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Nutrient Management in Nursery and Floriculture

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Although many factors have contributed to the nutrient load in surface and groundwater, fertilizer use has been one of the significant influences (Pettygrove et al. 1998). Fertilizer use is an integral part of nursery and floriculture production. It has also become a serious environmental issue. The two nutrients that have the greatest potential for harm to water quality are nitrogen (N) and phosphorus (P) in various forms.

Nitrogen and phosphorus loading in surface water bodies contribute to an *eutrophic* environment. Eutrophication is the process whereby a body of water becomes enriched in nutrients that stimulate the growth of aquatic plants (e.g., algae), which in turn lead to the depletion of dissolved oxygen in the water. Nitrate pollution of groundwater has the potential to be the most serious problem because of its impacts on drinking water quality. Nitrate in drinking water is suspected of playing a role in the onset of methemoglobinemia and stomach cancer in humans.

The federal Clean Water Act sets standards for the quality of water for a wide range of purposes, including human consumption, wildlife habitat, recreation, and agricultural and industrial use. Section 303 of the Clean Water Act sets a drinking water standard for nitrogen. The drinking water standard for nitrogen has been set at 10 parts per million (ppm) for nitrogen from nitrates (NO_3-N), also expressed as 45 ppm nitrate (NO_3). In coastal areas (Monterey, San Luis Obispo, Santa Barbara, and Ventura Counties), groundwater frequently exceeds 10 ppm NO_3-N (Pettygrove et al. 1998).

It is becoming harder for urban and rural water users in these areas to obtain drinking water in compliance with this standard. No specific standards have been set for phosphorus in freshwater. However, to be in compliance with the federal Clean Water Act, the phosphate concentration should be kept low to avoid eutrophication. To prevent eutrophication, phosphates should not exceed 25 parts per billion (ppb) in lakes, 50 ppb in streams flowing into lakes, and 100 ppb in streams that do not flow into lakes (US EPA 1986).

NITROGEN IN COASTAL NURSERIES AND FLORICULTURE

Current Nitrogen Use Patterns and Consequences

Nitrogen usually is applied to ornamental crops in amounts that exceed the plants' needs. Where fertilizers are injected into the irrigation water, nitrogen fertilizer overuse can also result from application of excessive amounts of water and from overspray that misses the plant containers or beds. Nitrogen application rates vary widely among nurseries and greenhouses, but typical annual values range from 1,000 to 7,000 lb/acre (1,100 – 7,800 kg/ha) (Cabrera et al. 1993). Nitrogen uptake by crops is also variable, but for most ornamental crops nitrogen uptake over the course of a year is between 400 and 1,000 lb/acre (450 – 1,100 kg/ha), which means the typical amount applied is more than six times more than is needed for plant growth.

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This reference sheet is part of the **Farm Water Quality Planning (FWQP)** series, developed for a short course that provides training for growers of irrigated crops who are interested in implementing water quality protection practices. The short course teaches the basic concepts of watersheds, nonpoint source pollution (NPS), self-assessment techniques, and evaluation techniques. Management goals and practices are presented for a variety of cropping systems.

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There are six possible fates for nitrogen other than uptake by plants:

- ***Leaching below the root zone.*** Nitrate moves readily with water that percolates through the root zone. Most of the nitrogen leached below the root zone of the crop is in the NO_3 form. Over the long term, much of the applied nitrogen leaches out of the root zone and becomes a potential contaminant of groundwater.

- ***Soilborne erosion losses.*** Nitrogen in soil aggregates and container media can be moved by water or wind. Both ammonium (NH_4) and nitrate (NO_3) will move with sediments.

- ***Denitrification.*** Soil microbes can convert NO_3 to nitrogen gas that is then lost to the atmosphere. This denitrification occurs to some extent in all soils when oxygen levels are low, for example after irrigation or rainfall has saturated soils. In heavy clay soils with poor drainage or in soils with restrictive layers that prevent drainage, nitrogen losses through denitrification may be 15 to 50 percent of applied fertilizer nitrogen. In general, only a small percentage of applied nitrogen is lost through denitrification.

- ***Immobilization in and mineralization from organic matter.*** Applied nitrogen may be tied up (immobilized) in soil organic matter or in the biomass of soil microbes as they work to decompose crop residues. Large amounts of applied nitrogen can be temporarily immobilized into organic nitrogen by the soil microbes, for example, when low-N plant material is incorporated into the soil. Organic nitrogen is slowly and constantly being recycled back into plant-available nitrogen through a process called *mineralization.* The loss of soil organic matter reduces the capacity of the soil to retain applied nitrogen.

- ***Residual soil nitrogen.*** Nitrogen may remain in the soil as residual soil nitrogen, available for subsequent season uptake. This residual soil nitrogen generally builds up over a season, as long as in-season irrigation is controlled to minimize leaching losses. During a typical winter in most of coastal California, however, rainfall is sufficient to leach most of the residual NO_3 out of the root zone.

- ***Ammonium volatilization.*** When animal manure, urea, or ammonium-containing fertilizers are left on the surface of the soil, nitrogen can be lost to the air as gaseous ammonia. This loss can be significant in alkaline (high-pH), sandy soils. If manure or fertilizers are incorporated within a few hours after application, this loss is negligible.

Nitrogen Application

Nitrate (NO_3) is the predominant form of fertilizer nitrogen used by nurseries and greenhouses. Nitrogen may also be applied as urea or ammonia (NH_4). Urea is rapidly converted to NH_4 in the soil. Although NH_4 is readily taken up by plants, it accounts for only a small percentage of any crop's nitrogen uptake. The microbial process called *nitrification* rapidly converts NH_4 to NO_3 in warm, moist soils. The majority of the nitrogen that is taken up by plants will typically be in the form of NO_3. Also, since NH_4 is bound to soil particles by its positive charge, it is less easily leached than NO_3. For these reasons, NO_3 is the focus of nitrogen management strategies.

Liquid feeding *(fertigation)* is widely used by both nurseries and greenhouses. After the initial cost of injectors, it is less expensive than using controlled-release fertilizers and it is well suited to production of large areas of uniform crops because the fertilizer concentrations can be varied according to crop needs (for example, the nitrogen supply for a chrysanthemum crop can be decreased late in the crop's season). The major disadvantages of liquid feeding are its inefficiency in putting nitrogen into the root zone and its susceptibility to leaching losses of nitrogen as a result of excessive irrigation.

Controlled-release fertilizers can greatly reduce nitrogen losses if they are correctly applied. Nutrient release rates are controlled by the properties of the capsule walls and by temperature and moisture, not by the plants' needs. This type of formulation restricts nitrogen leaching losses from over-irrigation to the small amount that has been released since the previous irrigation. Unlike fertigation, however, application of nutrients cannot easily be varied according to crop needs. For example, an amount of controlled-release fertilizer that releases enough nitrogen to feed a rapidly growing plant (for example, a 40-day-old chrysanthemum that requires as much as 30 mg N per day) would be far more than the amount needed for a young plant or one that is no longer taking up much nitrogen (for example, a 70-day-old chrysanthemum). The excess nitrogen that is released can be lost to leaching if the plants are over-irrigated.

The likelihood of nitrogen leaching losses from controlled-release fertilizers is greatest during the first few weeks after planting, when plant root systems are limited, nutrient demand is low, and plants are consuming relatively small amounts of water. It is best to apply controlled-release fertilizers just below the plant roots at the time of planting (sometimes called *dibbling*) or to broadcast the fertilizer onto the soil surface.

Crop Growth Stage and Nitrogen Requirements

Nutrient management practices should be targeted toward maintaining adequate mineral nitrogen in the root zone and minimizing the leaching of nitrates below that zone. Actual nitrogen fertilizer requirements are known for only a few nursery and floriculture crops. Plant requirements for nitrogen vary according to growth rate and stage of development. For example, the rate of nitrogen uptake for potted chrysanthemums increases during vegetative growth and then decreases sharply after flower buds form. Poinsettias behave in a similar fashion. Roses and some other woody species exhibit a cyclical pattern of nitrogen uptake that is related to episodes of shoot growth and either pruning or dormancy. Depending on the nitrogen application method, it may be possible for growers to adapt the fertilizer program to match changes in plant nitrogen demand.

Leaf tissue analysis for nitrogen provides a convenient way to determine the short-term need of some ornamental crops for additional nitrogen applications (see table 1). The mineral composition of a leaf blade depends on many factors, such as its stage of development, climatic conditions, availability of mineral elements in the soil, root distribution and activity, irrigation, water status, and so on. The plant responds to all of these factors, and the composition of the blade reflects this response. Nutrient concentrations required for optimal growth and nutrient levels above which toxicity occur have been established for many fruit and nut crops, but values are available for only a few ornamental crops. Check with your local University of California Cooperative Extension Farm Advisor for more detailed nitrogen fertilizer requirements and application schedules for your area. By testing at the correct time, you can ensure that adequate plant NO_3^--N concentrations are available in the soil and that unnecessary fertilizer applications are eliminated.

Table 1. Nitrogen content (grams) for certain ornamental crops at commercial maturity

Crop (and container size or unit)	Tissue nitrogen
	g
Acorus 'Ogon' (1-gallon)	0.6 – 0.9
Azalea (6-inch)	0.5 – 0.7
Chrysanthemum (6-inch)	1.2 – 1.7
Cosmos (6-inch)	0.5 – 1.0
Euonymus japonica (1-gallon)	0.9 – 1.6
Geranium (6-inch)	0.6 – 1.0
Holly (6-inch)	0.5 – 0.7
Hydrangea (1-gallon)	1.75
Impatiens (4-inch)	0.3 – 0.4
Pistachia chinensis (5-gallon, 1 season)	2.6
Platanus acerifolia (5-gallon, 1 season)	4.7
Poinsettia (6-inch)	0.5 – 0.7
Quercus agrifolia (5-gallon, 1 season)	0.6
Rose (per harvested stem)	0.2

PHOSPHORUS IN COASTAL NURSERIES AND FLORICULTURE

Phosphorus (P) is present in the soil in a number of chemical forms: a very small amount of soluble, inorganic phosphorus in the soil water, phosphorus adsorbed onto soil particles, chemical precipitates, and phosphorus as a constituent of organic matter. These different phosphorus sources establish equilibrium in the soil; as plants remove soluble phosphorus, other forms replenish the soluble phosphorus supply. In mineral soils, phosphorus solubility is low and most phosphorus is held in chemical precipitates that are relatively immobile. These forms of phosphorus are not usually transported off site unless rainfall or irrigation causes the movement of sediments that contain phosphorus. In contrast, the solubility of phosphorus in soilless media is relatively high, especially in acidic container media. This soluble phosphorus can be leached out of containers by rainfall or excessive irrigation. Leaching losses of 30 to 60 percent of fertilizer phosphorus are common. These leaching losses can be reduced significantly if you incorporate ferrous sulfate into the medium at a rate of 4.8 lb per cu yd (2.8 kg/m^3) (West 1990). In addition, phosphorus that is bound to particles of soilless media that have been spilled or washed out of containers can move off site in irrigation water or rainwater. The movement of phosphorus into streams and lakes can lead to algal blooms and subsequent fish kills.

Common laboratory soil test procedures provide an estimate of the amount of phosphorus in the soil that is available to plants. Unlike soil nitrate testing, which measures the actual amount of nitrate present, soil testing for phosphorus as carried out by most laboratories gives an index value or ranking of the available phosphorus supply. Researchers over many years have calibrated these soil test procedures in greenhouse and field trials so that the results can be used to predict whether a crop is likely to respond to additional phosphorus fertilization. In most ornamental crops, plant demand for phosphorus does not exceed about 15 mg per plant per day. For field-grown woody nursery plants, the typical recommendation is to supplement existing soil phosphorus with fertilizer to provide a total of 44 pounds per acre (49 kg/ha) of actual phosphorus per year (100 pounds per acre [112 kg/ha] when expressed as P_2O_5) (Davidson, Mecklenburg, and Peterson 1994). For container-grown crops, phosphorus is usually added to the growing medium as superphosphate (2 lb per cu yd

[1.2 kg/m^3]) or triple superphosphate (1 lb per cu yd [0.6 kg/m^3]) prior to planting. Alternatively, phosphorus can be added as a component of a complete, controlled-release fertilizer.

It is not normally necessary to supplement the pre-plant addition with a liquid feed source of phosphorus unless the crop will be grown for more than 3 to 6 months. In that case, injection of phosphorus into the irrigation water at a rate of 15 ppm is effective. However, liquid feeding with phosphorus is subject to the same problems that are associated with nitrogen.

The best way to keep phosphorus from moving off your property is to reduce runoff. Evaluate your property so that you know the surface drainage patterns and then take action to prevent excessive runoff from reaching surface water bodies. Filter strips, grassed waterways, sediment basins, nutrient management, and other NRCS practices should be used in conjunction with soil testing for effective prevention of phosphorus runoff.

INFLUENCE OF IRRIGATION

Uniform delivery of irrigation water is critical in achieving good nutrient management. Growers who irrigate efficiently will have less runoff and fewer leaching losses to contend with, and therefore fewer nutrient management problems. The key steps toward achieving high irrigation efficiency (where a high percentage of the applied water remains in the root zone, available for plant uptake) are to apply water evenly across the field or greenhouse and to schedule irrigations so they will deliver the proper amounts of water at the proper time.

The evenness with which water is applied across the field or greenhouse is measured as the *distribution uniformity* (DU). The greater the DU, the greater the potential for maximum irrigation efficiency. Irrigation system performance is dependent upon system design and maintenance, proper or improper redesigns or retrofits, equipment age, and water pressure variability, as well as on various management practices. For example, grouping plants according to their expected water use and capturing runoff water for recycling or filtering can significantly improve a field's irrigation efficiency. The distribution uniformity of a sprinkler irrigation system can also be affected significantly by wind conditions.

Conventional sprinkler or furrow irrigation techniques often have poor distribution uniformity or irrigation efficiency. Microirrigation (drip tape, drip emitters, microsprayers/sprinklers) has the potential for higher distribution uniformity than other irrigation methods, but frequently these systems are not designed and maintained well enough to meet this potential. These conditions were noted in irrigation system evaluations in San Luis Obispo and Santa Barbara Counties (Pitts et al. 1996). Low distribution uniformity and low efficiencies often lead to over-irrigation, with excessive amounts of water lost to deep percolation (drainage) below the crop's root zone.

Growers need to know how much water their crops use and then irrigate accordingly. Water use can be measured directly in nurseries and greenhouses that produce plants in containers. Using a scale that expresses weights to the nearest gram, growers can record the weights of a representative number of pots 1 hour after irrigation and again the next day, just before irrigation. The difference in weight, expressed in grams, represents water use in milliliters (ml). By periodically taking measurements, the grower can anticipate a crop's average seasonal water needs. The average daily water use of some mature ornamental crops grown in Davis, California, is presented in table 2.

Table 2. Average daily water use of some ornamental crops grown in Davis, California

Crop (and container size or unit)	Water use	
	ml / day	oz / day
Acorus 'Ogon' (1-gallon, outdoor shade)	140	5.0
Aucuba japonica (1-gallon, outdoor shade)	100	3.5
Camellia 'Winter's Star' (1-gallon, outdoor shade)	100	3.5
Chrysanthemum (6-inch)	240	8.0
Dietes vegeta (1-gallon, outdoor)	130	4.5
Holly (1-gallon, outdoor shade)	140	5.0
Hydrangea (1-gallon, outdoor shade)	340	11.5
Hydrangea (6-inch, greenhouse)	175	6.0
Impatiens (4-inch, greenhouse)	100	3.5
Juniperus scopulorum 'Moonglow' (1-gallon, outdoor)	140	5.0
Lantana 'Pink Caprice' (1-gallon, outdoor)	200	7.0
Lavandula dentata (1-gallon, outdoor)	160	5.5
Magnolia grandiflora (5-gallon, outdoor)	340	11.5
Nandina domestica (1-gallon, outdoor shade)	120	4.0
Pelargonium (6-inch, greenhouse)	175	6.0
Penstemon 'Red Rocks' (6-inch, greenhouse)	150	5.0
Pistacia chinensis (5-gallon, outdoor)	580	20.0
Platanus racemosa (5-gallon, outdoor)	940	32.0
Prunus ilicifolia (5-gallon, outdoor)	250	8.5
Quercus agrifolia (5-gallon, outdoor)	260	9.0
Quercus lobata (5-gallon, outdoor)	335	11.0
Rhododendron (1-gallon, outdoor shade)	200	7.0
Rose (mature greenhouse plant for cut flowers)	400	14.0
Sequoia sempervirens (5-gallon, outdoor)	390	13.0
Weigela 'Variegata Nana' (1-gallon, outdoor shade)	160	5.5

A grower can estimate a crop's water needs by referring to local values for reference *evapotranspiration* (ET). Evapotranspiration is the water lost by plant uptake from the soil and by evaporation from the soil surface. Table 3 presents the estimated water use of greenhouse and outdoor crops grown near the coast in San Mateo County, based on evapotranspiration. The available measured values for a few summer flower crops are about 20 percent lower than these calculated values show, so this method for estimating water needs is good but not perfect. Growers interested in estimating their own crops' water requirements should contact their local UC Cooperative Extension County Office.

Table 3. Calculated average daily water use of ornamental crops in Half Moon Bay, based on historic evapotranspiration values

Month	Outdoor crop		Greenhouse crop	
	oz / ft^2	mL/m^2	oz / ft^2	mL/m^2
Jan	4.0	1.3	6.0	1.9
Feb	4.3	1.4	6.4	2.0
Mar	6.4	2.0	6.4	2.0
Apr	7.7	2.5	5.8	1.8
May	10.4	3.3	7.8	2.5
Jun	11.2	3.6	8.4	2.7
Jul	11.4	3.6	8.6	2.7
Aug	10.9	3.5	8.2	2.6
Sep	9.3	3.0	7.0	2.2
Oct	7.4	2.4	7.4	2.4
Nov	3.4	1.1	6.1	1.9
Dec	2.7	0.9	5.3	1.7

Excessive irrigations can have a significant impact on soil NO_3-N levels. In a field with 20 ppm NO_3-N in the soil solution, 1 inch (2.5 cm) of water leaching from irrigation may carry with it as much as 20 lb N per acre (22 kg/ha) out of the root zone. In addition, irrigation water can be a source of NO_3. Many agricultural wells now contain more than 10 ppm NO_3-N. Application of 1 foot (30 cm) of irrigation water that contains 10 ppm NO_3-N would be equivalent to applying nitrogen at a rate of 27 lb per acre (30 kg/ha).

Efficient nitrogen fertilizer management is a necessity to keeping further NO_3 pollution of groundwater to a minimum and requires that a grower take into account a variety of site-specific factors. A variety of techniques is available to help growers keep track of how much fertilizer is in the soil and whether or not it is sufficient to meet current crop needs. Using the information gathered from these techniques, a grower can make decisions about when to fertilize and when to water that will minimize harmful and expensive losses of nutrients and moisture from the root zone.

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