Impact of Runoff Water Quality on Future Nursery Crop **Production**

Thomas H. Yeager

The nursery industry underwent many changes in the 1980s. Droughts and water regulations required increased use of low-volume irrigation, severe freezes promoted the use of fabric covers for cold protection, and governmental immigration reform necessitated re-evaluation of personnel resources. Production practices were required that used smaller quantities of fertilizer and pesticides. Additional restrictions limited the disposal of by-products and the use of inputs such as water, which once was taken for granted as an unlimited resource.

For the nursery industry to remain profitable, proactive thinking and a futuristic vision must be the focus of the 1990s. No one knows what future restrictions will be imposed, but environmental issues will receive the greatest attention, with water quality and quantity issues as top priorities. Those production practices having an impact on the environment must be identified and modified when needed, but progress can be achieved only by open-minded individuals with a willingness to change.

Studies and projects currently underway or completed can serve as a basis for orderly change. The U.S. Environmental Protection Agency (EPA) recently completed a national well-water survey that provided bench mark data for nitrate levels found in the nation's groundwater. Also, a nursery water quality project involving industry and university personnel in Alabama, Florida, North Carolina, New Jersey, Ohio, and Virginia, and funded by the Horticultural Research Institute (HRI), was completed this fall. Runoff water was sampled from container nurseries applying slow-release fertilizers or slow-release fertilizers supplemented with liquid fertilizers to document baseline or bench mark nitrate levels in runoff water. These studies revealed that runoff nitrate levels can exceed the 10-ppm federal drinking water standard regardless of whether slow-release or combined slow-release and liquid fertilizers are used. However, careful management of fertilization and water application systems resulted in < 10 ppm of nitrate in water leaving the nursery. The immediate solution to reducing nitrate runoff and water consumption depends on innovative management strategies.

Previous research regarding runoff, water consumption by woody ornamental plants, and water conservation related to production and maintenance has beencompiled in the *Bibliography of Water Use, Fertilizer, and Pesticide Impacts Relative to Woody Environmental Plants* (see Yeager, 1991). The compilation of this document was funded by HRI. This bibliography is divided into three main sections: water references, nutrient references, and pesticide references. The water section contains the following subsections: groundwater, plant-use/requirements, conservation/management/policy, irrigation water constituents/properties, amendments/media/soil/water relations, and delivery systems/drainage/reuse/runoff.

Water and fertilizer application methodology has improved tremendously during recent years, but many questions remain unanswered regarding the biology and biophysical relationships of water and nutrient use by woody plants. Perusing the literature, one quickly realizes that agronomic crop-production research and information on water and nutrient management far exceed the research and information for woody nursery crops. Probably more funding is available for agronomic crop water research with corn, cotton, and soybeans than for nursery crops. However, water and nutrient management information for nursery crops is gaining momentum, but nursery operators, researchers, and industry organizations must cooperate and accelerate communication with each other as well as the political leaders to meet the challenges of this "new era" of environmental conscientiousness. To provide a catalyst for communication, the ASHS Nursery Crops Working Group sponsored a workshop on the "Impact of Runoff Water Quality on Future Nursery Crop Production." The objective of the workshop was to provide participants with an integrated understanding of the political and technological realities of water quality implementation in nursery crop production. A political perspective on water quality impact was presented by Craig Regelbrugge, American Association of Nurserymen, Washington, DC. The second speaker, Wayne Mezitt, Westin Nurseries, Hopkinton, Mass., presented a nursery operators perspective on water-quality impact. Robert D. Wright, Dept. of Horticulture, Virginia Tech, Blacksburg, Va., presented a researchers perspective on current and future water quality research. A summary of the presentations follows.

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Political Perspective **on Water Quality Impact**

Ben Bolusky and Craig Regelbrugge

The irony at first is striking. Three-quarters of our planet is covered by water. Yet, although 75% of the earth is covered with water, 97% is salty ocean and 2% is frozen in glaciers and icecaps. Only 1% of all of the earth's water is fresh water. Clean, fresh water is one of the world's rarest and most precious resources. By this definition then, water is unmistakably one of our most political commodities.

But how *did* water and water quality come to the political forefront? The modern-day situation perhaps can be traced back to the 1960s and 1970s with the emerging environmental movement. As our population became more affluent, health-conscious, and leisure-time-oriented, people began taking stock of what we were doing to the environment—the air we breathe, and the water we drink. People became aware of the sobering realization that we did not have an inexhaustible supply of either. During this time, this public sentiment crystallized into political action and legislative achievement. The Clean Air Act, Clean Water Act, Endangered Species Act, Safe Water Drinking Act, and Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) were born. The focus of these and other legislative mileposts was largely directed at manufacturing industries-notagriculture. Why? Simply, in part, because one could easily see the industrial smokestacksbillowing into the air and the unsightly sewage discharged into our streams and rivers.

This tunnel-vision focus on manufacturing industries confirms the so-called "Custer Syndrome," where the guy in front catches the arrows only because he is the mostvisible. If we look purely from the water-use standpoint, manufacturing and mining account for only 9% of America's water use! Homes, hotels, and off ices comprise another 10%, while thermoelectric power represents 39% of our wateruse. It is agriculture that consumes the national lion's share, 42%, of our water use. This figure doubles to a whopping 85% in the leading agricultural-producing state—California—even though agriculture represents just 10% of that state's industry. From a supply perspective at least, it was only a matter of time before the public water debate began to zero-in on agriculture.

Historically, farmers have been regarded as

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the quiet stewards of the land—underpaid, hardworking tillers of the soil. Four pivotal factors have altered this perception and propelled agriculture to the political forefront of the water quality debate.

First, small family farms are disappearing from the American landscapes. In their place are large and efficient corporate agribusinesses, highly yield-oriented and often heavily reliant on chemical inputs. This dynamic change molded agriculture into a bigger, less wholesome target in the public eye. Second, sprawling suburban subdivisions pushed and fanned out into former agricultural areas where farmers had gone about their business for years. As a result, public awareness and concern about pesticides became much more sophisticated. Third, as we have made great strides in cleaning up *point* sources of pollution, such as factories and sewage treatment plants, an increasing percentage of our remaining pollution problems could be attributed to *nonpoint* sources, such as runoff from our cities, suburbs, and farms. Finally, dramatic technological advances, even in the past 7 to 8 years, in scientific analytical capabilities to measure pesticide and nutrient levels, and possible contamination, have catapulted pesticides and fertilizers right into the thick of the water quality debate.

This last point should not be underestimated. Scientists, farmers, nurseries, and researchers used pesticides for decades and there was little demonstrated negative impact. Today, we can measure not just parts per million, but parts per billion and even per trillion! In other words, we can detect levels that do not necessarily have biological risks, but we do have solid numbers; all at a time when you can hear public outcries for zero risk. "No detection" is now the trigger point. This leads us to one of today's most crucial questions: What does it really mean when there is a detection of pesticides in surface or groundwater? Does it really mean, as media headlines would lead the public to believe, that pesticide detections automatically mean water contamination?

Coming on the heels of the historic legislative precedents of the 1970s, the Congress of the 1980s if you forgive the pun, simply treaded water, never seeming able to rise above its own politics. The groundwater agenda, in Congress anyway, bogged down under weighty political questions that we will address below.

Couple this Congressional inaction with the Reagan Administration's ideological drive to deregulate and you have the two main ingredients for growing public impatience with the federal government. General public sentiment toward the federal government in the 1980s perhaps can best be characterized as having suffered from a loss of confidence. Ineffective oversight was perceived. Public opinion of the Environmental Protection Agency (EPA) fell to an all-time low during the Reagan years. So the stage was set in the mid- to late 1980s for the public and the state legislatures to leap in to fill the void with their own grass-roots and state level "protect the environment" initiatives.

Perhaps the best example was the overwhelming voter approval in 1986 for California's Proposition 65. This initiative was particularly noteworthy for two features: its criminalization of various toxic disposal activities likely to imperil drinking water supplies and its unusual grant of standing to ordinary citizens to undertake legal action against alleged polluters should public authoritiesfail to act within specified time periods. But perhaps the most far-reaching provision of Proposition 65 involves on-site and in-media publication notices of the presence of toxic chemicals. It is likely that the list of toxic substances so advertised in the market place, workplace, and neighborhood will continue to expand.

Texas and other states have recently stepped up regulatory efforts regarding surface water and groundwater pollution and pesticide use. We understand the Texas Water Commission has been very active in investigating nursery operations with an eye toward runoff water volume and quality. The Commission is establishing discharge permits regulating and/or eliminating runoff from these nurseries. Oregon's Dept. of Environmental Quality is also concentrating efforts on groundwater, as well as setting "total maximum daily load limits" for specific compounds in waterways. In Iowa, the nation's toughest state groundwater program was enacted in anticipation of findings of widespread pesticide contamination.

And, of course, there's California's Environmental Protection Act of 1990, better known as "Big Green," which did not pass on 6 Nov. 1990. This multitentacled initiative called for "full protection" for fish and other forms of wildlife, while current statutes require "reasonable protection." This wording infers that fish and wildlife potentially would have had priority over agriculture and nurseries, or even domestic uses. Other Big Green provisions stipulated that all drinking water must meet "the most stringent health standards"—a requirement that even bottled water companies may have trouble meeting. As further evidence of the public's general lack of confidence in the government to address water quality, the International Bottled Water Assn. estimates that annual sales of bottled water in the United States now stand at $2 billion (wholesale value). Such sales have increased by a whopping 500% over the past 10 years.

The states have been increasingly active in regulating the water agenda in the absence of federal programs—even in the general absence of federal dollars. We hear a lot about groundwater, Western water rights, quantity, access, and water quality. There are even moves in the southwestern United States to reshape whole water systems. As alluded to earlier, much of this state activity is a direct result of the inability of Congress toaddress the water debate head-on. If we can, let us step back from the current politics of Big Green, etc., and return briefly to the early 1980s.

During the early 1980s groundwater caught the eye and attention of the American public, and deservedly so, since 95% of rural America depends on groundwater as its source for drinking water. With increasing public concern about this issue, Congress began to take notice. This was especially appropriate because there was, and remainseven today, no single national groundwater program. Bits and parts are still scattered among a variety of federal agencies.

As Congress delved into the groundwater dilemma, many tough political questions were raised. First, to what extent should agricultural pesticides be treated like other groundwater contaminants, such as industrial wastes, sewage, or fertilizers? Second, what is the level or standard of protection that should be pursued? Pristine water, nondegradation, a health-based standard, a combined standard based on health and technology, or continuation of the FIFRA standard that is based on risk-benefit analyses? Third, what was the object of the protection—all groundwater, drinking water, potential drinking water, or all three? Fourth, should normal pesticide use, misuse, or both be considered potential contaminants? Fifth, what should be the scope of action—prevention, cleanup, or both? Sixth, how should proper roles be carved for the federal, state, and/or local governments? Groundwater movement certainly does not honor jurisdictional boundaries.

Last, whoshould be held liable for groundwater contamination—farmers or applicators, chemical manufacturers, or the government? Farmers and nurseries make a strong case that they should not be held liable provided pesticides were faithfully applied according to the labels. Chemical companies also have a strong position that they should not be held liable, because their products have survived rigorous testing and received approval from the government. The government, comparatively speaking, has the weakest argument; yet the 1990 Congressional budget battle demonstrated that the government does not have financial resources available to assume liability. These were some of the more poignant questions that Congress wrestled with in the 1980s groundwater debate. They are questions that, from a Congressional or political point of view, remain largely unresolved.

You see, Congress is research-and-development-oriented when it comes to substantive policy areas laden with heavy political overtones, such as groundwater. In keeping with that spirit, the 1990 Farm Bill contains groundwater research provisions. It now seems rather fortuitous that Congress has been incapable of addressing the groundwater debate except for albeit sorely needed research. Why? Because recent scientific findings have *not* indicated the amount and number of pesticide contamination concerns that were feared initially.

About 3 years ago, EPA began planning a survey of pesticides in groundwater. Until that time, there had been a number of spot checks of possible contamination, which did not give an adequate picture of the potential for pesticide contamination throughout the United States. The EPA's groundwater survey was completed 6 Nov.

1991. As mentioned above, but deserves repeating, findings so far have not indicated the amount and number of pesticide contamination concerns that were feared initially. The chemicals most frequently found have been soluble nitrogen, atrazine, alachlor, and dacthal, principally in high-use areas where soil conditions and possible misuse may have contributed to contamination. Even in those instances where these and other chemicals were found, in almost every case the concentrations were at or significantly lower than levels permitted in drinking water. This is not to say nurseries should not be concerned or not take prudent steps to manage pesticides and fertilizers properly.

EPA is also considering a groundwater strategy to assist itself in addressing pesticideand other chemical contamination problems across the different federal regulatory programs throughout the United States. This groundwater strategy will address such issues as whether the goal of regulation should be zero degradation, and whether groundwater should beclassified by intended use. These are issues that Congress wrestled with and ducked over the last few years. Classification of groundwater by intended use is very important when you consider that available regulatory, financial, and manpower resources may not be sufficient to protect all groundwater to drinking-water standards. In other words, should drinking water be protected at the highest level while groundwater under a farm or nursery operation is regulated at a less rigorous standard? This is perhaps an oversimplification, since groundwater recharge and movement depend on geology, precipitation, and other factors.

In addition, EPA is considering regulations to require restricted-use classification on certain pesticides that may or may not have been shown to contaminate groundwater. This will provide criteria for identifying pesticides that may pose an unacceptable hazard and require such pesticides to be managed only by statecertified applicators. The herbicide atrazine was the first pesticide to be classified as restricted-use because of groundwater concerns.

As you can see, EPA under the Bush Administration is taking a comparatively more aggressive water quality role in an effort, in part, to ensure that the increasing regulatory activities by the states reflect national policy priorities. Just as the focus of the 1980s was groundwater, the American Association of Nurserymen believes that we will witness a slow, but steady, change in regulatory emphasis away from groundwater and more toward surface water in the 1990s—if for no other reason than the fact that groundwater represents only 22% of our fresh water, while surface water represents the lion's share of 78%. We are already beginning to detect an ever-so-slight shift in political circles in our nation's capitol.

We hope this short presentation helped shed some light on how water quality recently came to the political forefront and on current political thinking and likely future political directions.

Nursery Operator's Perspective on Water Quality Impact

R. Wayne Mezitt[1]

The purpose of this paper is to discuss the impact of irrigation runoff and groundwater quality concerns on nurseries and nursery operators. From 1986 to 1990, the Water Management Committee (WMC) of the American Association of Nurserymen (AAN) studied what must be done to assure that the people in the nursery industry can effectively become better managers of their water resources I will examine our current nursery water management status nationally and locally and review a water management plan of action currently underway. I will then present some of my views about research needs. I hope some of these ideas and perspectives will assist researchers in helping nursery people become truly prudent managers of their most important and primary natural resource.

Although forward-thinking nurseries are clearly aware of the challenges, the majority of nursery operators across the country are relatively unaware that there is a problem with their use of water. Some believe that because they are in an industrywhose livelihood depends on an adequate supply of water, they have a right to use whatever water is necessary to enable them to produce their products. Most are doing what they perceive to be the right things with their water use and are confident that future water needs will be met in the same manner as in the past. Many have found it necessary to meet the immediate requirements of regulators, but they consider themselves to be powerless to change many of the ways they are using water and believe that they are already doing a good job of managing it. Many are truly shocked when faced with the realities of complying with new water restrictions and regulations,

The nursery industry is positioned in a uniquely environmentally oriented sector of our economy. We are far more than merely an assembly of profit-making endeavors. We propagate and bring to market the "tools" to naturally clean up and maintaina healthy environment. The trees and plants we produce are the solution to many of society's environmental (and perhaps social) problems. In many respects, our industry is comprised of people who are actually "practical environmentalists." In the absence of availability of living plants, society would be forced to resort to far less efficient artificial ways to filter water, recycle wastes, clean the air, and render life enjoyable. It is clearly in the best long-term interests of society that the nursery industry continue to thrive.

In this context, I believe our industry faces a critically important two-fold task. First, we must convince nursery operators that there is a problem with their perception of status quo water management and that future restrictions on water use are imminent. Second, we must show nurseries what a good water management program looks like, how each of them can reasonably achieve it, and how to market themselves effectively as prudent water managers.

It seems appropriate to characterize our current water management situation as a national (or even international) challenge requiring local solutions. Even though many policies and actions can be mandated and initiated nationally, it is only through local accomplishments that they can be truly effective. To their credit, our national nursery and landscapeassociations have begun to identify successfully in the minds of the consumer the value of nursery products to the environment, how living plantsare important to a person's health and well-being, and, of course, the aesthetic beauty of trees and shrubs. They are in an appropriate position to begin communicating in a similar manner the value of effective water management within our industry and to the public.

At the local level, the way our nurseries are perceived is the critical issue. Perception varies region by region and nursery by nursery depending on a number of factors, some of which may be beyond the nursery operator's control. An operation in a nonfarming region is certainly regarded differently than a similar one in a community accustomed to farmers and farming activities. Often the visibility of water use or the perception of water waste or conservation is a significant factor. What may be considered normal irrigation practice in Iowa or Texas might appear entirely wrong or inappropriate in Massachusetts, even though the activity may be identical. Attempting to educate the public about "normal" irrigation practices is a difficult long-term process at best and may even prove impossible in communities that have no way to relate to farming. This dichotomy becomes even more pronounced in times of stress, such as during water bans or water quality threats.

The relationship between an individual nursery and its community can also vary considerably, and often merely the attitude expressed by the nursery operator can make a major difference. The manner in which farmers assert their rights must be adapted to their standing in the community. It is one thing to be aggressive in a town that understands and supports the activities of the

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nursery; it is quite another to try the same approach in a region that does not understand or is antagonistic toward activities of the nursery. On the other hand, the nursery operating in a nonfarming community has an opportunity to position itself as unique and valuable, and it can give the area benefits that would be difficult to obtain in the absence of the nursery (such as open land, sites for meetings, inexpensive plants, interesting employment for students, etc.). It is at the local level that we find the greatest opportunity to enhance our industry's image by effectively demonstrating and communicating our prudent use of water.

The plan of action developed by WMC involves both a defensive and a proactive stance. The defensive activity encompasses a determination of our industry's base-line water needs, knowing which water regulations currently affect our nurseries, anticipation of future regulations, and identification of whatwater management resources are now available to us. Much of this is already underway. The WMC has set up a database to collect information from any member or region that wishes to participate. The AAN has also funded through the Horticultural Research Institute a number of studies on water use and management. Many other agricultural and horticultural groups are also sponsoring water studies and research. Knowing accurately where we are enables us to use our resources wisely and build our efforts from a position of strength.

As water becomes more scarce and as national concerns over the quality of water intensify, asignificant increase in theamount of guidanceat the national level is essential. This is where our national associations must assert a strongly proactiveand aggressive stance that enables local nurseries to demonstrate and communicate effectively how they prudently manage their water resources. The nursery industry must establish a national water-management policy that is acceptable to all nurseries and that provides uniform guidance on standards for prudent water use. Such a policy not only creates a framework for individual nurseries to use in their management of water, but also provides the mechanism for effectively telling our story to the public.

Our AAN WMC is now in the process of drafting "best management practices" for all segments of the nursery industry. Our intent is to document and analyze experiences of nurseries across the country in managing water. We believe this will help avoid duplication of efforts, recognize and step around pitfalls that others have encountered, and create bench marks against which we may measure progress. We foresee how presenting specific examples will enable nursery operators to use proven methods that have been effective for others. It also helps to develop a source of new ideas that will make it easy for people to build on successes of others. As an offshoot, we also hope that there will be such a vast amount of attention devoted to water issues that all nursery operators will clearly recognize the importance of water management to their future well-being.

As important as it is to do the right things with our management of water, telling our story effectively to those outside our industry will ultimately ensure that nurseries are perceived as prudent water managers. Nursery operators are by nature generally conservative and often reticent in telling others about their accomplishments, but communicating how and why we are effective managers of water is in many ways the most critical part of our strategy.

Nurseries face major challenges in preserving their right to use water. I believe we are making progress in identifying the problems and educating the members of our industry, but there is far more than we can accomplish by ourselves. The research community occupies a unique position in its ability to assist nursery operators on at least two fronts. First, there is an established network of communication that enables researchers to be very efficient in their use of resources. Second, and perhaps most important, researchers are by their nature very scientific in their approach to solving problems. They are perceived by the observer to be neutral in approaching solutions and their expertise confers credibility on the results. I believe it is by intelligently using the authoritative information provided by the research community that we can most effectively establish nursery operators as prudent water managers.

Research already has provided our industry with a vast amount of information on water management, largely in the areas I have referred to as the defensive part of our strategy. We still need more study, particularly on the specifics of water management for various regions and climates. Much of the recent research has focused on the proactiveand innovative aspects of water management. Studies such as those on controlling runoff and practical recycling are invaluable in creating good water-management programs. The leaders in our industry must continue to define our needs to enable researchers to concentrate on the most critical needs of nurseries. We must also commit to continuing funding to ensure future research.

To confidently assert that nurseries are managing their water resources effectively, we must ensure that nurseries use the information available to them and implement the recommendations from the researchers. This is no small task in a diverse and independent industry such as ours, but unless we are effective in this effort, it will be very difficult to present and support honestly our image as prudent water managers.

One of the major shortcomings of our industry is our apparent inability to communicate effectively vital information among ourselves and to those outside our industry, We must tap into some sort of network that enables us to distribute that information to those who need it. The AAN's WMC database seems to be a reasonable beginning to making information available, but we need guidance on how to set it up and use it most effectively so that the right people can benefit from the information. I am sure some members of the research and extension community can assist us in this effort. We may even discoverthat much of what we must do has already been accomplished, thereby avoiding waste of valuable resources through duplication of efforts.

Perhaps one of the most productive areas in which researcherscan furtherassist nurseries is in this communication process. Some researchers are equipped to communicate with those outside the nursery industry by using university resources, extension publications, or public relations resources Most have the ability to convey information within the nursery industry. I believe it is by combining and managing these communication networks that the research community can be of immense assistance in assuring the future of the nursery industry. It is apparent to me that the effectiveness of our communication efforts, especially with those who regulate us, will ultimately determine how successful we are in retaining our water use options.

Our longer-term objective must be to continue this educational process and to include eventually our customers and the public. While this is undoubtedly a worthy goal, our primary efforts must be concentrated on assuring the survival and well-being of the nursery industry itself. Some of the challenges of water supply and quality appear overwhelming, especially compared to the situation only a few years ago, but it is entirely appropriate for us as nursery operators to serve as the true protectors of theenvironment and providers of trees and shrubs for generations to come.

Researcher's Perspective on Current and Future Water Quality **Research**

Robert D. Wright

There is an expression that says, "Take change by the hand before it takes you by the throat." The change that is occurring in the public arena is one of perception, One of the contributors to this workshop stated that there is a perception in the public's eye that agriculture is the villain; the one contaminating and using too much water. There is also the perception that agriculture is the cause of all nitrates in groundwater.

I think the hand of change is still extended. The hand is very weak, but we can still take change by the hand and cooperatively develop crop production techniques that are safe for the environment. It is especially encouraging to see the recent cooperation among industry leaders, ASHS, and universities. We can do some things in the future to demonstrate that those in the nursery industry are environmentalists. We are trying to prevent global warming and to provide an atmosphere so people can enjoy life on this planet. We are not trying to poison the water systems of the world.

One of the problems with the nursery industry is that in some cases excessive amounts of fertilizers and pesticides are used. In another session, Charles E. Hess, the Assistant Secretary of Agriculturefor Science and Education, alluded to this specific problem with nurseries. I am not sure of the exact quote, but he made it clear that there is a problem with the nursery industry. Basically, the problem is that five to 10 times more fertilizer is used on container nurseries—whether slow-release or liquid fertilizer — than is used on field-grown agronomic crops. And of that applied, only a small percentage is actually used by the plant. The rest is going somewhere. But where does it go? About 4 to 5 years ago, I was visiting nurseries trying to determine the extent of nutrient runoff from container nurseries. I went into one nursery to check the runoff to see if it contained any pesticides or fertilizers. The manager immediately said that he did not have any runoff problems, so I could go right ahead. While I was there, I took a water sample from a drain leaving the nursery and found elevated nitrate levels in the water.

From a research perspective, I really did not know the extent of the problem for container nurseries, so a regional study was initiated involving Virginia, North Carolina, Florida, and New Jersey to monitor runoff of nutrients from container nurseries. Alabama, Ohio, and Washington later became part of the study. Grants from the Horticultural Research Institute and Grace-Sierra helped fund the study. Basically, we found that there is often a problem for container nurseries in relation to nutrient runoff, but there are some nurseries that grow excellent plants by properly using slow-release and liquid fertilizers, singularly or in combination, without having unacceptable levels of nutrients in the runoff. With current technology, nutrient runoff problems can be prevented. Yes, it will be at greater expense to the nursery operator, but runoff can be prevented. There are examples of nurseries that have overcome runoff problems by either retaining all runoff water and recycling it, or using the best management irrigation and fertilizer practices so that runoff water meets U.S. Environmental Protection Agency standards. If researchers, educators, nursery operators, and industry organizations work together, we can overcome the runoff problems and demonstrate to the public that we are good managers of the environment.

As far as specifically identifying critical areas in which to concentrate research, I would like to emphasize the importance of relating nutrient and pesticide runoff to irrigation management. Nutrient runoff and irrigation scheduling cannot be separated. There are many examples in the journals of nutrient management studies where no consideration was given to irrigation frequency and amount. When evaluating plant growth as the end product in our research programs, we must consider the interaction between fertilization and irrigation. The changing nutrient and water demands of a plant during the growing season must also be taken into consideration. With the technology available to determine plant and soil water status, it is possible to schedule irrigation based on plant need. We need to consider the plants nutrient needs on a weekly or monthly basis as the plant develops. We must develop some understanding of plant nutrient needs as they change during the growing season.

In recent years, we have been perplexed over how to supply nutrients in relation to plant need. If we read the literaturecarefully, we may find insight into our questions without conducting extensive research, and we will not have to reinvent the wheel. For example, one way nurseries have reduced water and fertilizer use is to apply small amounts of water and nutrients in multiple applications during the day. This would be in contrast to applying all the water and nutrients in one application. This approach is supported by basic plant science research that demonstrates that a plant will absorb just as much N if the root is exposed to low concentrations of nutrientsand the low concentration is constantly maintained. The plant will take up as much nutrients and grow just as fast as the plant growing under high-nutrient conditions. The driving force for nutrient uptake is plant need. If nutrients are maintained at that root interface, even though the concentration may be low, comparable nutrient uptake will occur. Obviously, the approach of applying small amounts of water and nutrients frequently reduces the potential for nutrient leaching and runoff from nurseries.

Controlled-release fertilizers certainly have a place in managing nutrition of container-grown plants. We need to understand more about how these fertilizers work, and how the nutrient release characteristics relate to plant nutrient uptake. We need to be working with manufacturers to develop controlled-release fertilizers that release nutrients in relation to plant need. Currently, many of these products release too much fertilizer in the early part of the season, when plants need less, and too little in the latter part of the season, when plants require more.

For a long time, I have been a proponent of fertilizing to get the maximum plant growth rate possible since nursery plants are sold according to plant size. Considering the law of diminishing returns, growth decreases with each increasing addition of a nutrient after reaching a growth threshold. For example, it may take only 100 units of N to reach 90% of maximum growth, but it may require another 100 units of N to reach 100% of maximum growth. The 200 units of N vs. the 100 units may be the way to go since a larger plant would probably result in 50 to 75 cents more per plant. However, if that nursery operator is faced with paying $1000 a day in fines because of excessive nitrates in the runoff water, the nursery operator may settle for 90% of maximum growth and have clean water leaving the nursery.

Also, we do not want to get away from the pesticide issue. The mentality in the retail trade is if a plant has leaf damage due to an insect or disease, then it is not marketable. Maybe we will have to accept some plants with insect damage in the garden center. During the 1990 ASHS Annual Meeting, I became even more convinced of this. In the colloquium, "The Impact of Reduced Pesticide Tolerance Legislation," we learned that when dealing with the production of cabbage for making sauerkraut in New York, standards are set on the number of thrips that would beallowable in the sauerkraut. Now, if processors can tolerate a few thrips in their sauerkraut, why can't we, in the interest of reduced pesticide usage and clean water, have a few insects or some insect damage on our nursery plants that go into the landscape?

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