boxes	21	17.7	38
Baskets	13	3.7	8
Other	1	< 0.5	< 1

Question 6 asked about compost type used (Table 4.10).

Table 4.10 Compost types used by pot and bedding plant growers

Compost type	Number of growers using ...		
	Pots	Boxes	Baskets
Coarse	5	2	4
Medium	20	19	15
Fine	0	2	0

Of the 22 nurseries in this group, 4 (18%) applied liquid feed with every watering, 17 (77%) did not.

Table 4.11 summarises the results of the fertiliser application questions.

Table 4.11 Methods of fertilisation on nurseries producing bedding and pot plants

Fertiliser type	Number of nurseries	% of total (B + PP nurseries)
CRFs only	0	0
Liquid feed only	8	36
CRF + Liquid feed	14	64

Question 12 relates to sampling frequency amongst the 22 growers (see Table 4.12).

Table 4.12 Number of nurseries growing pot and bedding plants that sample and frequency of analysis

	Number of growers that sample ...				
	Before planting	Daily	Weekly	Monthly	Never
Compost	5	0	0	9	8
Plant	0	0	0	5	9
Feed	2	3	3	1	11

Question 17 asked growers to specify irrigation type in the 22 nurseries (see Table 4.13).

Table 4.13 Irrigation types used by nurseries growing pot and bedding plants

Irrigation type	Pots	Boxes	Baskets
Overhead	22	22	15
Low level	3	0	7
Capillary	12	4	1

As with all nurseries so far, none of these measured run-off. 11 estimated run-off; estimates ranged between 5 and 75%, with an average of 20% run-off.

Cut flower nurseries

30 of the questionnaire responses came from cut flower growers, the results are shown below. The first question applying to these nurseries was Question 2 (see Table 4.14).

Table 4.14 Crops grown by cut flower growers

Crop	Number of nurseries growing it	Area grown (ha)	% of total area
Alstromeria	5	2.1	10
Chrysanthemum	14	11.8	56
Freesia	4	2.5	12
Carnations/Pinks	4	1.6	8
Stocks	4	0.3	1
Other	16	2.9	14

Question 5 related to the use of base dressings on cut flower production. The following dressings were used (see Table 4.15).

Table 4.15 Base dressings used in cut flower production

Base dressing	Number of nurseries	% of nurseries using the dressing
Compound fertiliser	10	33
Ammonium Nitrate	11	37
Triple superphosphate	10	33
Potassium sulphate	10	33
Other	9	30

Twenty (66%) of the 30 cut flower nurseries also use liquid feed. Of those which do apply liquid feed, 7 (35%) do it on every watering.

Question 12 asked growers about frequency of sampling (Table 4.16).

Table 4.16 Numbers of cut flower growers sampling and frequency of analysis

	Number of growers that sample ...				
	Before planting	Daily	Weekly	Monthly	Never
Soil	16	0	0	2	3
Liquid feed	0	0	1	1	2

Question 17 relates to irrigation methods. The results for soil grown cut flowers are shown in Table 4.17.

Table 4.17 Irrigation methods used by cut flower growers

Irrigation type	Number of nurseries	% of nurseries using the system
Overhead	23	77
Low level	14	47
Closed systems	0	0

Again, none of the cut flower growers measured run-off. 11 tried to estimate, figures ranged from 2 to 40% with an average estimate of 20% run-off.

All nurseries

Questions 13-16, 18 and 19 can be analysed without grouping them in the categories used above. Therefore, this analysis is based on the 72 useable responses for the entire survey.

Question 13 asked how plant and compost waste was disposed. Thirty-two (44%) of the 72 nurseries skip their waste, 47 (65%) have it composted or re-used in some way.

Question 14 considered water treatment and asked for details about water supplies. The results of this are shown in Table 4.18.

Table 4.18 Water treatment used by all growers surveyed

	Treated by ...				
Water type	Not treated	Acid dose	Chlorine	Ultra Violet	Filter
Mains	43	10	2	0	5
Borehole	5	7	0	0	4
Well	0	1	0	0	0
Rainwater	11	1	0	0	5
River/lake/stream	3	0	0	0	1

Of those that treated their water supply by acid dosing, all used nitric acid for the purpose (Question 15).

Question 16 asked the location of water storage tanks (see Table 4.19). Numbers do not always add exactly to 72; some nurseries use more than one type and some did not give an answer.

Table 4.19 The location of water storage tanks

Storage tanks	Covered	Uncovered
Outside	42	13
Inside	16	4

Question 18 asked if an underdrainage system was in use and if so where its outfall is (see Table 4.20).

Table 4.20 Use of underdrainage systems and location of outfall

	Number of nurseries	% of total nurseries
No underdrainage	36	50
Underdrainage	34	47
Outfall - Water course	28	39
Lagoon	1	1
Soakaway	5	7
Other	1	1

Question 19 asked if rainwater from the glasshouse roof is used for irrigation and if not, where does it go (see Table 4.21).

Table 4.21 Use of rainwater

	Number of nurseries	% of total nurseries
Rainwater used	18	25
Rainwater not used	52	72
Where it goes- Water course	37	51
Lagoon	1	1
Soakaway	6	8
Other	3	4

Discussion of questionnaire results

Pot plant nurseries

Poinsettias and Chrysanthemums appeared to be the main crops produced by the growers responding to the survey. The crops tend to be grown in coarse and medium textured media. The answers to this question on compost grade are, obviously, going to be fairly subjective, depending on the growers perception of the growing media used. The use of more open and free draining composts is typical of the trend in methods. Free draining composts are more easily manipulated and require less skilful management; they also enable the use of leaching to flush through the media to reduce the build up of salts. However, this aspect of the crop management, also increase the levels of nutrient and pesticide run-off.

This high degree of accuracy which is required in pot plant production also explains why none of the growers surveyed used controlled-release fertilisers. Liquid feeds were applied exclusively and most applied them at practically every watering. As pot plant production has developed this has been shown to produce the most high quality crops but in future there may be more concern about where the run-off is going. Liquid feed rates are varied in accordance with monthly (on the whole) analysis of plant and/or growing media material.

All nurseries were using some form of capillary irrigation which was supplemented by overhead or low level irrigation; none of these pot plant growers was using a closed production system.

Bedding plant nurseries

Thirteen bedding plant growers responded; most of the growing area of these nurseries was used for producing pot bedding but also a considerable area produced bedding in strips and packs. Most growers used a medium grade compost.

In contrast to the pot plant producers, most bedding growers used liquid feed, only to supplement fertiliser already applied in a controlled release form. Leaching can still be a problem from CRFs (controlled-release fertilisers) but to a much lesser extent than leaching resulting from the repeated application of liquid feed.

Bedding plant growers appear to be much less likely to sample the plants, growing medium and/or feed used. Growers would use judgement based on experience for much of the fertiliser application. All the growers used overhead irrigation to some extent. This reflects the fact that bedding, which is often a mass produced, lower value, product does not justify the installation of an expensive closed production system.

Pot and bedding plant nurseries

As with the bedding plant growers, most of these 22 growers use a medium grade compost and liquid feed in association with controlled release fertilisers. The sampling which was carried out would probably have been on the pot plants, although it is not possible to tell this, for certain, from the results. Again, all the nurseries used some form of overhead irrigation. Some clearly thought that their methods of irrigation were very wasteful. Most growers underestimate the amount of run-off which is actually taking place, but one grower estimated a 75% run-off rate.

Cut flower nurseries

From the 30 cut flower growers that responded, 56% of the area was used for Chrysanthemums using a fairly equal balance of the different base dressings available; 66% of these nurseries supplement this dressing with liquid feed. Soil sampling is common, and would be expected for a crop which requires accurate manipulation of soil nutrient levels.

Generally, overhead irrigation systems are used and all leachate will run deeper into the soil and eventually into the water table or to wherever the underground water drains. Estimating run-off on such a soil grown crop is extremely difficult. Research in The Netherlands on this aspect is discussed in Section 7.

All nurseries

The use and availability of water is of increasing concern to growers and is prompting many to look seriously at recirculation and careful water management. Of those surveyed, at least 75% use mains water to some extent; as the price of this increases and as other abstraction licences become harder to obtain, reducing water use will be an essential feature in nursery planning.

Only 1% of the nurseries collect any of the run-off water through the underdrainage system. Most systems drain directly into a stream or ditch. 50% do not have any form of underdrainage. Only 25% collect the rainwater from glasshouse roofs, the others allow it to drain away. This is quite a contrast from the situation in Holland where growers must collect roof water (at least 500m^3 /ha/yr, see Section 7).

Although it is difficult to draw firm conclusions, on the state of the protected ornamental industry in relation to run-off, this questionnaire has given a good impression of the factors which may become problems in the future. For example, the application of liquid feed through relatively coarse growing media, the inefficient use of water. and reliance on overhead irrigation systems. The use of recirculation systems and collection of rainwater must be important considerations for any future nursery development.

Limitations of the Questionnaire

Although it has been possible to gain some useful information from the questionnaire, it has generally not provided a lot of information which could be used to make definite assessments of the protected ornamental industry. Growers generally completed questions about crops grown and irrigation types, because these could be answered without having to do extra research. But where extra research was required the questionnaires were not completed in sufficient detail.

If a survey was being done in future then a postal survey, using a database of relevant growers, could be useful. However the questions on the survey, which would have to be brief, must be simple and answerable without extensive research from the grower. This would give broad information on industry practices and views. More detailed information is gained by visiting nurseries and extracting the desired information. This method ensures that information given is consistent between nurseries and will be presented in the same way. Details on fertiliser inputs and losses are seldom held by growers and relying on a guess, by them, on a questionnaire will not produce reliable results. A visit can assess whether or not such figures can accurately be calculated.

5. ENVIRONMENTAL IMPACT COMPARISONS BETWEEN PROTECTED CROPS, EDIBLE CROPS AND HONS

No agricultural system can be 100% efficient in its use of nitrogen; nitrate leaching is a natural process and some loss each year is inevitable (Archer and Thompson, 1993). Agricultural land is the main source of nitrate in rural catchments. The amount of nitrate lost from a given area depends on the overall balance of agriculture and horticulture in the catchment. This means that the presence of some fields, intensive livestock units or glasshouses with high losses will not necessarily result in the overall water concentration exceeding 11.3 mg/l NO_3-N. The quantity of nitrate lost from a farming system depends on the balance between inputs of nitrogen in the form of fertilisers and imported animal feeds, the quantity removed in crops and animal products from the farm and that lost by gaseous routes (i.e. ammonia volatilisation and denitrification) (Archer and Thompson, 1993).

Three particular practices can result in unnecessarily high leaching from any farming system:

- nitrogen use in excess of crop requirement.

- application of animal manures, sewage sludge or other organic wastes at excessive rates or inappropriate times.

- lack of crop cover during the Autumn and Winter months.

The contribution of a nitrate source to pollution in a water course will depend on the concentration of the nitrate input, and the water volume in relation to other water inputs. In agriculture these are closely linked; the volume of water is determined mainly by rainfall, and to a lesser degree by the crop, which affects water use. The nitrate load is affected mainly by crop husbandry, and to a lesser degree by drainage volume. In the drier areas, and especially on the better bodied soils, there may be insufficient drainage to wash all the nitrate out of the soil profile over winter. However, in general, the greater the drainage volume, the smaller the concentration of nitrate. Also, drainage volumes from adjacent areas of land are normally fairly similar, so that contributions are related to the area occupied by a particular land use. Losses take place chiefly over winter, when fertiliser is not applied, so that total losses are limited to the quantity of nitrate held in the soil during the winter.

In horticulture, these compensating effects may not occur. Water volume is determined by irrigation practice; and concentration by liquid feed applied. There is no intrinsic limit to the quantity of nitrate removed, and losses may take place throughout the year. There is a risk of large losses at times when the input from other agricultural sources is small.

Losses by leaching depend on soil type and rainfall. The lightest arable soils only retain about 150 mm total water per metre depth; so nitrate in these, and the shallow soils which are so extensive in the UK, is much more easily leached than nitrate in deep clay or silt soils which may retain more than 400 mm of total water per metre. The amount of rain which is in excess of evaporation and crop transpiration, and which therefore results in leaching, varies from about 150 mm in the east to more than 300 mm in some western and northern arable regions and to more than 1,000 mm in some grassland regions.

Estimates of Leaching Loss

Estimates of the nitrate, that is actually leaching from soils, are difficult to make; typical values are shown in Table 5.1.

Table 5.1 Nitrate leaching loss from different crops, fertilised correctly and without use of manures

Crop	kg N/ha/year
Unfertilised grass	0-10 (1)
Intensive dairying (grazed)	70-130 (2)
Winter cereals, Spring barley, Sugar beet	30
Beans and peas	60-70 (1)
Winter Oilseed Rape	75 (1)
Potatoes	100 (1)
Field Vegetables	100
HONS	80-360 (3)
Rockwool tomatoes	500-1500 (4)
NFT tomatoes	200-500 (4)
Rockwool cucumbers and peppers	400-1000 (4)
Soil grown tomatoes	100-300 (4)
Pot plants and bedding	100-200 (4)
Pine Forest	< 1

Refs.
(1) Sylvester-Bradley and Powlson, 1993.
(2) Vaughan, 1994.
(3) Harris and Burbridge, 1991.
(4) Unpublished ADAS Research.

Leaching losses in terms of kg N/ha/year can be converted to concentrations in the water passing down the soil profile if the annual rainfall is known. For example, in areas with 200 mm excess winter rain (e.g. the Midlands) a loss of 23 kg N/ha would give an average concentration of 50 mg/l nitrate (11.3 mg/l NO_3-N).

Cover Crops

Crop cover during winter is the main factor affecting how much of the nitrate present in soil in Autumn will be lost by leaching. An early sown and well established crop can take up a substantial amount of N (e.g. 30-50 kg/ha) during autumn and early winter (Powlson and Davies, 1993). Sometimes it is not possible to grow a commercial crop during winter and high nitrate leaching often occurs as a result. For example, in the winter prior to growing potatoes, sugar beet or other crops that are not frost hardy, or in the autumn following a crop that is harvested late, such as potatoes. One option is to grow a winter cover crop with the aim of absorbing as much nitrate as possible during the autumn before winter leaching begins. Cover crops such as rye, winter barley, mustard or stubble turnips can sometimes absorb 50-90 kg N/ha (Powlson and Davies, 1993).

Animal Manures

The risk of nitrate leaching from land which has received organic manures is considerable because they are commonly applied in amounts and at times which do not allow efficient uptake of N by crops (Pain and Smith, 1993). The main organic manures applied to agricultural land originate from housed livestock in the form of semi-liquid slurries or as more solid material containing straw, wood shavings, etc. such as farmyard manure (FYM) and poultry litter. Sewage sludge is applied to land as a means of disposal; 40% of the total is accounted for by spreading on farms (Pain and Smith, 1993). These manures are often applied to arable stubbles and grassland throughout the autumn and winter as and when convenient and soil conditions permit. By way of comparison, 500,000 t of N as animal manure, 15,000 t of N in sewage sludge and 1.5 m tonnes of N as chemical fertiliser are applied annually to agricultural land. Between 10 and 70% of the nitrogen applied in manures is in a readily available form which is at risk of leaching in the winter of application.

Nitrate losses after cattle slurry applications to grassland are relatively low but more significant losses are likely from applications to arable land. The most convenient time for applying slurries and manures is often on cereal stubble before cultivating for the next crop. This maximises the risk of leaching as work at ADAS Gleadthorpe has shown. After poultry manures had been applied in October (on bare ground), all the available nitrogen was lost by leaching. Losses from a November application were over 50%, but from a mid-December application losses were below 10% (Unwin *et al.*, 1990).

If manures are applied correctly, they should not lead to much extra leaching. However, fields which have been used for disposal of manures for many years at high rates may have annual losses in excess of 900 kg N/ha.

These experiments at Gleadthorpe also showed that losses from FYM were much smaller than from slurries or poultry manures. The nitrogen in such straw based manures is known to be released more slowly. Nevertheless, it is generally true that addition of organic material to soils eventually increases the potential for nitrate leaching.

There has been a considerable amount of work on nitrate losses associated with manure applications. For a review including experimental results see Pain and Smith (1993).

The consultation document for the revised Code of Good Agricultural Practice for the Protection of Water (1997/8) suggests that growers should draw up a Farm Waste Management Plan to help to decide when, where and at what rate to spread manure, slurry and dirty water on the farm. Restricting the time and rate of application is the simplest and most reliable way of reducing the risk of nitrate leaching from organic manures. Application rates should be adjusted so that the supply of plant nutrients does not exceed crop requirements. The CoGAP recommends a maximum application rate of 250 kg N/ha although lower limits are required in Nitrate Vulnerable Zones to keep within the limit of 170 kg N/ha set by the EU Nitrate Directive for these zones (see Section 3).

Grassland

The current maximum recommended rates for dairy systems range from 300 to 380 kg N/ha for grazed grassland from 340 to 420 kg N/ha for cut swards; 11% of intensively managed grassland in the UK receives more than 300 kg N/ha. Where grass is cut, even very high fertiliser rates are unlikely to result in substantial nitrate leaching if applications are made which closely match the crop's needs. However, once grazing animals are introduced, grassland may become a significant source of nitrate leaching and of gaseous N losses (Jarvis and Dampney, 1993). Very large proportions of the N consumed in the herbage are excreted and recycled back to pastures. Increasing the inputs of fertiliser N increases ingestion by the ruminant and the total amount of N excreted. This in turn increases the leaching losses.

Because of the extent of losses from grazed systems, the concentration of nitrate in leachate is often high, especially under long term swards; values ranging from 34 to 90 mg/l N have been measured for conventionally grazed swards (Jarvis and Dampney, 1993). The 1997/8 CoGAP revision suggests reducing the intensity of grazing, particularly in the autumn, to reduce the amount of nitrate lost.

Container grown hardy ornamental nursery stock

Only a minority of container grown nursery stock is grown under glass or polythene where water application can be (relatively) carefully controlled. The majority stands outside receiving rainfall and also irrigation in dry periods. Container HONS production in the UK has increased rapidly over the past 25 years. MAFF Census Data (Anon., 1997b) states the area in 1996 at 8,279 hectares. However, the rapid expansion of the industry during the 1980's has not been sustained into the 1990's and any increases in production have been gradual. Harris (1991) estimated that 20% of the area consists of capillary type sand beds where leaching should be substantially reduced.

The majority of container HONS is grown in peat-based growing media, with an open structure (air-filled porosity 13-15% +), and stood out on gravel beds with overhead irrigation. These factors, coupled with the use of controlled-release fertilisers (CRFs) at high rates lead to the potential for severe leaching. Furthermore, acidification of "hard" water with nitric acid is on the increase and this adds nitrogen to the applied water. Clearly, nitrogen added in this way to water which falls on the standing-out ground will add to the leaching losses.

An experiment was set up at HRI Efford in spring 1990 to measure levels of nitrate, phosphate and pesticides leaching from a typical container HONS production system by monitoring regularly the drainage water from an area of gravel beds. This was a joint project, funded by MAFF, involving HRI, ADAS and the Pesticide Analysis Group of the Central Science Laboratory (Harris and Burbridge, 1991; Harris, *et al.*, 1997).

All the leachate was collected from drained gravel beds which were lined with polythene to prevent seepage to ground water. There were four treatments:

1. Standard rate CRF and standard irrigation (designed to meet crop requirements).

2. Standard rate CRF and high irrigation (significantly above crop requirements to simulate a wet season).

3. Low rate CRF plus supplementary liquid feeds and standard irrigation.

4. Low rate CRF plus supplementary feed and high irrigation.

The standard rate of CRF was 8 kg/m^3 'Osmocote Plus' 12-14 month (15% N), the low rate was 4 kg/m^3. This is equivalent to 512 kg N/ha at the low rate and 1024 kg N/ha at the standard rate (excluding N in background water, acid and liquid feed).

Rainfall over the experimental periods (July to November inclusive) in 1990 and 1991 represented just over 60% of the long term average. Rainfall in 1992 was much higher than that experienced in 1990 or 1991, representing 177-185% of the long term average (July to November inclusive). Total leaching of nitrate was calculated from run-off and concentration data. Results for the three seasons tested are given in Table 5.2. Average losses over a season for the standard rate CRF and standard irrigation treatment on a gravel bed ranged from 68-127 kg N/ha. Average nitrate-N concentrations in the run-off for the same treatment ranged from 69 to 207 mg/l NO_3-N.

In 1990, the growing system in the trial represented the "worst-case" scenario with overhead irrigation, open-structured growing media and a drained gravel bed. In 1991, three of the beds were converted to capillary type sand beds to identify what effect this had on leaching.

Table 5.2. Nitrate N concentrations and total N losses from the Efford leaching work from container grown HONS trial (Vaughan, 1994)

	Mean values and ranges	
	NO_3-N mg/l	kg N/ha
1990		
Treatment 1	69	127
All treatments range	20-140	78-358
1991		
Treatment 1 Gravel	207	114
Treatment 3 Sand	177	101
1992		
Treatment 1 Gravel	66	68
Treatment 1 Sand	65	74
All treatments range	6.5-132	37-92

In 1992, where the standard treatment could be compared on sand and gravel beds, total N losses were slightly higher from the sand beds than from gravel, although nitrate concentrations were similar. This was despite the fact that the sand beds used 34% of the irrigation applied to the gravel systems. This was due to the fact that nutrients accumulated at the sand surface so that when rain did come they were all washed down at once. This gave high levels of point source pollution over a short period of time (Hodgkinson and Scott, 1996).

This trial does not completely reflect reality, as all the run-off was captured and recorded. Losses are, therefore, calculated per ha of bed, ignoring any pathways. Irrigation (with or without acid and feed) and rainfall falling on paths on a commercial nursery would affect overall N losses. Also, drainage of the leachate through the soil would be expected to have a mitigating effect on phosphate and some of the agrochemicals, but probably less effect on the nitrate on a free-draining sandy soil.

Container HONS growers in Holland can only use CRF products that will not cause leaching of more than 70 kg N/ha or 10 kg P/ha. Some trials commissioned by Scotts at the Boskoop Research Station (Anon., 1997c) tested percentage leaching for all their CRF products from 3-4 mth to 12-14 mth 'Osmocote Plus'. The leaching of N in the 3-4, 5-6, 8-9 month products, in various pot sizes ranged from 8 to 12%, and from 4 to 6% in the 12-14 month product. For phosphate the leaching percentage ranged from 5 to 7% in the shorter term products and 2 to 4% in the 12-14 month product (Anon., 1997c). In the Efford trials, no significant difference was found in leaching between half and standard rates of Osmocote (Hodgkinson and Scott, 1996).

In a survey of container nurseries in six US States, it was found that run-off of NO_3-N from production beds averaged at 8 ppm for nurseries using only CRFs and 20 ppm for nurseries using CRFs along with liquid fertiliser. Run-off from the nurseries using purely CRFs periodically exceeded the US 10 ppm federal drinking water standard (Yeager and Cashion, 1993). Further CRF developments will be based strongly upon leaching rates in order to meet the Dutch standards.

Edible crop production using hydroponics

This subject is described in detail in the HDC funded project, PC59, which preceded this work (Vaughan, 1994). Protected edible crop production systems vary widely with differing degrees of run-off. Vaughan highlighted work done on soil mineral N (SMN), which is a measure of nitrate plus ammonium-N. Values for SMN after rockwool cucumber crops varied from 97-712 kg N/ha in the rows to 251-1319 kg N/ha under the paths. Values under a soil crop were only 11% lower. For a rockwool tomato crop corresponding values were 230 kg N/ha (path) and 356 kg N/ha (row). Values for a soil-grown tomato crop on the same nursery were 967 and 1177 kg N/ha respectively. These figures are much higher than those found in most other agricultural and horticultural situations. Values in excess of 900 kg N/ha would only occur in exceptional cases, for example where a field had been used as a "sacrifice area" for disposal of large quantities of poultry manure or pig slurry for a number of years. Such practices contravene the Code of Good Agricultural Practice for the Protection of Water (Anon., 1991). The potential for loss of nitrate-N is extremely high if the soil is leached after a succession of rockwool or soil grown crops. For rockwool crops, much NO_3-N is lost in run-off as well as leaving high residues in the soil (Vaughan, 1994).

Vaughan (1994) carried out seven case studies of hydroponic nurseries. These show widely differing nutrient losses between different systems (e.g. NFT versus run-to-waste rockwool) and between different growers using the same systems for the same crop. Water use varied from 663 litres/m^2/year (NFT tomatoes) to 2080 litres/m^2/year (run-to-waste rockwool tomatoes).

The detailed study covered nurseries growing tomatoes, cucumbers or peppers, covering the major areas of hydroponic production in England and three growing systems (run-to-waste rockwool, recirculated rockwool and NFT). The lowest run-off from a run-to-waste system was c. 30% of the applied solution; water applications by some growers were 50-60% in excess of theoretical crop requirement. The study found that the losses from the run-to-waste systems, in the survey, ranged from 477 to 3400 kg N/ha plus 138-357 kg P/ha. It was concluded that the lack of accuracy in irrigation is a major constraint to reducing nitrate losses but that there are valid arguments for reducing recommended N levels to crops and some systems are considerably more polluting to the environment than others.

Clearly losses of nitrate-N from hydroponic systems are excessive when compared to those from arable crops or even other horticultural crops. In agricultural systems, losses take place chiefly over winter, when fertiliser is not applied. For glasshouse situations, losses may take place throughout the year. There is a risk of large losses at times when the input from other agricultural sources is small.

Assessing losses of nitrate from whole catchments

In order to estimate present and future leaching losses from whole catchments models have been developed. By using these models it is possible to estimate the amount of nitrate that will be leached in different situations, to identify the most effective and cost-effective ways of reducing nitrate leaching and to estimate the timescale for changes to be reflected in abstracted water (Lord *et al.*, 1993).

The factors which affect N losses include previous crops, soil type, manure and nitrogen inputs as well as yield. The concentration of leaching N is also affected by drainage volume. In streams, N concentrations reflect recent losses. In ground waters, concentrations at the borehole reflect losses in previous decades, since it takes many years for water to pass through the rock to the borehole (see Section 2.1).

Estimates from the models of nitrate leaching, for the 20 years up to 1993, indicate that in several NSAs nitrate concentrations leaving the soil zone have been well above the 11.3 mg/l NO_3-N Drinking Water Directive limit (Lord *et al.*, 1993). However, nitrate concentrations in the water abstracted from the boreholes in these areas, which have been monitored over the same period, are below 11.3 mg/l on average.

Data are not presented here on the losses of nitrate and other nutrients, from protected ornamental crops. However, with the use of liquid feeding into growing media the losses would be expected to be greater than in HONS but less than from rockwool.

6. COMPARISONS BETWEEN 'OPEN' AND 'CLOSED' PRODUCTION SYSTEMS

There are many considerations for a nursery when deciding on which production system to adopt. These considerations will cover economic issues relating to the cost of inputs and maintenance, plant quality issues and also environmental issues. These latter issues may not be of great importance in the mind of the grower, but any progressive nursery will consider them, as customers will apply increasing pressure on producers to be more environmentally friendly. Water, fertiliser, pesticide and plant growth regulator consumption are all greatly affected by the type of system chosen. The following section considers these issues in more depth.

Cost of setting up the system

A closed production system will be more expensive to set up than an open system. Exact figures are difficult to give as there is such a diversity of materials available. The figures given are general and designed to give an indication only of potential costs.

An open system, consisting of a polythene base, overlaid with 2.5 cm sand, overlaid with 'Mypex' with a low level irrigation, such as lay flat tubing, would total at approximately £3-4 / m^2 (W. George, pers comm.). This is based on the following estimates:

Polythene	20p/m^2
Sand	25p/m^2 if used at 2.5 cm depth
Mypex	50p/m^2
Irrigation	£1-2/m^2

There are other considerations including maintenance costs and a shorter lifespan than a closed system.

A closed system, consisting of a basic mobile benching system with inserts for ebb and flow, would cost about £40/m^2. Another £2 would have to be added on for getting the irrigation to the benches. Therefore flood benching costs approximately £42/m^2 to set up (P. Stearne, pers comm.). This figure would vary depending on the exchange rate between the Dutch guilder and the pound. Such a closed system would cost approximately £30/m^2 (£120,000/acre) based on a March 1998 rate of 3.37 guilders to the pound (The strength of the pound against German and Danish currencies should also be considered when developing such a system). This compares with the £24/m^2 required to erect an average glasshouse.

A closed system, such as this, is clearly very expensive and on the grounds of fertiliser and pesticide saving alone it would probably not be justified. However, there are a considerable number of other advantages with such a system and the increase in plant quality, which would follow, may pay for the extra investment required.

Long term economics

This is an area which is really impossible to predict. Every nursery will have its own set of crops which may be more or less suited to a closed system. It has often been shown that pot plant crops, such as Poinsettias, are produced to a higher quality in closed systems. A higher quality will, therefore, demand a higher price and may enable the cornering of an otherwise unobtainable market. A sophisticated bench system will also use the glasshouse space more efficiently and, on the whole, labour costs would be reduced.

Water quality is an area that may need to be addressed, high levels of chlorides or sulphides may require expensive treatment processes or may not suit a closed system (N. Bragg, pers comm.).

A closed system, such as ebb and flow can produce a more even, higher grade crop in a shorter time. This increased throughput will lead to an increase in value. An ebb and flow system can typically increase throughput by between 15 and 30% (H. Kitchener, pers comm.). The benching enables plants to be spaced more often, therefore, using a more economical spacing throughout the course of the year. An example would be for a unit of production worth £1, if throughput was increased by 10% it would be worth £1.10 per unit, an area of production worth £100,000 would then become worth £110,000. A real example is Begonia; this is worth about £80 - 100/m^2. An ebb and flow bench system would enable the crop to be spaced 4-5 times, therefore, increasing the density from 23 to 28/m^2. This raises the value to £106.00/m^2 and reduces labour requirements.

Labour costs are another major issue, ebb and flow production is probably one of the only major labour saving methods for the future (H. Kitchener, pers comm.). Each nursery would have to decide whether it would be economically viable to change their production system taking all these factors into consideration. For some crops e.g. primroses it would not be viable to convert to a closed system. If 55 plants could be produced per square metre that could mean a sale value of about £16.00. Profit would be about £2.00/m^2 and would, therefore, take about 15 years to pay off the capital required to convert. These are all considerations, but apart from environmental issues, the best reason to convert to closed systems is for labour savings and the ability to increase mechanisation.

Ebb and flow watering

Much research has been carried out studying the factors affecting plant growth and how closed system, ebb and flow watering affects the plant. The research has lead to the development of ideal procedures in the use of ebb and flow.

Boonstra (1988) highlights the benefits and issues faced in ebb and flow. They are as follows:

- Greater manipulation - This is obtained as every drop of water that reaches the crop is under the control of the grower and it is possible to know the amounts of fertiliser and water consumed by the crop. The fertiliser regime can easily be adjusted through the life of the crop. It is suggested by Meinken and Fischer (1989) that root damage in such systems is not caused by waterlogging and lack of oxygen, but rather by the accumulation of ammonium in the flood solution. This leads to the formation of nitrite during nitrification, it also lowers pH, therefore enabling the nitrite to have a damaging effect. Use of nitrate-N will prevent root damage, therefore, the use of a compound fertiliser, with a high ammonium content, is not recommended.

- Relative humidity control - When water is applied to the base of the plant the humidity of the air surrounding the plant can be kept lower. Humidity is high in overhead watering systems and high humidities, particularly just above root level, can encourage disease and slow down the transpiration stream. Ebb and flow exposes the crop to short bursts of water keeping the surrounding environment drier. There is less water exposed for any period of time so evaporation to the air is reduced. Monitoring of relative humidity needs to become a more widely used operation in protected ornamental production.

- Speed of supplying and removing water - When plants are in need, water can be provided very quickly, without having to wait for the watering person to reach one particular set of plants. This means that plants can always be watered exactly when required, therefore they always grow to optimum potential.

- Watering frequency - Frequency can be adjusted as required to ensure plants never get too dry or too wet. Kwast *et al.*(1989) described how long flooding times can lead to root damage from excessive nitrite or *Pythium* accumulation.

- Holes in pot base - These must be large enough to enable good contact with the growing media and to allow good drainage. Van Weel (1986) showed that if holes are too small a water seal is created under the pot which restricts oxygen to the roots. He also showed that if holes are too big the water velocity increases and can lead to the compaction of the lower layers of the growing media.

- Growing medium - Texture and pore sizes are important considerations. Boonstra (1988) suggests the media should be 90% pores of which 40-50% would be air filled pores. By the UK (ADAS) method an air filled porosity of 14 - 17% might be considered suitable for a growing medium to be used in a capillary watering system such as ebb and flow.

- Use of pesticides and plant growth regulators - Pesticides should be required less as plants are growing stronger and more resistant to many disease problems. The drier environment around the stem base and in the foliage also helps reduce disease invasion, therefore less pesticide is required. Plant growth can be regulated to some extent by the amounts and timings of watering, therefore, reducing dependence on growth regulators.

- Double decking - Ebb and flow benches enable double tiers to be grown, this is not possible where any plants grown above will normally drip.
- Container HONS - Ebb and flow systems are widely used in Holland on HONS and have been shown to greatly increase throughput and improve quality (H. Kitchener, pers comm.).
- Recirculation - All water and fertiliser that is not used by the crop can be recirculated. However, there are some fears that this can create its own problems. The risk of disease spread is highlighted by Thinggaard and Middelbre (1989), however, good hygiene and filtration should prevent problems occurring.
- The temperature of the pot and the whole climate of the glasshouse is affected by the system.

Nutrient loss comparisons

Dole *et al.*(1994) carried some extensive experimental work comparing plants produced in different systems. They found that percentage run-off was 43 and 29% greater for hand watering and microtube irrigation systems, respectively, than for ebb and flow systems. They showed that the amount of water retained by the pot and medium was similar for all systems. It may be that the optimum nutrient concentrations may vary between irrigation systems. They suggest that plants grown with ebb and flow should receive a lower fertiliser concentration than hand watered plants. Dole *et al.* (1994) compared four irrigation systems (hand watering, capillary matting, microtube and ebb and flow) at two fertiliser rates, for plant growth, nutrient leaching and water-use efficiency. The results were as follows:

- Hand watering - This produced lower quality plants and lower dry weights than the microtube and ebb and flow systems. This may be due to the contact of the hose lance with the plant which could have reduced shoot elongation. Handwatered pots retained the least amount of water of the four systems because of forceful top irrigation. It maybe that compaction of the growing media could reduce aeration and available water. This system required more water than the ebb and flow.
- Microtube - This system produced the highest total dry weights but more run-off and water use than the ebb and flow. More irrigations were required than were used in the hand watering.

- Capillary matting - This system produced plants with the lowest total dry weights and lowest quality. The electrical conductivity (EC) in the media and run-off water was highest for this system, it also had the biggest water requirement. Evaporation from the mats also increased water loss, this evaporation reduced as the canopy increased in size. This system may prove to be more efficient in areas with lower light levels, lower temperatures and higher humidity. Water retention was less than for the ebb and flow because drainage would have been greater with more drainage columns produced in the media.

- Ebb and flow - This had the least water use and run-off, the most efficient system. Plants fed at the lower fertiliser rate (i.e. 175 mg N/l as opposed to 250 mg/l) had higher dry weights than those at the higher rates.

On the whole, microtube and hand watering produced run-off with a lower concentration of nitrates than ebb and flow, but they also produced much more of it.

Experiments have also been carried out comparing nutrient losses from plants fed with liquid fertiliser and plants fed with controlled release fertiliser (CRFs). Yeager and Cashion (1993) surveyed container nurseries in six US States; they found that NO_3-N in run-off from production beds, averaged at 8 ppm for nurseries using only CRFs and 20 ppm for nurseries using CRFs and liquid feed.

Hershey and Paul (1982) compared leaching losses of N from pot chrysanthemums with CRFs or liquid fertiliser, over an 11 week cycle. The leaching fraction (volume of solution leached ÷ total solution applied) averaged 27% in both treatments. Higher rates increased the leaching, most of the losses from the CRFs were during the first half of the cycle, whereas the liquid feed had leaching throughout. 15-20% of the N released from CRFs was leached, the N leached from the CRFs was half that leached from the liquid feed at the same N rate.

McAvoy (1992) analysed the effect of leachate fraction on nitrate loading, to the soil profile underlying a greenhouse crop. They found up to 2000 kg N/ha in the top metre of greenhouse soil. Two leaching fractions were analysed: 10 and 50%. Two factors seemed to affect the nitrate accumulation and movement in the profile:

1. At low leaching fractions, hydraulic loading is limited and nitrate does not move as far down through the profile, as it does at higher levels.
2. Low leaching fractions produced lower total nitrate loads reaching the soil despite the fact that lower leaching fractions need a higher nitrate concentration.

They concluded that reducing leaching fractions by altering irrigation management will reduce the movement of NO_3-N through the profile. Reducing irrigation will increase the accumulation of nitrates in the upper soil levels. A careful adjustment of irrigation practice (i.e. little and often) produces less leaching without a deterioration in plant quality.

Conclusion

Clearly losses of nutrients and water are far greater from open systems than from closed systems. The work which has been described, however, shows that there is considerable scope for reducing nutrient and other chemical losses from open systems. How this can be done will be discussed further in Section 8.

7. UK SITUATION COMPARED WITH HOLLAND AND GERMANY

Holland

This section updates Chapter 7 of HDC project PC59 where the UK situation was compared with Holland. As is widely known, the agricultural and horticultural sectors, are very significant aspects of the Dutch economy, making up 12.5% of the national income in 1988. The Dutch glasshouse industry is four times the area of ours, in an area one quarter the size of England and Wales. In addition, the glass is concentrated in only a few areas. In terms of area, the Westland and De Kring represent around 1% of the Netherlands, but in these districts alone growers use one sixth of the total quantity of crop protection chemicals applied (van Oosterhout, 1991).

An environmental action plan was developed by The Netherlands with a target set for the year 2000. This target stated that glasshouse horticulture must have achieved a totally, or almost totally, closed operating system with no emissions. Anything that is allowed to escape into the environment must meet strict standards.

These controls are mainly governed by the following two acts of legislation:

- Surface Water Pollution Act
- Soil Protection Act

Surface water is covered by different legislation to ground water. Under the surface water pollution act, bodies known as 'Local water authorities' have been set up. These authorities have legal powers to dictate and enforce pollution control measures. The impact of these authorities is mainly felt in the western parts of The Netherlands; this is because the water table in the east is lower and, therefore, not covered by this act.

The latest timetable for change was formulated in 1996.

- By 1 January 1996, all growers were forced to specify their system of production and the crops they were producing.
- By November 1996, growers producing crops on substrates had to recirculate all run-off. Any new enterprise must have a recirculation system.
- By January 1997, all soil grown crops must have precipitation collecting facilities.
- By January 1998, it was forbidden for growers of soil grown crops to discharge waste into water courses. The local authorities also have powers to introduce new rules.

- By January 2000, all water waste must go into the mains sewage system and not into ditches.

The local water authorities are responsible for setting the standards and ensuring all growers meet them. The system took some time to get established but now is up and running effectively. The local authorities regularly impose fines on growers that fail to reach the required standards.

Local Water Authorities

Ensuring the targets, set out above, are actually reached is a difficult task to be implemented in practice. The following procedures have been dictated by the authorities:

1. Every grower must register, monthly, the volume of water coming in to his nursery (and therefore on the crop) and the amount which is not used by the crop. In closed systems this would be the amount recirculated and in open systems it would be the amount reaching the soil, drains or ditches.

2. Fertiliser use must be registered to calculate nutrient uptake by the plants. This is done by having total plant analysis in laboratories on a quarterly basis. The requirements for collecting this detailed information began in 1997; the data will be evaluated in 1999. The results should give a very accurate impression of pollution from the whole industry in The Netherlands.

3. Water quality. Growers are obliged to build water stores to store all roof run-off. The minimum amount which must be stored is 500m^3/ha/yr. This amount was calculated using precipitation figures for the last 100 years.

Holland has no shortage of water, but as far as horticulture is concerned it has a shortage of useable water. The water from ditches, canals and mains water has levels of salt which are too high. The levels would not be too high for a one off watering but in a closed, recirculating system, the levels will soon build up to levels which will reduce plant growth. Plants do not take up sufficient chloride, so this simply gets passed back around the system.

Rainwater is low in salts, therefore, this is the only viable water source for use in recirculation systems. However, even in the purest systems, sodium will build up and growers will want to be able to drain their recirculation systems when the levels of salts gets too high. Each crop has a set level of salts which it can tolerate e.g. for tomatoes it is 8 mmol/litre. The government sets levels for each crop and when levels exceed that stated then growers have permission to discharge the solution. The figures for each crop are aggressively negotiated by growers, researchers and the local water authorities.

Water use is another area which is being challenged. The government aims to reduce water use in order to reduce leaching. Typical targets for cut flowers are:

- 10,000 m^3/ha/yr by 1995
- 9,200 m^3/ha/yr by 1996
- 8,600 m^3/ha/yr by 1997.

4. If a grower can save as much as 150kg of N/ha/year then the local authorities will consider a change, to a closed system, worthwhile. This figure is still being negotiated. Growers want it to be increased and the authorities want it lowered. The final figure may well be a compromise of about 125kg of N/ha/year. If that figure is accepted then soil growers using the 'Fertigation' methods, being researched at PBG Naaldwijk, will be able to continue growing in soil without having to change to substrates on a closed system. At 1998 prices, the investments that cut flower growers would have to make to change to closed production, would not be earned back. Therefore, if many cut flower growers are to continue in business they must be permitted to grow in the soil.

It seems that the authorities are eventually facing up to some of these commercial realities. Research at PBG Naaldwijk (J. Kipp, pers comm.) is seeking to help the case put forward by the soil growers. They have demonstrated that many glasshouse crops would not be viable on substrates; therefore, research now aims to minimise fertiliser inputs, only applying exactly what the plants needs, when they need it. Research on chrysanthemums uses a fertigation model based on plant transpiration and nutrient uptake. The system has produced very accurate fertiliser use. One area identified as being very significant in relation to leaching is the eveness of watering. If water can be applied at an even rate across the crop then leaching can be reduced by 50%.

Soil has been considered increasingly as a media which cannot be sufficiently manipulated, however the 'Fertigation' research shows that this is not necessarily the case.

5. Pesticides. Growers must record the amounts bought into the nursery and the amounts used. This will be rigorously checked by inspectors from the local authorities at least annually.

The Multi Year Crop Protection Plan (MYCPP) was described in project PC59. This has targets for reducing the use of all pesticides. This is considered to be progressing well. Not all targets are being reached but the industry is clearly moving in the right direction. There is a considerable increase in the use of biological control. Extensive work is being carried out at the Research Station for Nursery Stock in Boskoop on disease control in recirculation systems (A. van den Boom, pers comm.).

The view of researchers in Holland is that the research into nutrient usage will be applied to pesticides. This will be an important aspect of future production as pressure from retailers, for 'green' products, increases (J. Kipp, pers comm.).

Germany

Information on the German situation has been supplied by Dr. Volker Behrens of the Geisenheim Research Station.

Whether or not a grower has to react to government legislation on water conservation depends on where the nursery is situated. If the nursery is situated in a water conservation area then it will have to convert to some form of closed irrigation system. Any surplus or run-off water will have to be collected, stored and recycled. The monitoring of this is not as stringent as in Holland and local authorities will usually only get involved when contaminated water has been found or if new glasshouses or container areas are being constructed.

Water conservation areas cover a large proportion of Germany and are increasing in number. Even outside these areas groundwater contamination is not permitted although regulation of this is not as strict as it is within the conservation areas. Public opinion in Germany is very opposed to any form of pollution; anyone considered to be breaching pollution laws will be reported.

Growers of containerised nursery stock have managed to convince the government that there is more or less no leaching of fertilisers because of the use of coated slow-release fertilisers. Groundwater pollution is prevented by the use of semi-closed irrigation systems. A lot of run-off is produced due to the use of intensive overhead irrigation, this increases leaching but also successfully dilutes the concentrations of fertiliser salts in the run-off water. A contaminant pond is used to store this water where it is permanently diluted with as much rain water as possible. When water samples are taken and analysed the result always shows a very dilute concentration of chemicals. Heavy rainfall causes these stores to flood and eventually reach watercourses.

Nurseries using a water saving irrigation system, e.g. drip or capillary, are increasing in number but are still very much in the minority.

Glasshouse growers try to convince their local authorities that the hot conditions in a glasshouse mean more water evaporates than is applied in irrigation, therefore, avoiding groundwater contamination. This may be a somewhat dubious claim; time may well be limited for growers who try to 'get away with' groundwater pollution.

As can be seen by these descriptions of the situations in Holland and Germany, these countries are far in advance of the UK when it comes to horticultural pollution control. UK growers would do well to get familiar with closed production systems so we can be ahead of the game when similar environmental controls reach here.

8. MINIMISING RUN-OFF AND TREATMENT ALTERNATIVES

For many nurseries it will be uneconomical to convert to an entirely closed production system. However, this does not mean that run-off or water usage can be ignored. There are many ways, even in open production systems, whereby water can be conserved and run-off reduced. The following section considers the options for water management (Biernbaum, 1992):

- Irrigation scheduling - The timing and duration of irrigation must be reconsidered and water application should be based on more than just a programme set to the clock. A programme for watering is easy to manage and entails little risk and room for mistake, but such a technique can involve applying water that the crop does not need. Accurate scheduling for irrigation should consider environmental conditions, for example reducing water input on dull, humid days; it should also consider plant requirements. Growers could allow plants to dry to a predetermined target weight and watering only when this weight is reached, however in practice this may be difficult to achieve with different cultivar demands, environmental conditions and product specification. The duration of water application is also important, the approach of watering 'little and often' wastes far less water than occasional heavy waterings. However, for other reasons this may not be the best approach for protected ornamentals. For example, if a small volume of water is applied to the base of a pot this will cause the media to dry out further up the pot and conductivity will also increase. If watering from the top, the amount of root lower in the pot could be reduced, due to the lack of moisture reaching the base. This highlights the many factors which would need to be considered when adjusting watering regimes.

- Media selection - Typically crops are grown using open, fast draining growing media which can cope with large applications of water and leaching. However, this is an extremely wasteful management of resources. From the point of view of conserving the water that is applied, media with a higher water holding capacity should be used. Bragg (1997) suggests that Poinsettias grow best with a more open structured substrate and that particles less than 1mm should be screened out of the media. However, it may be that a compromise is needed. Wetting agents can be added to the compost to improve water retention or media with lower air-filled porosity can be used. This will require more skill in watering and care must be taken to avoid overwatering, but extra water saving is possible even in the most open systems. Most proprietary growing media mixes should already have wetting agents incorporated, however, these may not last the lifetime of the crop (N. Bragg, pers comm.).

- Fertiliser application - Run-off of fertilisers can be reduced by fertilising only when the plants require the nutrients. This involves the use of regular applications, controlled leaching and monitoring of nutritional status. Ideally, this would include a weekly analysis of the growing medium. This regular analysis would ensure that fertiliser would not be added when not required and would only be used to meet demand. This would be ideal but may not be financially viable, hence monthly sampling of the growing medium, coupled with the use of conductivity meters on the nursery, may be more practical.

- Irrigation system - This needs to provide uniform pressure and uniform water flow at all locations to prevent some areas receiving more water than others. Irrigation can be pulsed (i.e. 2 one minute applications rather than 1 three minute application), this gives the crop a chance to make use of the water it is given.

- Controlled Release Fertilisers (CRFs) - These are widely used in the HONS sector but less under protection where crops require more precise manipulation. They release nutrients much more slowly, and therefore, leaching is reduced. However, for some crops, it should be possible for liquid fertiliser to be applied only to the amounts required and have the benefits of CRFs without the disadvantages, such as the inability to manipulate nutrient levels. The main disadvantage of liquid feeding compared with CRFs is the reduced 'shelf-life' of the final plant and the greater expertise needed in managing the plant nutrition.

- System type - As was discussed in Section 6, water can be conserved by using a closed system such as ebb and flow.

- Costs - One of the main reasons why many of these methods are not used is that they may not be financially viable in all situations. Fertiliser and water costs make up a relatively small proportion of production costs. However this may change in the future. Water costs are increasing annually and fertiliser prices may also increase as environmental legislation plays an increasing role in crop production. Costings have been considered in more depth in Section 6.

Collecting and Recycling run-off

The systems used for this approach are many and varied, they range from sophisticated ebb and flow systems to basic drainage systems. In the basic systems, water is drained through field drains to a water holding area from where it can be pumped back into the system. Clearly not quite all water will be collected.

Another issue in recycling is the control of pathogens, particularly *Pythium* and *Phytophthora*. From this point of view, systems not based on hydroponic principles are better, as potentially pathogen carrying water is not passed from plant to plant. Pathogens are best controlled by keeping the temperature low during storage and maintaining good aeration. Slow sand filters can be used to filter out many pathogens, research on this is still in progress. It is also good to keep the volume of stored water at a minimum, this ensures a quick turnover and reduces time for pathogens to establish. Considerable work is being carried out in Holland on preventing the spread of disease through these systems. The key to success is good nursery hygiene thereby removing the possibilities for contamination.

There are also options for treatment of recirculated water using chlorine, heat, ozonation, UV irradiation and ultrafiltration (Biernbaum, 1992).

The Future

Pressure will increase to reduce the unnecessary usage of fertilisers and water. The future will certainly require research into defining, more precisely plant water and fertiliser requirements, so fertiliser can be applied to meet exact needs.

There may also be a need for research into methods for controlling evaporation. Evaporation is not such a problem where high leaching is used in production but in low leaching systems it can encourage salt build up.

There is potential for reducing water and fertiliser inputs into some crops and pressure to do so will increase, particularly from the multiple retailers who will impose their environmental policies on their suppliers.

9. DISCUSSION

The present situation with run-off from protected ornamentals

One aspect which will have become clear through this project is the variability in results from previous experiments, on levels of run-off, from different production systems. Table 5.1 shown in the chapter on Nitrate Loss Comparisons, highlights this. This variability is a finding in itself. It demonstrates that different production methods and systems produce considerably different levels of run-off.

Section 4 described the results of the questionnaire; these showed that most growers of protected ornamentals are still using mostly overhead irrigation systems, although some use some degree of capillary watering as well. Overhead irrigation causes the highest level of leaching from growing media and leads to higher run-off rates than capillary irrigation which does not wash nutrients through the media. However, as described in Section 6, capillary irrigation can cause a build up of salts and, therefore, conductivity at the higher parts of the pot which can reduce root growth in these regions with possible phytotoxic effects. Ebb and flow benching was described as one of the best options for irrigation under protection. Apart from the high initial investment, there are few drawbacks with ebb and flow production. It produces a higher quality crop and a greater nursery throughput with the ability to mechanise reducing labour costs.

The questionnaire also highlighted the fact that most growers use a fairly open textured media. This increasing trend can give greater manipulation of the growing crop but also enables added fertilisers to leach through very easily. With liquid feed representing a relatively low proportion of production costs this wasteful use is not considered a problem. It is unlikely that the cost of the feed will ever become significant enough to adjust growing practices but other factors, including legislation and customer pressure, may bring about the adjustment.

The Pressures for Change

Environmental Impact

A grower that is aware of the environmental damage caused by waste fertilisers and pesticides will be able to address the risks of such wastage on their own particular nursery. The implications of polluted run-off were discussed in Section 2.

The level of pollution that occurs from nutrient rich run-off is dependent upon a number of variables. These include soil type, rainfall levels and proximity to water including ground and surface water. Growers should take these factors into consideration when designing any new production systems.

Nitrate and phosphorus in the water can promote eutrophication where algae proliferates and uses the oxygen in the water. This upsets the ecological balance of the water and leads to the death of oxygen demanding fish and other organisms. The questionnaire showed that many nurseries allow run-off into a ditch or drain which eventually leads to a water course. Growers need to be sure that the solution flowing down to the water course does not exceed the EU limit of 50 mg/l of NO_3.

Pesticide damage can be even more severe if it reaches the environment. The use of biological control agents, in many protected cropping situations, has reduced the use of many harmful pesticides. Section 2.2 contained a section on pesticide usage under protection. This showed that the ten most widely used chemicals did not appear on the pesticide analysis of UK waters carried out in the 1991 survey. Therefore, on a national level, the protected ornamentals industry is not significantly contributing to pesticide pollution. However, growers need to be aware of the risks of pollution from this source, the penalties for which can be very severe, as discussed in Section 3.

Legislation

As described in Section 3, legislation is gradually being put together in order to enable the UK to conform to the demands of EU legislation particularly the Drinking Water and Nitrate Directives. At present, a nursery could be prosecuted if it could be demonstrated that surface waters were being polluted by nursery run-off which exceeded the EU levels. Up until now, these aspects of legislation have probably not had much effect on ornamental producers. But this situation, whereby nurseries are almost overlooked as being potential polluters, is about to change.

The proposed new Groundwater Regulations, due to be brought into force in April 1999, will require much stricter regulation of discharge waters from all holdings. Discharge of solution containing any of the substances listed in the regulations (includes ammonia, nitrites and phosphorus) will require authorisation following an inspection by the Environment Agency. This will probably mean that growers collecting run-off or allowing it to drain to a ditch will require authorisation to allow that solution to go into the ground. A specific code of practice will also be drawn up for situations where run-off drains directly into the ground. Growers will have to conform to this, either by getting the necessary authorisation, at their own expense, or ensuring that their run-off does not contain the listed substances. This may well require a change in production practices for many nurseries to ensure high levels of fertiliser are not found in run-off water.

Growers should also be aware of the revised Code of Good Agricultural Practice for the Protection of Water, due to be released in October 1998. As described in Section 3, this lists areas where growers will have to adjust production methods to ensure they conform to the code.

The Nitrate Directive has seen the setting up of Nitrate Vulnerable Zones across the UK. These are areas which have been identified as being particularly vulnerable. The Nitrate Sensitive Areas scheme was set up for landowners to voluntarily reduce nitrate inputs onto agricultural land. They do this in return for an acreage based payment. The scheme, which has now been closed, was generally not viable for protected horticultural producers as the incentives were not high enough to change production on this more valuable land. However, within these areas and within the NVZs the regulation of discharges will probably have even tighter enforcement in the Government's drive to reduce nitrate pollution.

Other Pressures

The unavoidable reality is that production methods and systems will have to change eventually as environmental pressures increase. This discussion has already considered the pressures from legislation. It is legislation that has forced the changes in The Netherlands with imposed limits and deadlines, as described in Section 7. However, perhaps even more significantly the pressures may come from the customers.

As multiple retailers increasingly develop their environmental policies, their interest in nursery run-off and its effect on the environment will also increase. If UK suppliers are unable to produce plants without producing run-off to the environment, then they may look abroad to suppliers that can. If this happens then countries such as The Netherlands, Denmark and Germany will be ahead of the game and the UK will be less able to compete.

The forward thinking producer will be looking seriously at their production methods and considering closed systems. Other factors should also influence these decisions to change including the increased throughput and ability to mechanise, as described above.

Options for the Future

The first option is to continue as we are. Many will choose this option and wait until legislation forces change. For some this may be the best and most viable approach. They will continue to leach fertiliser, until economics says that a change is necessary. However, the fear is, that by the time this change is imposed, it may be too late to adapt and competitors, which have developed new production methods, will have taken the market. The second option is to be ahead of the game by facing the challenge of reducing nutrient and pesticide leaching to the environment. This can be done by:

- Reducing run-off by methods outlined in Section 8.
- Changing the production system to a more closed, recirculating system.
- Carrying out more research on economics and environmental impact of different systems and methods used for protected ornamental production.

Looking into the future, the second option is clearly the best. If the UK protected ornamental industry wants to stay at the top it must seriously consider new methods of production.

10. RECOMMENDATIONS

Growers of protected ornamental crops should be made aware of the issue of the environmental impact of run-off, in particular:

1. The fact that run-off from their nurseries may be contributing to an increase in N and P levels in local surface and ground waters.

2. Causing levels of N, P or pesticides, in local 'controlled waters', to rise above the stated levels can incur a significant fine of up to £20,000 in a Magistrates Court.

3. The approaching new Groundwater regulations are due to be enforced from 1 April 1999. These concern discharges of listed substances both directly and indirectly into ground waters. Authorisation will be required for future disposal of listed substances, contact should be made with local Environment Agency offices.

4. The new Code of Good Agricultural Practice for Water is due to be launched in October 1998. This will contain new sections relating to intensive horticulture.

5. Growers should assess the future market requirements and leanings towards environmental awareness when planning future production systems. Large customers may well require run-off minimisation to be incorporated into an environmental policy.

6. Growers should consider closed production systems, such as ebb and flow benching, when planning future production, particularly for higher value pot plant crops.

7. R&D is required comparing the economics of closed ebb and flow production with open systems.

8. Further R&D is required on protected ornamentals comparing methods of run-off minimisation including use of different irrigation regimes and type of growing media.

9. The UK industry must be kept updated on planned changes in legislation and the possible implications of European Directives.

10. It is important that the UK industry keeps up with developments in Europe, particularly Holland where legislation has forced growers to change production systems. Visits and reports on visits should be regularly made to monitor developments, and should be made available to the industry.

11. The survey has shown how difficult it is to get information in this way. It is recommended that future survey work on this subject would involve visits to nurseries with interviews to extract the required information.

12. Some work was done, during the production of this report, which indicated the need for further detailed analysis of water use and run-off in different production systems. It is recommended that a more detailed research project is carried out to enable a more accurate assessment of the UK situation and to enable the development of appropriate methods to reduce run-off and prevent wastage and environmental contamination.

13. Visits should be made to nurseries in subsequent years to monitor how the information, produced in this and future reports, has been used on nurseries. This should be used to review work done to see whether targets have been met and it should also direct future work.

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12. REFERENCES

Addiscott, T. M., Whitmore, A. P., Powlson, D. S., 1991. *Farming, fertilisers and the nitrate problem*. CAB International, Wallingford, 170 pp.

Anon., 1981. *The health effects of nitrate, nitrite and N-nitroso compounds*. US National Research Council, National Academy Press, Washington.

Anon., 1985. Report on the Thanet nitrate investigation. *Southern Water Authority Report IV*, 112 pp.

Anon., 1990. *Pesticides, chemicals and health*. British Medical Association, 178 pp.

Anon., 1991. *Code of Good Agricultural Practice for the Protection of Water*. MAFF, London, 80 pp.

Anon., 1992a. *The influence of agriculture on the quality of natural waters in England and Wales*. Water Quality series No 6, National Rivers Authority, Bristol, 154 pp.

Anon., 1992b. *Code of Good Agricultural Practice for the Protection of Air*. MAFF, London, 74 pp.

Anon., 1993a. *Digest of environmental protection and water statistics*. No 15, Department of the Environment, 1992 HMSO, London, 149 pp.

Anon., 1993b. *Code of Good Agricultural Practice for the Protection of Soil*. MAFF, London, 55 pp.

Anon., 1996. *Drinking Water 1995*. Department of the Environment, HMSO, London, 221 pp.

Anon., 1997a. *Annual Report and Accounts 1996-1997*. Environment Agency, Rio House, Waterside Drive, Bristol, UK.

Anon., 1997b. *Basic Horticultural Statistics for the UK 1986-1996*. MAFF, London.

Anon., 1997c. *Leaching of controlled release fertilisers*. Scotts Company, Boskoop trials, 1997.

Anon., 1998. *Code of Practice for the safe use of Pesticides on Farms and Holdings -Green Code*. MAFF, London, 111 pp.

Archer, J., Thompson, 1993. Background to the nitrate problem in the UK. in *Solving the nitrate problem*. MAFF, London, 37 pp.

Biernbaum, J. A., 1992. Root zone management of greenhouse container grown crops to control water and fertiliser use. *Hort Technology* **2**: 1.

Boonstra, J. J., 1988. Pot plants on concrete floors with ebb and flow watering. *Vakblad voor de Bloemisterij* **25**: 28-29.

Bragg, N., 1997. Attention to Detail. *Nurseryman and Garden Centre* **22**, 186: 11.

Dole, J. M., Cole, J. C., von Broembsen, S. L., 1994. Growth of Poinsettias, Nutrient leaching, and water use efficiency respond to irrigation methods. *HortScience* **29**: 858-864.

Flury, M., Papritz, A., 1993. Bromide in the natural environment: occurrence and toxicity. *Journal of Environmental Quality* **22**: 747-758.

Foster, D. M., Rachwal, A. J., White, S. L., 1991. *Journal of the Chartered Institution of Water and Environmental Management*. **5**: 466.

Fussell, M., Hand, D. J., 1994. Tomatoes: the influence of reduced nitrate input on yield and fruit quality 1992/93. *HDC Report No PC 55a (Year One)*, East Malling, Kent.

Harris, G. L., Hodgkinson, R. A., Scott, M., Mason, D. J., Pepper, T. J., 1997. Impact of hardy ornamental nursery stock systems on the environment. *Agricultural Water Management* 34: 95-110

Harris, G. L., 1991. *Nitrate-N leaching from HONS containers and glasshouse horticultural systems*. Report to MAFF, 9 pp.

Harris, G. L., Burbridge, B., 1991. *The Efford Leaching Experiment 1990: measurement of pesticides, nitrate and phosphate leached from beds of container grown hardy nursery stock*. Report to MAFF, June 1991, 118 pp.

Hershey, D. R., Paul, J. L., 1982. Leaching losses of N from pot chrysanthemum with controlled release or liquid fertiliser. *Scientia Horticulturae* **17**: 145-152.

Hirayama, T., 1982. Does daily intake of green-yellow vegetables reduce the risk of cancer in man? An example of the application of epidemiological methods to the identification of individuals at low risk. in *Host factors in human carcinogenesis*, Armstrong, B., Bartsch, H., (Eds), IARC Scientific Publication No 39, Lyon.

Hodgkinson, R., Scott, M., 1996. Run-off, the full picture. *Grower* **126**, 10: 22-23.

Hydes, O. D., Hill, C. Y., Marsden, P. K., Waite, W. M., 1992. *Nitrate, pesticides and lead 1989 and 1990*. Drinking Water Inspectorate, London, 80 pp.

Jarvis, S., Dampney, P. M. R., 1993. Progress in grassland nitrogen management. in *Solving the nitrate problem*, MAFF, London, 37 pp.

Jenkins, J., Smith, T. M., 1992. Pesticide Persistence and movement in soil - Important elements in groundwater protection. *Pot plant Growers Association News (USA)*, March 1992, 4-5.

Jenkinson, D. S., 1990. An introduction to the global nitrogen cycle. *Soil use and Management* **6**: 56-61.

Kwast, A., Luck, H. J., Grantzau, E., Scharpf, H. C., 1989. Watering duration and nitrite. *Gb + Gw* **15**: 710-713.

Lord, E., Addiscott, T. M., Scolefield, D., 1993. Assessing catchment nitrate losses. in *Solving the nitrate problem*, MAFF, London, 37 pp.

McAvoy, R. J., 1992. Effect of Leachate fraction on nitrate loading to the soil profile underlying a greenhouse crop. *Journal of Environmental Horticulture* **10**: 167-171.

Meinken, E., Fischer, P., 1989. Nitrogen in the form of nitrate prevents root damage on flood benches. *Gb + Gw* **37**: 1784-1788.

Muscutt, A. D., Bailey, S. W., Davies, D. B., 1991. The effect of buffer strips on the run-off of pollutants from agricultural land. *Interim ADAS review report to MAFF*, 29 pp.

Muscutt, A. D., Harris, G. L., Bailey, S. W., Davies, D. B., 1993. Buffer zones to improve water quality: a review of there potential use in UK agriculture. *Agricultural Water Management* **45**: 59-77.

Onstand, C. A., Blake, J., 1980. Thames basin nitrate and agricultural relations. in *Proceedings of the symposium on watershed management*, Boise, Idaho, 961-973.

van Oosterhout, G., 1991. Westlands water moet veel schone. *Groenten en Fruit / Algemeen* No 38, 20 September 1991, 22-24.

Pain, B., Smith, K. A., 1993. Organic manures and nitrate leaching. in *Solving the nitrate problem*, MAFF, London, 37 pp.

Powlson, D., Davies, D. B., 1993. Autumn and winter land management. in *Solving the nitrate problem*, MAFF, London, 37 pp.

Roughan, J. A., 1980. A review of the use of methyl bromide in horticulture. in *MAFF/ADAS Agricultural Science Service Research and Development Report - Pesticide Science 1980 - Reference book 252*, (80), 46-53.

Sylvester-Bradley, R., Powlson, D., 1993. Fertiliser nitrogen for arable crops. in *Solving the nitrate problem*, MAFF, London, 37 pp.

Thinggaard, K., Middelbre, A. L., 1989. Phytophthora and Pythium in pot plant cultures grown on an ebb and flow bench with recircultaing nutrient solution. *Journal of Phytopathology* **125**: 343-352.

Thomas, M. R., Davies, R. P., Gartwaite, D. G., 1992. *Pesticide Usage Survey report 102 - Protected Crops (Edible and Ornamental) 1991.*

Tomlin, C., 1994. *The Pesticides Manual: a world compendium (10th edition).* British Crop Protection Council / The Royal Society of Chemistry, UK.

Unwin, R.J., Shepherd, M. A., Smith, A., 1990. Controls on manure and sludge applications to limit nitrate leaching: does the evidence justify the restrictions which are being proposed?. *Proceedings EC Conference, Athens*, Sept 1990, 261-270, CEC.

Vaughan, J., 1994. Environmental impact of waste solutions from hydroponic systems for the production of edible crops. *HDC PC 59, Final Report*, HDC, East Malling, Kent.

van Weel, P. A., 1986. Ebb and flow: new system makes watering and feeding completely automatable. *Deutscher Gartenbau* **20:** 942-947.

Yeager, T., Cashion, G., 1993. Controlled release fertilisers affect nitrate-N run-off from container plants. *HortTechnology* **3:** 174-177.

Young, C. P., 1986. Nitrate in groundwater and the effects of ploughing on release of nitrate. in *Effects of land use on fresh waters*, Ed Solbe, Ellis Horwood, Chichester, 221-237.

Zepp, R. G., 1991. Phytochemical fate of agrochemicals in natural waters. in *Pesticide Chemistry: advances in international research development and legislation: Proceedings of the 7th international congress of pesticides chemistry (IUPAC)*, Frehse, H. (ed) Weinheim, Germany, 329-345.

APPENDIX

Questionnaire

Questionnaire

Environmental Impact of Run-off from Protected Ornamental Crops

Background details

1

Title: Initials: Surname:

Address:

County: Postcode: Tel. No:

ADAS Consultant (if applicable) ☐

Area of glasshouse and/or plastic structures used for protected ornamentals. ☐ Acres

Cropping details

For questions 2, 3 and 4 please give details of crops grown under glass or polythene structures only.

2 **Cut flowers**

	Type	Soil grown	Peat troughs	Rockwool	Pumice	Cropped area (acres) or (m^2)		No. of weeks
Alstromeria	☐ 1	☐ 1	☐ 2	☐ 3	☐ 4	☐	☐	☐
Chrysanthemum	☐ 1	☐ 1	☐ 2	☐ 3	☐ 4	☐	☐	☐
Freesia	☐ 1	☐ 1	☐ 2	☐ 3	☐ 4	☐	☐	☐
Carnations/pinks	☐ 1	☐ 1	☐ 2	☐ 3	☐ 4	☐	☐	☐
Stocks	☐ 1	☐ 1	☐ 2	☐ 3	☐ 4	☐	☐	☐
Specify other	☐	☐ 1	☐ 2	☐ 3	☐ 4	☐	☐	☐

Please give the size of irrigated area not used for cropping (eg. paths) ☐ ☐

3 **Pot plants**

Please give details for your **3 most important** crops in terms of crop area/year.

	Type	Pot size (diameter)	No. of pots per m^2 in cropped area	Cropped area (acres) or (m^2)		No. of weeks
Begonia	☐ 1	cm	☐	☐	☐	☐
Cyclamen	☐ 1	cm	☐	☐	☐	☐
Foliage	☐ 1	cm	☐	☐	☐	☐
Chrysanthemum	☐ 1	cm	☐	☐	☐	☐
Poinsettia	☐ 1	cm	☐	☐	☐	☐
Primrose	☐ 1	cm	☐	☐	☐	☐
Specify other	☐	cm	☐	☐	☐	☐

Please give the size of irrigated area not used for cropping (eg. paths) ☐ ☐

✓

4 **Bedding plants**

	Type	Size (cm)	Cropped area (acres) or (m^2)		No. of weeks
Pots	☐ 1	9			
Pots (other than 9cm)	☐ 1				
Strip bedding and boxes	☐ 1				
Baskets	☐ 1				
Specify other	☐				

Please give the size of irrigated area not used for cropping (eg. paths) ☐☐

Base dressings

Soil grown cut flowers only

5 What base dressings do you use?

	Type	Analysis N	Analysis P_2O_5	Analysis K_2O	Rate (g/m^2) or ($oz/yard^2$)	
Compound fertiliser (eg. Palmers)	☐ 1					
Ammonium Nitrate	☐ 1					
Triple superphosphate	☐ 1					
Potassium sulphate	☐ 1					
Specify other	☐					

Compost details

Cut flowers in peat troughs, Pot plants and Bedding plants only

6 What grade of compost do you use and where?

	Type	Peat troughs	Pots	Boxes	Baskets	Other container *(please specify)*
Coarse (free draining)	☐ 1	☐ 1	☐ 2	☐ 3	☐ 4	
Medium	☐ 1	☐ 1	☐ 2	☐ 3	☐ 4	
Fine (moisture retentive)	☐ 1	☐ 1	☐ 2	☐ 3	☐ 4	

Fertiliser details

Cut flowers in peat troughs, Pot plants and Bedding plants only

7 Do you use Controlled-Release Fertiliser? Yes ☐ 1 No ☐ 2

8 If **yes**, what fertiliser do you use?

	Type	Peat troughs	Pots	Boxes	Baskets	Other *(please specify)*	Formula *eg. 18.10.10*	Release rate (if known) *eg. 8-9 months*	Rate (kg/m^3)
Ficote	☐ 1	☐ 1	☐ 2	☐ 3	☐ 4				
Osmocote	☐ 2	☐ 1	☐ 2	☐ 3	☐ 4				
Specify other	☐	☐ 1	☐ 2	☐ 3	☐ 4				

Liquid feed details

9 Do you use liquid feed? Yes ☐ 1 No ☐ 2

☑ 99

10 If **yes**, what liquid feed do you use?

	Type	Soil	Peat troughs	Pots	Boxes	Baskets	Other container *(please specify)*	Analysis N	Analysis P_2O_5	Analysis K_2O
Peters	☐ 1	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5				
Sangral	☐ 1	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5				
Solufeed	☐ 1	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5				
Specify other	☐	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5				

11 Do you apply liquid feed with every watering? Yes ☐ 1 No ☐ 2

If no, how many times a week on average do you apply it? ____ /week

Sampling

12 How often do you sample your soil compost, plants and liquid feeds?

	Before Planting	Daily	Weekly	Monthly	Never
Soil	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Compost	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Plants	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Liquid feeds	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

Waste

13 How do you dispose of your plant & compost waste?

Skip ☐ 1

Composted ☐ 2

Specify other ☐

Water treatment

Please give the following details about your water supply.

14

	Type	Not treated	Treated by Acid dose	Treated by Chlorine	Treated by Ultra violet	Treated by Filter	If filter Type	If filter Location	Other treatment *(please specify)*
Mains	☐ 1	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5			
Borehole	☐ 1	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5			
Well	☐ 1	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5			
Rainwater	☐ 1	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5			
River/lake/stream	☐ 1	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5			

15 If you **acid dose**, which acid dose do you use?

Nitric ☐ 1

Specify other ☐

Water bicarbonate content (mg/litre) ____

16 Where are your water storage tanks?

	Covered	Uncovered
Outside	☐ 1	☐ 2
Inside	☐ 1	☐ 2

☑ 99

17

Irrigation method

	Type	Soil	Pots	Boxes	Baskets	Other container *(please specify)*	Cropped area (acres) or (m^2)	
Hose pipe/lance	☐ 1	☐ 1	☐ 2	☐ 3	☐ 4	☐	☐	☐
Overhead spraylines	☐ 1	☐ 1	☐ 2	☐ 3	☐ 4	☐	☐	☐
Trickle	☐ 1	☐ 1	☐ 2	☐ 3	☐ 4	☐	☐	☐
Ebb & flood benches	☐ 1	☐ 1	☐ 2	☐ 3	☐ 4	☐	☐	☐
Ebb & flood floor	☐ 1	☐ 1	☐ 2	☐ 3	☐ 4	☐	☐	☐
Capillary matting (laminated)	☐ 1	☐ 1	☐ 2	☐ 3	☐ 4	☐	☐	☐
Capillary matting (single)	☐ 1	☐ 1	☐ 2	☐ 3	☐ 4	☐	☐	☐
Gantry	☐ 1	☐ 1	☐ 2	☐ 3	☐ 4	☐	☐	☐
Trough track	☐ 1	☐ 1	☐ 2	☐ 3	☐ 4	☐	☐	☐
Lay flat	☐ 1	☐ 1	☐ 2	☐ 3	☐ 4	☐	☐	☐
Specify other	☐	☐ 1	☐ 2	☐ 3	☐ 4	☐	☐	☐

Drainage

18

Is there an underdrainage system (ie. tile or plastic pipes)? Yes ☐ 1 No ☐ 2

If **yes**, where is the outfall? Water course eg. stream or ditch ☐ 1 Lagoon ☐ 2

Specify other ☐ Soakaway ☐ 3

19

Is the rainwater from the glasshouse roof used for irrigation? Yes ☐ 1 No ☐ 2

If **no**, where does it go? Water course eg. stream or ditch ☐ 1 Lagoon ☐ 2

Specify other ☐ Soakaway ☐ 3

Water consumption

20

Please indicate whether your water source(s) is metered?

	No meter	Water co. meter	Own meter
Mains	☐ 1	☐ 2	☐ 3
Borehole	☐ 1	☐ 2	☐ 3
Well	☐ 1	☐ 2	☐ 3
Roof water/Rainwater	☐ 1	☐ 2	☐ 3
River/lake/stream	☐ 1	☐ 2	☐ 3

21

How much water did you use last year? (Please give your best estimate if no water source is metered) ☐ m^3

22

What is the estimated percentage of water used in glasshouses/polythene structures last year? ie. not including outside hardening off areas etc. ☐ %

Run-off

23

Do you measure run-off? Yes ☐ 1 No ☐ 2

If yes, how? ☐

What is the percentage of applied water which is lost? (Please give your best estimate if you do not measure run-off) ☐ %

Thank you for completing this questionnaire. Please return it in the envelope provided to:
ADAS Market Research Team, Freepost, Wharf House, Wharf Road, Guildford, Surrey GU1 4BR

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