Removing Nutrients and Pesticides from Runoff Water Using Natural Systems©

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INTRODUCTION

Landscape plant and greenhouse production rely on an adequate supply of nutrients to achieve profitable growth rates and the application of supplemental chemicals in the form of pesticides and growth regulators to control insect pests and plant fungal and bacterial pathogens and to guide plant development. Currently, only the use of pesticides and some growth regulators, e.g., daminozide, are under regulatory agency directed use and disposal guidelines. However in the near future, state environmental agencies are likely to come under increased pressure from federal agencies and special interest groups to further improve water quality. Pollutants originating from horticultural practices will include not only pesticides and growth regulators but will include the nitrogen and phosphorus components from fertilizers. Today, horticultural enterprises are considered non-point sources of pollutants and thus have fewer regulatory requirements to meet compared to point source polluters, e.g., industry and sewage treatment plants. How individual states will approach regulation to achieve cleaner waters is unknown but they are likely to use one of two approaches, the maximum contaminant level (MCL), which sets the maximum concentration of a pollutant that can be discharged into surface waters, or the total maximum daily load, which sets the maximum quantity of a pollutant that can be discharged into surface waters each day. Either approach will have dramatic impacts on how nurseries and greenhouses will deal with their irrigation runoff.

PROBLEM EVALUATION

In a 3-year study monitoring runoff from a large container production area at a commercial nursery, we found the levels of nitrogen in runoff varied by season with the lowest levels occurring during winter months (3–5 $mg \cdot L^{-1}$ N), highest levels in the spring months (8–32 $mg \cdot L^{-1}$ N), and intermediate concentrations occurring during the remaining summer and fall months (6–11 $mg \cdot L^{-1}$ N). Phosphorus concentrations in runoff showed less dramatic changes through the seasons with minimum levels occurring during winter months (1.2–1.5 $mg \cdot L^{-1}$ P), intermediate levels during the spring months (1.3–2.0 $mg \cdot L^{-1}$ P), and slightly higher levels during the summer and fall months (1.4–2.2 $mg \cdot L^{-1}$ P). Both nitrogen and phosphorus levels in runoff have declined seasonally over the 3-year study period as nursery personnel have moved proactively to reduce nutrient pollution impacts and thereby reduce plant-growing costs. The current drinking water standard for nitrogen is a MCL of 10 ppm N (National Academy of Sciences, 1977), but there is no current standard set for phosphorus. During 2004, nursery runoff to a holding pond has exceeded the MCL for nitrogen only during April (16 ppm) and May (14 ppm) and this water was remediated by a constructed wetland system to below 0.5 ppm prior to discharge into the receiving stream.

The potential impact of nutrients on surface waters lies not in its potential use as drinking water but in causing eutrophication of streams, lakes, and estuaries downstream from the nursery or greenhouse operation. Eutrophication, although a natural process in water body aging, can be greatly accelerated by increased human inputs of nutrients and organic substances into aquatic ecosystems. These substances can over stimulate the growth of algae, creating algal blooms that hurt the aquatic system by clouding the water thereby blocking sunlight and by depleting oxygen in the water when the algae die and decompose. Of the major nutrients in fertilizers, two can lead to algal blooms. Excess nitrogen (>0.4 ppm) in surface waters can cause accelerated eutrophication in both freshwater and estuarine systems (Wetzel, 1983; Vitousek et al., 1997), noxious algae blooms (Rabalais et al., 1996), and seagrass decline (Burkholder et al., 1992). Phosphorus has been shown to contribute to eutrophication in freshwater systems and the USEPA recommends that total phosphorus not exceed 0.1 ppm for water entering lakes and reservoirs (USEPA, 1986). Daniel et al. (1998) in a review of the literature considered levels of P between 0.01 and 0.02 ppm as accelerating eutrophication. These levels of N and P can be exceeded in nursery runoff and thus it is incumbent on the nursery industry to consider ways to reduce nutrients in their runoff.

PHOSPHORUS OPTIONS

Phosphorus will likely be the most recalcitrant nutrient problem nurseries will deal with. This comes as a consequence of the geochemical phosphorus cycle in which the applied form is soluble phosphate, the pollutant form also phosphate, the global sink phosphate, and the unavailable form buried phosphate-bearing rock. Our monitoring study of a commercial constructed wetland has shown that they are generally ineffective at removing phosphorus from runoff. Plant growth in the wetland does sequester some P during the months of highest phosphorus levels in runoff, but export of P from the wetland occurs during other months. We have also screened in greenhouse experiments 19 landscape varieties for their potential to hyper-accumulate P. A few species show some potential for removing excess P from runoff and these include the cannas [yellow King Humbert and *Canna* 'Striata' (Bengal tiger canna)], *Peltandra virginica* (L.) Schott, *Eleocharis dulcis* (Burm. f.) Trin. ex Henschel, and *Phyla lanceolata* (Michaux) Greene. A more productive approach for the industry would be to attack the problem from the front end by reducing the levels of phosphorus in soil mixes, using low P fertilizers for liquid feeding programs, and by using fired clays that have been shown to bind P in soil mixes (Bilderback, TE, pers. commun.). Their research has shown that less P is needed initially, less leaches from the pot, and less water is required to grow plants of equal quality.

For operations with low runoff volumes, other options are available including holding and recycling tanks, retention ponds, bioretention basins, and vegetated buffer strips where runoff is applied as a light irrigation to raise contact time and improve adsorption and uptake by the vegetation.

NITROGEN OPTIONS

Nitrogen is a lesser problem when it comes to remediation because in the nitrogen cycle there is a nonpolluting form of nitrogen, N_2, a gas which makes up 80% of the air we breathe. The ammoniacal form of nitrogen in fertilizers is converted to nitrate in the presence of oxygen, the process of nitrification, which is necessary to convert the nitrogen into the form required for plant growth. Nitrogen in nursery runoff is primarily in the nitrate form and for remediation this is converted to nitrogen gas under anaerobic conditions by microbial metabolism in a process termed denitrification. There are a number of options for limiting nitrogen in nursery discharge water and the approach taken depends on whether rainfall is below irrigation needs or exceeds them. Where there is limited rainfall or extended periods of drought, nurseries may opt to use capture or holding ponds to store water for reuse and recycling in their irrigation regime. However this technique requires careful attention and strict management procedures for success by using the three "M"s: managing salts, monitoring water quality, and managing disease organisms in the ponds. Where rainfall exceeds nursery irrigation usage, excess nitrogen in runoff may need to be remediated. There are several remediation methods available including constructed wetlands for moderate to high volumes of runoff, denitrification walls for low volumes, vegetated ditches for moderate to low volumes, and vegetated or turfgrass buffer strips for low volumes. Obviously, the choice of remediation system depends on the volume of runoff, its frequency, whether continuous flow or intermittent, and level of remediation needed based on the concentration of nitrogen in the runoff. The remediation methods are discussed below.

We have monitored the functioning of a 9.3-acre constructed wetland at a large commercial nursery in southwest Georgia that has been used to remediate nutrients in runoff from a 120-acre watershed since 1997. Except during drought conditions, throughput ranges from ¾ to 1 million gallons per day. Nitrogen removal efficiency for this wetland system has remained above 90% from March through November each year. While efficiency drops during winter months, averaging 43% from December 2002 through February 2003 and 79% from December 2003 through February 2004, significant remediation of nitrogen continues. Besides the benefits of cleaner discharge water, wetlands provide habitat for many forms of wildlife and are aesthetically quite pleasing.

Denitrification walls form a permeable reactive barrier for runoff water allowing time for microbial transformation of nitrates to nitrogen gas (Schipper and Vojvodic-Vukovic, 1998). Their basic design is simple. A wall of organic matter 1–3 m thick is placed perpendicular to the discharge water plume and kept saturated to maintain the anaerobic conditions required for denitrification. The organic matter supplies the carbon food source for microbial metabolism. As the type of organic matter can determine the flow rate through the wall, its permeability should be matched to the anticipated flow rate. Compost, sawdust, wood chips, and landscape plant trimmings are among the possible choices for organic matter with the latter two allowing higher flow rates. Relatively constant flow is needed to maintain anaerobic conditions in the wall and to reduce aerobic degradation of the organic matter (Schink, 1999). Schipper and Vojvodic-Vukovic (2001) found their effectiveness to be greater than 95% during a 5-year denitrification wall pilot study. For small nurseries using microirrigation and many greenhouse operations, this inexpensive technique could be useful. However, the inflow ditch to the denitrification wall should be sized to capture and hold the initial leachate from containerized plants during rainfall events as this water may be higher in nitrogen (a first flush effect).

Another method for removing nitrogen from runoff is the use of vegetated buffer strips, already a best management practice for protecting sensitive surface and ground waters (Lowrance et al., 2000). These work to remove pollutants by retarding surface runoff velocity and promoting sedimentation and infiltration. Nutrients may not be removed under steep slope conditions, when the levels of dissolved constituents are high, and during heavy rainfall events. This can be mitigated somewhat by increasing filter strip length but even this may not be effective with shallow soils or in highly structured or nonreactive soils. For buffer strips to work efficiently, water flow across them should be even and slow to allow sufficient time for infiltration, plant nutrient uptake, and microbial processes.

A similar approach is the use of vegetated ditches for nitrogen removal. A heavily vegetated, wide, shallow ditch accepts and holds runoff to allow sufficient contact time between water, plants, and organic laden soil. Land used for these ditches should have minimal slope or a step-down approach from one level to the next could be used. Plantings can be bands of individual species or mixed plantings of wetland species. Ditches should remain wet and allow several days of contact if possible. Depending on their length, vegetated ditches can handle low to moderate flow rates but do require significant land area, which may be a problem for small nurseries and greenhouses.

CONCLUSIONS

Nurseries and greenhouses have a number of options for meeting current and future water quality standards. The least expensive alternative is to reduce their use of N and P to the minimum levels required to achieve profitable plant growth rates and plant quality. For those operations generating large quantities of runoff that require remediation, constructed wetlands offer the best alternative. While constructed wetlands can be expensive to build and plant initially, they require little maintenance thereafter. They are highly effective for nitrogen removal from runoff but only marginally effective for P removal and can export P during some months. Constructed wetlands require sufficient land for their construction but can be placed on low unusable land. Denitrification walls, vegetated or grass buffer strips, and vegetated ditches are less expensive alternatives when flow volume is sufficiently low. Currently, nurseries and greenhouses operate under easily achievable water quality standards, a single MCL of 10 ppm nitrogen. Future regulatory requirements are likely to be much more difficult to meet without turning to some form of remediation. The options discussed here should be viewed by nursery and greenhouse operators as starting points for planning a comprehensive water management strategy for their enterprise.

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The 2005 Gainesville Florida Meeting of the IPPS Southern Region of North America©

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WELCOME TO GAINESVILLE

As Local Site Chair, I want to review the 30th Annual Meeting of the IPPS Southern Region of North America, which will be held 23–26 Oct. 2005 in Gainesville, Florida. Gainesville is a college town in North Central Florida and home of the University of Florida Fighting Gators. It sits 70 miles inland from the Atlantic Ocean and 53 miles from the Gulf of Mexico. We're 2 hours from Tallahassee, Orlando, and Tampa, and 90 min from Jacksonville. Ocala is just 35 miles south of us.

Alachua County is an area of rolling hills, giant moss-draped live oaks, tall loblolly pines, hay fields, lakes, and rivers. We've got cows and horse farms, corn and watermelon fields, and we have students — lots of them — with over 50,000 at the University of Florida alone.

Because we are a young vibrant community, there are many things to do in Gainesville. You can tube the Ichetucknee River, scuba dive in underwater caves at Ginnie Springs, sail or fish on Newnan's Lake, hike or bike the San Felasco Hammock, kayak down the Sante Fe River, see a performance at the Hippodrome State Theater, watch the Gatornationals at the Gainesville Raceway, view an art exhibit at the Harn Museum, or feed the alligators at Lake Alice.

Our host hotel is the University Conference Center. It is a Hilton Hotel right across from campus and is a first rate facility. Parking is free, and the hotel room rate will be $92 per night. The Environmental Horticulture Greenhouses, Natural History Museum, and Art Museum are all within walking distance.

Like most college towns, we have people here from all over the world. And so, there are many fine restaurants in Gainesville with every type of cuisine imag-