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The Use of a Non-Point Source Pollution Self-Assessment for Greenhouse and Nursery Operators in California

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Abstract: Water quality rules adopted in 2001 in San Diego, California, created new requirements for greenhouse and plant nursery growers to manage surface run-off that could potentially affect drinking water, recreational locations, and wildlife habitat. A "Run-off and Non-Point Source Pollution Self-Assessment for Greenhouse and Container Nurseries" was developed as a series of worksheets that translated technical information for growers to meet legal requirements, maintain their property value, and enhance the quality of their environment. Self-assessment results determined a need for additional training on run-off management and prevention pollution through more site-specific fertilization and pest

management techniques based on routine monitoring.

Introduction

Water Quality Regulations with Respect to Agriculture in San Diego, California

Agriculture is the fifth largest industry in San Diego County, California, with a total reported value of $1.46 billion and the full economic impact estimated at over $5 billion. Recent quarantines due to exotic pests, rising energy costs, and water quality issues have placed extreme pressure on agriculture producers in San Diego County. Addressing agricultural non-point source pollution and run-off is no longer an option for growers in San Diego County, but a mandatory regulatory reality. The Clean Water Act (C.W.A.) of 1977 originally focused on "point-sources" of pollution, or readily identifiable discharges from a particular "point," such as a drainage pipe, but in 1987, the C.W.A. was amended to address non-point source pollution from diffuse sources (USEPA, 2006).

Agricultural non-point source pollution moves with rainfall and snowmelt over and through the ground and may contain numerous compounds, including sediments, fertilizers, pesticides, salts, and animal manure-all of which may contain various nutrients. Excess nutrients flowing into surface waters can impair water bodies and aquatic ecosystem functionality and are associated with nuisance and toxic algal blooms, health problems, and increased municipal water treatment costs (Carpenter, Caraco, Correll, Howarth, Sharpley, & Smith, 1998; Howarth, Anderson, Cloern, Elfring, Hopkinson, Lapointe, Malone, Marcus, McGlathery, Sharpley, & Walker, 2000). A watershed-scale approach to non-point source pollution management and total maximum daily loads (TMDLs) is the current U.S. Environmental Protection Agency focus in surface water quality regulations (USEPA Office of Water, 1999).

Water quality rules adopted in 2001 by the San Diego Regional Water Quality Control Board created additional requirements for growers to manage surface run-off entering waterways, storm drains, and coastal areas with the potential to affect drinking water, recreational locations, and wildlife habitat. Responsibility lies with the grower in identifying potential compliance issues and selecting best management practices (BMPs) to comply with regulations or risk fines. In contrast to other locations in the U.S., San Diego County has unique challenges related to non-point source pollution and run-off, including extensive irrigated agriculture, heavily developed urban areas, seasonal rainfall, hilly and mountainous topography, and 11 coastal watersheds that drain into the Pacific Ocean. Due to a favorable climate, southern California coastal watersheds are particularly vulnerable to degradation from urbanization, and as coastal watersheds undergo increased conversion, nutrient loading is expected to increase (Robinson, Leydecker, Keller, & Melack, 2005).

Only 5% of San Diego's drinking water comes from local ground and surface water supplies (SDCWA, 2005), but the water quality of waterways has implications for wildlife and aquatic habitat and the coastal beaches that are important to San Diego's tourism economy. In recent years, land management has increasingly focused on watersheds and reversing the trend towards declining fish and wildlife populations and improving drinking water quality (Conway, Godwin, Cloughesy, & Nierenberg, 2003). Average rainfall in San Diego County is approximately 10 inches per year and occurs between October and April. Algal blooms and eutrophication from nutrient overloads and excessive sedimentation can create problems for aquatic life, along with contaminants and other run-off entering any of the 11 watersheds that feed coastal waters. Although residential and urban landscaped areas also contribute to these problems, agriculture is targeted as a major contributor of these contaminants.

Potential Pollution Effects from Greenhouses and Plant Nurseries

The primary pollution concern from greenhouses and plant nurseries is irrigation run-off, but "dry weather run-off," including wash run-off, water treatment system discharge, and liquid spills, must also be contained and managed on the property, according to water quality regulations. Growers are required to prevent contaminants, sediments, fertilizers, pesticides, hazardous materials, trash, green waste, and organic matter that may occur in "wet weather run-off" from entering storm drains and waterways through proper materials storage, equipment maintenance, and erosion control.

Nitrate concentrations from greenhouse operations in California was determined to average 4.4 pounds per acre per inch of storm water over a 2-year period (Robinson, Leydecker, Keller, & Melack, 2005). With the onset of wet weather, nutrient concentrations can be high due to accumulated dry season deposition of fertilizers and other nutrient sources, although, initially, storm discharge is low because of high soil moisture deficits (Robinson, Leydecker, Keller, & Melack, 2005). With continuing storms, however, storm discharge can increase as soil moisture levels meet or exceed field capacity and groundwater and shallow subsurface waters flow into storm discharge. Additionally, pesticides may create problems. Within a 100-acre commercial nursery in California, researchers found significant amounts of two synthetic pyrethroid pesticides, biefenthrin and permethrin, in nursery run-off (Kabashima, Lee, Haver, Goh, Wu, & Gan, 2004).

Self-Assessment Tools for Managing Pollution

Self-assessment tools have been developed for a wide variety of topics, such as environmental audits to ensure farmers' compliance with applicable legislation in Great Britain (Blake, 2006). The term "audit" and the concepts behind an audit are similar to a self-assessment, as both involve assessing or analyzing inputs and potential impacts. Previous research has shown that participants in self-assessments will be motivated to make changes to reduce pollution risks if these issues are perceived as threatening to family well-being, the value of their property, and the quality of their environment (Castelnuovo, 1999).

Many agricultural self-assessment tools exist in the U.S., including the USDA Farmstead Assessment System (Farm*A*Syst), a nationwide program that was designed to expand farmer knowledge regarding pollution risks to groundwater associated with storage and use of pesticides and fertilizers (Holsman & Krueger, 2002) and the Greenhouse*A*Syst program to assess water management, environmental risk and business profitability (University of Georgia, 2005). Other examples include an educational tool in Kansas to address total maximum daily load (TMDL) regulations (Graber, 2003); the "Livestock System Environmental Assessment" (LSEA) tool developed for producers to identify the level of risk for current practices, such as land application of manure and runoff controls for outdoor feedlots in Nebraska (Koelsch, Howard, Pritchard, & Hay, 2000); and an advanced self-assessment tool that results in a set of recommended BMP's for the livestock producer to protect water quality (Hudson, Harrison, & Koelsch, 2006). Self-assessments have also been used to illuminate the true state of pollution risks from nutrient loading from livestock feed rations (Downing, French, Peters, & Higgs, 2007).

With pressure from encroaching urban areas and an increasing emphasis on clean water initiatives, practical, inexpensive approaches to regulatory run-off issues must be developed to help growers remain viable. In response to this need, personnel at the University of California Cooperative Extension Service in San Diego County have developed education and research programs, including a self-assessment tool for growers for managing agricultural run-off and to aid in improving water quality in San Diego County. The "Run-off and Non-Point Source Pollution Self-Assessment for Greenhouse and Container Nurseries" tool was developed in 2002 in response to San Diego County growers' expressed confusion regarding new water quality regulations. The need arose to assist growers with determining which aspects of their operations could be considered out of compliance with these regulations and BMPs that could be instituted to remedy potential problems.

Objectives

The overall goal of the Agriculture Water Quality Research and Education Program at UC-Extension, San Diego, is to maintain clean drinking water for all citizens of San Diego County and to assist growers in meeting clean water regulations. Because greenhouses and plant nurseries must be inspected for run-off and contaminated storm water as part of new regulations in San Diego County, the objective of the study reported here was to develop and administer a self-assessment tool to help greenhouse and nursery managers identify existing run-off and non-point source pollution issues and to begin a self-education process of developing BMPs for their operations. By engaging growers in developing and administering the self-assessment tool, Extension personnel gained understanding of the challenges faced by growers and the need for future programs to address these challenges.

Procedures

Requirements for the self-assessment tool were simplicity and ease of use in addressing all run-off regulations pertinent to greenhouse and plant nursery growers. The major resources for topic questions and explanations were the Extension publication *Management Options for Nonpoint Source Pollution, Greenhouse and Container Crop Industries* (Robb & Mellano, 1998) and the San Diego County run-off regulations (County of San Diego, 2002). The Extension publication provided practical answers to the growers' questions, and the San Diego County run-off regulations were used as a checklist to ensure all required items were being addressed. In addition to these resources, personal observations and experience obtained while visiting numerous greenhouse and nursery properties assisted in designing questions and writing explanations.

In the process of deigning the self-assessment tool, several agricultural operations were surveyed to determine average quantities of irrigation run-off and factors affecting run-off volume, such as irrigation efficiency, weather, crop moisture requirements, topography, proximity to drainage areas, and soil permeability. Run-off volumes observed in San Diego County greenhouses ranged from 3 to 15 gallons per 1000 ft of greenhouse surface (DeJong, 2001), signifying a need to modify practices to comply with regulations. After evaluating all factors affecting run-off in a typical operation, the self-assessment tool was written and pre-tested on six nursery and greenhouse growers who expressed interest in evaluating their operations. After the questionnaire was revised based on input from the pre-testing sector, the final questionnaire was written and distributed.

The final self-assessment tool contained 50 major questions (sample questions in Figure 1), with additional sub-questions. The questionnaire was designed to serve as a checklist for property attributes and potential compliance issues. Previous research determined that worksheets that translate technical and legal information into a format non-experts can apply to their property are the most useful to prevent pollution (Castelnuovo, 1999).

The questionnaire was designed to function as an educational tool without requiring outside assistance or references, except in the most complex of issues. Similar to other self-assessments, worksheets prompted growers to examine different aspects of their facilities and activities to uncover pollution risks (Castelnuovo, 1999). The major outline of the self-assessment tool included six categories: 1) property management; 2) road management; 3) irrigation practices; 4) leaching and run-off; 5) nutrient assessment and fertilizer management, and 6) pest management.

A simple yes/no format was designed in a two-column table for ease of use. A "no" response did not always indicate a pollution problem or violation of a regulation, but may have indicated to the grower a need to further investigate a potential problem. Questions were followed by brief explanations of the importance of the question to run-off, pollution, and/or BMPs, and included brief suggestions to resolve any problems raised under each issue.

Figure 1.
Sample questions from the "Run-off and Non-Point Source Pollution Self-Assessment"

1. **Does irrigation and other dry weather runoff remain on the property?** All irrigation and other dry weather run-off is prohibited from entering the storm drain system, which includes street gutters, public waterways, and other conveyances that drain to public waterways. Other dry weather run-off includes all types of wash run-off and discharge from reverse osmosis systems. Discharging dry weather run-off onto neighboring properties is not allowed unless done with consent. Dry weather run-off may also not be discharged onto or across public streets and roads.	___Yes ___No ___N/A
2. **Is the property located away from public waterways, which includes streams, rivers, lakes, lagoons, wetlands, and bays?** A higher potential to pollute exists when public water bodies are located directly on or adjacent to a growing operation. In addition, commercial operations near public water bodies designated as "impaired" under Clean Water Act section 303(d), or regulated under a "total maximum daily load" (TMDL) requirement may have more stringent requirements.	___Yes ___No ___N/A

The self-assessment tool was made available to growers through the Extension Web site and distributed at monthly educational seminars and tours conducted by the Extension office. Growers voluntarily completed the self-assessment, and their responses were anonymous. Results of the survey were recorded, and response percentages were tabulated for each question.

Results

Assessing Operation Characteristics Affecting Run-off

The clientele associated with the self-assessment tool consisted of full-time growers. Due to the considerable time commitment required to execute the detailed, 13-page questionnaire, we were fortunate to have 33 growers complete all pages of the self-assessment and allow sufficient time to meet with Extension personnel to discuss their results during an individual site visit. These 33 questionnaires contained thorough, detailed responses and were critical in evaluating the current state of knowledge and compliance with water quality regulations among San Diego County nursery and greenhouse growers.

Assessment by growers themselves, as opposed to Extension staff completing the questionnaire for them, was integral to the success of the project (Holsman & Krueger, 2002). The size of the operations in the study ranged from 2 to 200 acres, with an average size of 26 acres (Table 1). Of the 33 respondents, the largest group (43%) was greenhouse operators, 41% operated container nurseries, and the remainder of respondents had mixed operations. Forty-one percent of growers surveyed had open surface waters (e.g., creeks or sumps) present on their properties, which would increase the need to monitor the volume and content of run-off from their property.

Table 1.

Non-Point Source Pollution Self-Assessment Responses Related to Operation Characteristics

Legal or Technical Parameter	Percent of Respondents
Type of Operation	
-Greenhouse	43.2^{z}
-Containers	40.5
-Shade House	13.5
-Nursery	27.0
Surface type used in indoor production areas	
-Gravel	100
-Cement	37.5
-Native soil	25.0
-Plastic	50.0
-Weed cloth	50.0
-Ground cover cloth	25.0
Surface types used in outdoor production areas	
-Gravel	50.0
-Plastic	12.5
-Ground cloth	12.5
Open surface waters present on property	
-Yes	41.2
-No	58.8
Type of waterway	
-Creek	17.0
-Wetland	0
-Pond	0
-Sump	5.9
Connection of private drains	
-Storm water system	63.6
-Creek/Pond	9.1

-Storage tank	9.1
-Evaporation area	9.1
-Not sure	9.1
Shading compounds used on greenhouses	
-Latex paint	45.4
-Double binder	18.2
-Shade cloth	18.2
-Single binder	9.1
-No binder	9.1

[z]Summation of responses under each question may be less than or greater than 100% due to the percent of growers who reported multiple applicable practices or did not answer.

Unlike typical rural agricultural operations across the U.S., 91% of respondents used municipal water sources, with 18% using recycled irrigation water (Table 2). Fifty percent of respondents reported that their employees received training in run-off, spill, waste, and sanitation management and all applicable regulations.

A major challenge for horticultural operations in San Diego County is the poor quality of imported irrigation water, which, along with many local wells, contains high levels of soluble salts that accumulate in plant containers and root zones. Excessive salts are often leached by applying more water than is necessary for crop moisture needs in order to flush the water and salts below the root zone or out of a container. In some field situations, this extra water will simply soak deep into the soil. In other situations, the topsoil may be shallow and subsurface run-off will drain to bedrock or hardpan and begin to move down-slope. In container situations, the extra water will flow out of the container and either soak into the soil below or create surface run-off.

Table 2.

Non-Point Source Pollution Self-Assessment Responses Related to Water Use and Leaching Practices

Legal or Technical Parameter	**Percent of Respondents**
Location of runoff exiting property	
-Storm drain	54.4[z]
-Neighboring property	36.4
-Surface waters	9.1
Washing runoff	
-Remains on property	11.8
-Storm water system	17.6
-Not sure	29.4
Sources of irrigation water	
-Municipal	90.9
-Well	18.2

-Creek/Pond	18.2
-Recovered irrigation	18.2
Types of irrigation systems	
-Overhead	54.5
-Drip	54.5
-Hand water	63.6
-Micro-sprinkler	27.3
-Loop	9.1
-Spot-spitter	9.1
Methods to determine irrigation schedules	
-Visual cues	100
-Pot weight	9.1
-Tensiometer	9.1
-Evapotranspiration	9.1
-Temperature	9.1
-Transpiration	9.1
-Timer	9.1
-Other	18.2
Factors used to determine amount of leaching	
-EC of root media	36.4
-EC of leachate	18.2
-pH	18.2
Frequency of fertilizer application	
-Every watering	63.6
-Throughout life cycle	9.1
-Varies	9.1
[z]Summation of responses under each question may be less than or greater than 100% due to the percent of growers who reported multiple applicable practices or did not answer that question.	

Assessing Nutrient and Pest Management Practices

Another challenge to maintaining water quality is the practice of injecting soluble fertilizers through the irrigation system. Leachate from containers or the field soil root zone can create a higher risk for discharging run-off that is very high in nitrates. Forty-nine percent of growers reported regularly monitoring their water quality, and 81% of those reported keeping water quality records. Despite the water-saving efficiency of drip irrigation, only 54% of respondents were relying of this method, and only 18% of respondents used tensiometers or other instruments to base watering on plant needs versus predetermined schedules.

Regarding potential run-off contaminants, 64% of respondents practiced constant liquid fertilization (fertilizing at every watering), and 22% added wetting agents to pot media, with 100% using synthetic or readily mobile forms of fertilizers, predominantly ammonium nitrate (73%). Per local regulations, 91% collected irrigation run-off and 63% stated that they were able to contain all run-off on their properties. A total of 36% of those surveyed based fertilization schedules on plant nutrient requirements, and of those, 27% use plant tissue testing and 37% use soil tests (Table 3). Injector systems designed for different ratios of fertilizers were employed by 27% of respondents, thus applying fertilizers at rates more sensitive to plant needs.

Table 3.
Non-Point Source Pollution Self-Assessment Responses Related to Nutrient and Pest Management

Legal or Technical Parameter	**Percent of Respondents**
Crop nutrient requirements well defined and utilized	
-Yes	36.4[z]
-No	9.1
Factors used to determine amount, timing and frequency of fertilization	
-Lab results	27.3
-Plant conditions	18.2
-Weather	9.1
-Stage of crop	9.1
-Experience	9.1
-Time of year	9.1
-Temperature	9.1
-Type of plant	9.1
-EC	9.1
-pH	9.1
Types of fertilizer application	
-Synthetic	100
-Compost/Manure	0
-Other	9.1
Method of fertilizer application	

-Incorporated	27.3
-Top dressed	45.5
-Injected	90.9
Type of nitrogen used	
-Ammonium nitrate	72.7
-Ammonium sulfate	9.1
-Nitric acid	9.1
-Calcium nitrate	36.4
Pests managed on property	
-Aphids	45.4
-Spider mites	36.4
-Mealy bugs	36.4
-Other mites	36.4
-Whiteflies	36.4
-Weeds	27.3
-Thrips	27.3
-Snails	27.3
-Caterpillars	18.2
-Diseases	18.2
-Other insects (beetles, scale insects, ants, plant bugs, fungus)	9.1
[z]Summation of responses under each question may be less that or greater than 100% due to the percent of growers who reported multiple applicable practices or did not answer that question.	

Another major challenge in managing run-off in San Diego County is the rolling topography on which many nurseries and greenhouses are located. Even if irrigation run-off can be eliminated during dry weather, soil and substrate erosion control is a constant challenge during wet weather. Certain management practices, such as terraces, can help manage run-off and erosion on slopes. Thirty percent of respondents stated that they managed their non-production areas of their properties to prevent erosion, and 46% managed these areas to prevent run-off and contamination from fertilizers and pesticides. Despite BMPs to prevent run-off, 90% of respondents stated that some of their irrigation exited their properties. The majority (73%) managed drainage pipes on their properties that were connected to storm water systems.

With the advance of Integrated Pest Management (IPM) in California agricultural operations, the use of persistent pesticides has declined. All respondents reported using monitoring before spraying pesticides, with 36% monitoring with traps. The majority of pest species managed in these operations were aphids (45%), spider mites (36%), and mealy bugs (36%), with the next highest ranking (27%) assigned to thrips, snails, and whiteflies. Over 15 pesticides were reported from these operations, with 18% reporting using pesticides approved for organic production. Fifty-one percent reported using biological controls. Other methods of preventing excessive application of pesticides included the use of resistant or tolerant cultivars. Twenty-seven percent reported using these in their operations.

Conclusions

The Value of Grower-Focused Management Schemes

Water quality issues related to pesticide and nutrient run-off will continue to exert great pressure on greenhouses and plant nurseries nation-wide. Initially, the 2001 water quality regulations affecting San Diego County growers were perceived as confusing for many growers, and some were skeptical about allowing outside persons, including Extension personnel, to analyze their properties. Similar to other Extension surveys on the West coast (Downing, French, Peters, & Higgs, 2007), growers were very knowledgeable about water quality issues, but self-assessment results verified that additional training and action was needed for all growers to be in full compliance.

Because of the strong commitment in the U.S. to voluntary approaches to pollution prevention that are centered on education, technical assistance, and economic incentives (Castelnuovo, 1999), Extension staff members were able to elicit accurate responses by developing and distributing a simple self-assessment tool in concert with growers. This assessment process helped identify key areas in need of attention, such as improving containment of run-off on production properties, while recognizing and reinforcing BMPs already implemented by the affected grower. While cost-share incentives for preventing water pollution may encourage behavior change more than educational material (Holsman & Krueger, 2002), growers in San Diego County who completed the self-assessment nevertheless requested additional training on computer-based water quality monitoring systems that scheduled fertilization based on plant nutrient requirements and BMPs for least-toxic pest management for ornamental crops.

Further extending the utility of the self-assessment tool, BMPs described for surface run-off in the self-assessment tool could also be applied towards groundwater protection in general, as evidenced by an Extension office in Ventura County, California, that used the information to guide the development of water quality self-assessments for their local growers.

Potential Solutions with National Implications

Innovative responses to regulations, such as a group of California growers' implementation of BMPs, including optimizing irrigation, creating sediment traps and ponds, establishing vegetative strips, and adding polyacrylamide to the effluent to bind pollutants, can significantly reduce pesticides in nursery run-off (Kabashima, Lee, Haver, Goh, Wu, & Gan, 2004). In this era of rising urban populations and increased scrutiny of the agricultural sector, Extension is in a unique position to help guide compliance of clean drinking water regulations through self-assessment tools that are designed to alert, as well as educate, the agricultural community, particularly in highly urbanized areas.

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