

Developing Water and Nutrient Management Plans for Container Nursery and Greenhouse Production Systems

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Abstract

Nutrient management regulations are a reality, or on the horizon for horticultural operations in the United States and Canada. In 1998, the state of Maryland adopted one of the toughest nutrient management planning laws in the US, requiring that virtually all agricultural operations write and implement nitrogen (N) and phosphorus (P) based management plans by December 31, 2002. The federal Environmental Protection Agency (EPA) may soon enforce provisions of the Clean Water Act of 1972, to ensure that states implement section 303(d) regulations and identify non-point (diffuse) sources of nutrient loading to the nations' rivers and streams. Writing water and nutrient management plans for most ornamental nursery and greenhouse operations is a complicated task, since these operations grow a large number of plant species, and utilize a range of fertilization and irrigation strategies. We have developed a planning process that combines water management (i.e. leaching fraction, interception efficiency and potential runoff) data with nutrient management (source and application rate) data, to provide an estimate of total daily maximum loading rates. A risk assessment process of site-specific plant production and management processes identifies those operational factors that contribute most to nutrient leaching and runoff. This risk assessment matrix enables targeted best management practices (BMP's) to be identified for each unique growing operation, to reduce the risk of N and P run-off into local surface and groundwater resources.

INTRODUCTION

The 'Green' industry, which includes the floricultural, ornamental, turf and landscape maintenance industries, is one of the fastest growing segments of agriculture in the United States. Many greenhouse and container-nursery production operations can be classified as intensive agriculture because they use a combination of fertilizers, growth regulators, insecticides, and fungicides to mass-produce landscape and ornamental plants in high volumes on small acreages. Greenhouse and container-nursery fertility programs commonly utilize high levels of soluble applied nutrients, and total applications of N can reach several thousand kg ha⁻¹ yr⁻¹ (Nelson, 1991; Chen, 2001). Over half of the irrigation water used by both open and protected horticulture is applied by sprinkler systems (USDA, 1998). Based on irrigation system design recommendations (Aldrich and Bartok, 1994), water applications using overhead sprinkler irrigation can exceed 180,000 L ha⁻¹ yr⁻¹. This can generate from 18 to 90 kL ha⁻¹ yr⁻¹ of wastewater (Berghage et al., 1999). Nearly half of the plants grown in Maryland and the US are now grown in containers (Klapproth et al., 2001; USDA, 1998), utilizing some kind of soilless substrate.

Various state (Maryland Dept. Agric., 2000) and federal (EPA, 2000) nutrient

management regulations are making the nursery and greenhouse industries reexamine the efficiency of water and nutrient use (Lea-Cox and Ross, 2001), particularly when plants are grown in containers using various soilless substrates. The nutrient management planning process is complicated for nursery and greenhouse operations, for a number of reasons including minimal data on nutrient use of many ornamental species, local environmental conditions, the wide range of production times, and the variety of production methods.

Nutrient applications are thus only one factor for the container nursery and greenhouse industries that may impact the nutrient management process. Water is an integral component of the nutrient management equation, particularly where irrigation or rainfall has the ability to move soluble nutrients with ease. Water application methods and efficiencies must be considered in the nutrient management planning process, and combined with any unique infrastructure and site characteristics that may contribute to water and nutrient runoff from growing areas. Container-production and greenhouse sites can be compacted, which usually means surface-water control measures are necessary to regulate runoff.

A water and nutrient management planning strategy has recently been developed that should provide an accurate assessment of nutrient loss potential from a wide variety of nursery and greenhouse production scenarios (Lea-Cox et al., 2001). The objective of this paper is to provide an overview of how this integrated water and nutrient management planning process can estimate water and nutrient loading rates for these agricultural operations by examining site, fertilization and water application practices within a risk assessment and risk (best) management process. The process identifies site-specific factors that contribute to nutrient leaching, and provides a mechanism to quantify and assess irrigation efficiency and runoff potential (Ross et al., 2001) that combine with nutrient applications to determine nutrient loading rates (Lea-Cox et al., 2002). Using an operational risk assessment, the nutrient management planner and grower can choose from various alternative and cost-effective best management practices, to reduce the potential for nutrient runoff, without compromising plant quality or production efficiency (Lea-Cox et al., 2001).

DEVELOPING WATER AND NUTRIENT MANAGEMENT PLANS

A nutrient management plan should systematically address four basic points:

1. A description of the production operation with production data and site sketches so the reviewer understands the operation;
2. An accounting of the total nutrients applied to the growing area per year or crop cycle;
3. A site assessment of the potential for nutrient runoff from growing areas, and,
4. Measures to contain and/or abate any nutrients that leach from production areas.

The reason for having a nutrient management plan is to demonstrate that water and nutrients are applied efficiently, and that the operation poses little risk to the environment. A number of approaches to developing a nutrient management plan for a nursery or greenhouse are possible. A simple and effective method is to evaluate the cultural practices that affect water and nutrient runoff.

Management Units

Cultural factors in container nursery and greenhouse production include substrate physical and chemical properties, fertilizer application methods and rates, and irrigation water application methods, rates and duration (Lea-Cox et al., 2001). Management units are used to logically divide the annual plant production of the nursery or greenhouse into a minimum number of planning units. Agronomic management units have traditionally been “production areas with common characteristics,” based on crop species, soil type, predicted yield etc. For most container-production systems, management units based on “broad plant categories” and “container size” are favored, as this often dictates the water and nutrient uptake efficiency in these systems, i.e. nutrient application rates, plant spacing and irrigation duration. The goal is to group plants and containers that are treated

similarly (irrigation and fertilization) into the least number of units to make the documentation process easier. In our experience, most nurseries can group their entire production into four to six management units. Production data can be compiled and reported in a table, an example of which is provided in Table 1.

Documenting Nutrient Applications

All the nutrients used in plant production need to be documented. The first attempt in putting records together can be merely collecting the purchase receipts showing the quantity of fertilizer used for the production year, divided by the total growing area (kg nutrient unit area⁻¹ year⁻¹). A more detailed approach is to keep records of nutrient applications by management unit. These data sum:

- The rate and frequency of application from all nutrient sources (i.e. pre-incorporated, topdressed, soluble, organic, foliar etc.) and,
- The total N:P₂O₅:K₂O applied per management unit (kg ha⁻¹) per production cycle/year.

The total nutrients applied, the frequency of application, and the fertilizer source then provide the some of the data for the management risk assessment process.

Site Risk Assessment

The management of water plays a critical role in the nutrient management planning process, since nitrate-N and orthophosphate are soluble and soilless substrates have little anion-exchange potential (Handreck and Black, 1999). A site risk assessment involves looking at several factors, including the topography, surface conditions, irrigation practices that contribute to water movement, handling of runoff at the property border, and those factors that mitigate the effects of surface water runoff. Surface conditions include control of water velocity and erosion, sediment removal basins, and grass waterways to remove some nutrients. Ultimately, the water must be managed as it leaves the property. Two methods are commonly used: the use of containment structures and/or the use of vegetative areas.

Since the goal is to prevent nutrients from leaving the production site, site risk assessment assigns a low risk to systems that keep nutrients on the property, or that treat, remove or recycle sediment and nutrients before they leave the property. Containment systems are active management systems because the grower is capturing the runoff daily for recycling, post-capture treatment with constructed or natural wetlands, or controlled release through grass buffer stripes. Also, stormwater must be taken into account and some provision must be made for its' effect. Sediment basins may be used to slow water flow and to trap sediment. Some nutrient reduction of nitrogen (by denitrification) and phosphorus (by adsorption) may also occur in the sediment basin. More passive management systems utilize actively-growing vegetated areas of a minimum width, to trap sediment loads and remove nutrients as the water passes over it in thin sheet flow. A set of site risk-assessment criteria (MDA, 2000) and water management and nutrient loading criteria (Lea-Cox et al., 2001) have been developed for Maryland, which are used to rate growing operations as low, moderate or high risk for water and nutrient runoff.

Irrigation Application Efficiency Assessment

The irrigation system itself can be assessed for efficiency and for its contribution to runoff. Many factors may influence irrigation efficiency (i.e. size and spacing of container, type of substrate, the number of times water is applied per day, and the size and maturity of the crop). The risk assessment process (Lea-Cox et al., 2001) estimates the efficiency of irrigation practices by calculating both the amount of water passing through a container (a measure of excess application) and the amount of water that misses the containers (not intercepted). These two factors are called leaching fraction (LF; Fig. 1) and interception efficiency (IE; Fig 2). Collectively, these factors can be used to estimate potential runoff (Table 3; Ross et al., 2001). Both variables are influenced by crop maturity and plant architecture, so coefficients need to be developed in the future to adjust

for changes by these factors.

Irrigation application efficiency is an important factor in risk assessment. The goal is to achieve a low LF (15% LF is considered low risk) and to prevent excess water application that would leach nutrients from the plant container. IE can be improved by closer spacing of containers, or by adopting drip or low-volume micro-irrigation systems with large container stock.

Management Unit Risk Assessment

The management unit risk assessment process is used to provide an evaluation of the water and nutrient management factors that are unique to each operation (Lea-Cox et al., 2001). It is essentially a “matrix” of all the variables that can contribute to nutrients moving from production areas. The key variables common to all operations, i.e. LF, IE, fertilizer source, N and P application rates, are measured and then scored against a set of irrigation (Table 3) and nutrient application (Lea-Cox et al., 2001) risk assessment criteria. These data are entered into each management unit risk assessment table (Table 4). Minimum leaching fraction values were based on data from Ku and Hershey (1991, 1992) and Tyler et al. (1996). Interception efficiency data are based on theoretical interception rates (Ross et al., 2001).

The risk assessment process is therefore focused on the measurement and assessment of a few key production system variables. The measurement of leaching fraction and interception efficiency in the water management process integrates differences in plant density, irrigation duration, container height, and substrate physical characteristics into an estimate of the potential runoff of water that may occur from any particular management unit (Lea-Cox et al., 2001). If the nutrient loading rate is then quantified for that management unit, i.e. by using the nutrient concentration of liquid fertilizer ($\text{mg L}^{-1} \times \text{L}$) or the rate of applying slow release (g container) per unit time, we can then gain an accurate estimate of the total maximum daily water and nutrient load for that management unit (Lea-Cox et al., 2002).

Risk (Best) Management Practice Recommendations

By examining the risk assessment values for each nursery or greenhouse operation, the higher risk practices within each management unit can be ascertained. By lowering the assessed value of a particular factor with a set of alternative best management practices (Yeager et al., 1997), the overall system risk is reduced (Lea-Cox et al., 2001). The nutrient management planner targets the best management practice to reduce risk of the highest risk factors. It is not necessary to reduce the risk of all factors, since it is the combination of factors for any one management unit that determines the overall risk of runoff.

Of course, the effectiveness of a risk management practice depends on adoption and implementation of the practice. More than one option may be available. For example, the practice of overhead irrigation application of soluble fertilizers can be improved by reduced concentration in application by overhead irrigation, the use of slow release fertilizer, containment and recycling of nutrient laden water and reduced frequency of application. Least cost options should be explored in consultation with the grower (Lea-Cox et al., 2001).

Thus, an effective nutrient loss reduction strategy for nursery and greenhouse systems is being developed using site-specific water and nutrient management plans, with the implementation of those plans through the selection of economic best management and monitoring practices. Finding a simple but rational method for assessing the potential for nutrient runoff is important to maintain the economic viability of the nursery and greenhouse industry.

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Tables

Table 1. Sample data table of management unit production data for a hypothetical nursery.

Managed Unit	Crop	Container size	Number of plants	Growing area (m ²)	Area under production (%)	Production time/goal
A1	Annuals	Plugs	100,000	500	1	Feb-June (2 cycles)
H1	Herbaceous perennial	< 1 gal	75,000	7,500	13	Mar-Oct (1 cycle)
W2	Woody perennial	1-3 gal	175,000	20,000	34	6-15 months (1 cycle)
W3	Woody perennial	4-7 gal	150,000	30,000	52	12-24 months (1 cycle)

Table 2. Sample data table of annual nutrient application from controlled-release fertilizer (CRF) and soluble sources (kg cycle⁻¹ year⁻¹) for a hypothetical nursery.

Managed Unit	Pre-incorporated CRF (18-6-12)			Topdressed CRF + soluble (20-10-20)			Total (kg/cycle per year)		
	N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O
A1	-	-	-	136	69	137	136	69	137
H1	205	69	137	114	58	115	319	127	252
W2	205	69	137	68	35	69	273	104	206
W3	295	99	197	68	35	69	363	134	266

Table 3. Irrigation risk assessment criteria, i.e. leaching fraction (LF), interception efficiency (IE) and potential runoff (PR), for container-production operations in Maryland.

Risk Value	Variables		
	LF	IE	PR
Low	< 15%	> 80%	< 32%
Medium	16-29%	61-80%	33-57%
High	> 30%	> 60%	> 58%

Table 4. Sample risk assessment for a single management unit from a hypothetical nursery.

Risk Factor	Low (=1)	Moderate (=2)	High (=4)	Total
Leaching Fraction		2		
Interception Efficiency		2		
Fertilizer Source			4	
N Application rate	1			
P Application rate		2		
Containment		2		
Riparian Buffer width	N/A ^Z			
Subtotals	1	8	4	13
Percent Water Recycled ^Y				- 5
Total Risk Assessment Score				8

^Z If a factor is not applicable, insert N/A (i.e. no value) for that factor.

^Y There are some factors, such as percentage of water recycled, that are ‘beneficial factors’. Points are credited for percentage of potential runoff recycled (i.e. 1-40% recycled = deduct 5 points; 41-60% recycled = deduct 10 points; >60% recycled = deduct 15 points).

Figures

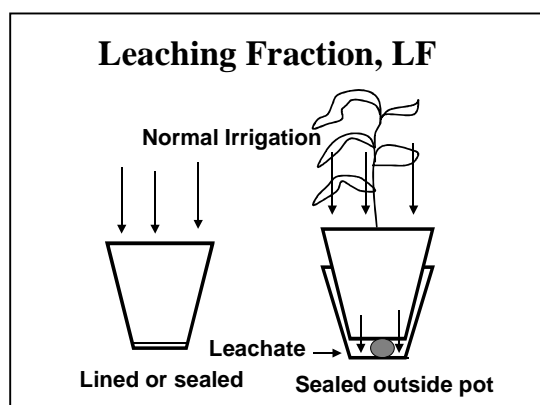


Fig. 1. Leaching Fraction compares the amount of leachate from each container, relative to the irrigation water intercepted.

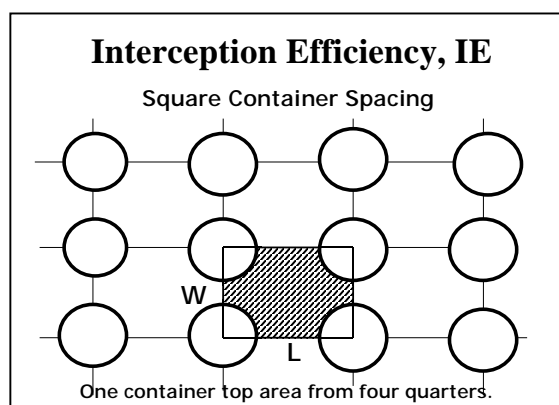


Fig. 2. Interception Efficiency is calculated from container diameter and spacing. Note the relative amount of ground allotted to each container top area.