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E299

Bulletin

Pest and Pesticide Management Practices in Nursery Operations

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Introduction

A pest may be an insect, fungus, weed, slug, rodent, or plant disease agent. A pesticide may be a chemical used to control a pest. Therefore, insecticides, rodenticides, herbicides, and fungicides are all types of pesticides. Biopesticides are certain types of pesticides derived from natural materials. Pesticides used in nursery settings should be selected not only to control the pest, but also to limit its ability to negatively impact the environment. Runoff water from irrigation and rainfall can be contaminated with fertilizers and pesticides sprayed on nurseries operations. The runoff can cause possible contamination in both surface and groundwater. Therefore, it is critical that all runoff be minimized by the efficient use of irrigation systems and wise management of environmentally sensitive chemicals.

Pest control and pesticide management are integral parts of the best management practices during the growing period of nursery crops. Nursery producers grow a vast range of nursery plant species and cultivars in containers which makes pest management a complex operation. Management practices that include combinations of pesticide and non-pesticide methods promote beneficial organisms, and minimize the applied amounts of pesticides. These practices are defined as integrated pest management practices (IPM). IPM is a sustainable approach to managing pests by combining biological, cultural, physical, and chemical tools in a way that minimizes economic, health, and environmental risks. An IPM program involves using resistant cultivars, building up populations of beneficial organisms, monitoring numbers of pests, developing treatment thresholds, and using spot treatments of pesticides that are least harmful to beneficial organisms and the environment. IPM can be used to systematically allocate pest management resources in response to both fluctuating pest pressures and market needs. It is important to identify pests early on, so that appropriate measures can be taken quickly. For easy access to information of interest on nursery IPM, check the website link *www.pestmanagement.rutgers.edu/IPM/index.html*.

Recommendations on Pest and Pesticide Management in Nursery Operations:

Adopting an IPM program. Assign an "IPM manager" to coordinate and assign responsibilities for **scouting pests**. Use a plant location map of your nursery to scout for pest problems to determine appropriate control options on a weekly basis. Locate pest problems, assess the threat to crop health and appearance, and apply the appropriate pest control tactics. Increase the frequency of scouting for signs of disease and remove any diseased plants from production beds quickly. The web link: *www.entm.purdue.edu/Entomology/ext/targets/e-series/EseriesPDF/E-213.pdf* provides general information (not all aspects tested in NJ) on sources for scouting supplies, approximate insect and mite action threshold for key insect and mite pests for woody plants in nurseries, pest control guidelines, and IPM problem reporting forms for insects and diseases. These forms are helpful to use to keep records of the pest activity and pest management actions.

Detection and monitoring devices. Simple hand lenses help identify some insects and plant diseases. Special devices and tools are available to detect and monitor insects in some crops. These include pheromone traps and other attractants, blacklight traps, and sticky traps. Monitoring or scouting is used to determine the number and types of pests present. If the monitoring program indicates that the pest outbreak is confined to a particular

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location, spot treatment of only the infested area will save time and money, and will conserve natural enemies located in other parts of the nursery operation. Refer to Rutgers Cooperative Research & Extension Bulletin, E036, *Pest Control Recommendations for Shade Trees and Commercial Nursery Crops*, to access more information on pests that attack various nursery crops, time of occurrence, and recommended pest control measures. To identify insect pests that attack different parts of nursery crops and the symptoms of their damage refer to website *http://woodypests.cas.psu.edu/PestDiagnosis/index.html*.

Use beneficial organisms (natural enemies) in pest control. Include plants that have diversity in flowering times, such as herbs (fennel, caraway, chervil, and coriander), coneflowers, daisies, lavender, and sunflowers, around the production beds. These promote beneficial organisms, such as green lacewings, ladybird beetles, praying mantis, ground beetles, trichogramma wasps, and spiders that prey on detrimental pest species. For example, natural enemies of pests such as aphids include ladybird beetles and their larvae, green lacewing larvae (aphid lions), whereas, braconid and ichneumonid wasps parasitize the larval and pupal stages of juniper webworms. In most nursery situations, conservation of naturally occurring biological control organisms is emphasized. Use care in selecting and spraying pesticides. Apply pesticides at time when beneficial insects are likely to be present, if intended pesticide will not kill or injure beneficials. Incorporate biological management options in your spraying program. For example, bacterial insecticides such as *Bacillus thuringiensis* (Bt) var. *kurstaki*, *Bacillus thuringiensis* var. *san diego* are useful in controlling early instar of caterpillars. The website *www.nysaes.cornell.edu/ent/biocontrol/* provides information on biological control agents, their description (including life cycle), and their photographs.

Selection and use of pesticides. Apply pesticides, when needed, based on **economic threshold.** An economic or action threshold is reached when the cost of potential damage exceeds the cost of control. Use traditional chemical pesticides effectively following manufacturers' recommendations and label directions. Consider using pesticides with water solubility of 5 ppm or less, low persistence (half-life, $T_{1/2}$), and/or a low potential risk for leaching (pesticides with higher potential for soil adsorption, K_{oc}). Include in your spraying program some of the many highly effective, softer pesticides that are much less toxic to the environment, for example, horticultural oils or soaps. **Biopesticides** are certain types of pesticides derived from such natural materials as animals, plants, and bacteria. These pesticides are usually inherently less toxic than conventional pesticides and generally affect only the target pest and closely related organisms, in contrast to broad spectrum, conventional pesticides that may affect organisms as different as birds, insects, and mammals. They are often effective in very small quantities and decompose quickly, thereby, resulting in lower exposures and largely avoiding the pollution problems caused by conventional pesticides. When used as a component of IPM programs, biopesticides can greatly decrease the use of conventional pesticides, while crop yields remain high. Microbial and biochemical pesticides fall under biopesticides. Microbial pesticides consist of a microorganism (e.g., a bacterium, fungus, virus, or protozoan) as the active ingredient. For example, there are fungi that control certain weeds, and other fungi that kill specific insects. The most widely used microbial pesticides are subspecies and strains of *Bacillus thuringiensis*, that specifically kills one or a few related species of insect larvae. Biochemical pesticides are naturally occurring substances that control pests by non-toxic mechanisms compared to conventional pesticides, which are generally synthetic materials that directly kill or inactivate the pest. Biochemical pesticides include substances, such as insect sex pheromones, which interfere with mating, as well as various scented plant extracts that attract insect pests to traps.

Pesticide application. To achieve balance in controlling the pest, and protect the environment, the applicator must be knowledgeable of a pesticide's efficacy and water solubility. The latter can be obtained from the pesticide's label and material safety data sheet (MSDS). Avoid applying pesticides when weather is not favorable for spraying such as during windy days (above 5 mph), rainfall is imminent or long hours of irrigation are scheduled. Use the correct application rate as indicated on the label. Increasing the rate, increases the cost, contributes to the potential for resistance development by the pest, increases chances of environmental contamination, and is illegal. Follow a safe pesticide use checklist in conjunction with the label directions anytime you plan to use a pesticide. Protect water bodies, when spraying pesticides. Leave an unsprayed buffer strip around surface waters or near other sensitive areas (such as wetlands). For detailed information on handling pesticides, refer to RCRE bulletin E261, *www.rcre.rutgers.edu/pubs/pdfs/e261.pdf*, and MCE pesticide information leaflets no. 9 and 11 at *www.pesticide.umd.edu/Leaflets.html*.

Fate of pesticides. Know the soil type in your nursery and ground water level to assess the potential risk from various pesticide management options. Shallow water tables tend to be more vulnerable to contamination. **Soils with high**

clay or organic matter contents may hold water that may carry pesticides, and reduce its movement to the ground water. Soils with coarser particle size hold less water than finer textured ones. If leaching or runoff is likely to occur, steps should be taken to prevent contamination. Such measures may include less pesticide application frequency, and incorporation of non-chemical tactics. Use pesticides that have a low water solubility, shorter half-life and higher sorption coefficient.

Applied pesticides may evaporate, adsorb to soil particles, stay in solution, be broken down into other substances, or taken up by plants or insects. The primary factors that decide the chemical's fate are the pesticide properties, the soil properties, site conditions, soil moisture and temperature, soil microbial populations, and the application practices. The more water soluble a chemical is, the more likely it is to leach. **Pesticides that are adsorbed or tightly held by soil particles are less likely to leach through soil profile to ground water** (Table 1). Adsorption depends on chemical properties, soil type, and organic matter content. Pesticides are degraded by many natural forces, including sunlight, plants, microbes, and naturally-occurring chemical reactions in the soil. Most pesticide degradation occurs in the top few inches of the soil. The longer the compound persists in the soil, the longer it is available to leach into ground water. **Persistence** (half-life, $T_{1/2}$) is a term given to the days required for the pesticide in soil to degrade to one-half of its previous concentration. Each half-life that passes reduces the amount of pesticide present in the soil by one-half, for example, 1 to 1/2 to 1/4 to 1/8 to 1/16, etc. In general, the longer the half-life, the greater the likelihood the pesticide will be able to move into surface or ground waters and cause environmental impacts (Table 1). **Nonpersistent pesticides have a half-life below 30 days, moderately persistent have a half-life of 31 to 99 days, and persistent pesticides have a half-life greater than 100 days.** Pesticides that are highly soluble in water may contribute to ground water contamination more than those which are not. **Water solubility** is the degree to which a pesticide can dissolve in water, measured in parts per million (ppm). Solubility affects how easily a pesticide can runoff or leach. In general, pesticides with solubility of 1 ppm or less tend to remain at the soil surface, tend not to leach, but may move off-site with soil. **Pesticides with water solubility greater than 30 ppm are more likely to leach**. Chemicals that vaporize are considered volatile. If chemicals are highly volatile and not very water soluble, they are less likely to leach into ground water. However, highly volatile compounds that are also highly soluble in water may become ground water contaminants. The coarser the soil is, the faster the movement of percolating water, and the less opportunity for adsorption or evaporation. Soils with higher clay or organic matter content have greater numbers of micropores, tend to hold water and dissolved chemicals longer, and provide higher surface area for pesticide adsorption. Each soil type has a soil adsorption property, which is the tendency of the pesticide to become attached to soil. The higher the soil adsorption capacity, the more likely the pesticide will attach to the soil and move off the land with soil erosion. The lower the adsorption capacity, the less likely the pesticide will bind with the soil, but the more likely the pesticide will have the potential to runoff or leach to groundwater. Leaching and runoff potential characteristics are directly related to the soil adsorption and water solubility characteristics. Quite often a trade-off must be made between two pesticides, and the final selection of that pesticide should be based on the soil and groundwater conditions. If one pesticide has a low potential leaching factor and another with a high one, then the low leachable pesticide should be chosen to protect the groundwater. The Groundwater Ubiquity Score, or **GUS**, frequently is used to rate pesticides for their potential to move downward groundwater. The GUS is a number that relates pesticide persistence (half-life) and sorption (K_{oc}) in soil. A pesticide with short half-life and high K_{oc} will have a lower GUS than a pesticide with long half-life and low sorption coefficient. Pesticides with a score of less than 2.0 have a low leaching potential; those scoring 2.0–3.0 have a moderate leaching potential; and those with a score above 3.0 have a high leaching potential. Refer to Table 2 for more information on the pesticides movement, persistence, water solubility, and sorption coefficients.

Proper irrigation management. Pesticides should be applied efficiently and at times when runoff losses are minimal. Don't turn on the irrigation system immediately after pesticide application, or when rain is expected that day, unless required by a pesticide's label. Managing irrigation rates (less contact time of water on leaf surface) in an overhead irrigation system during hot summers reduces disease spread and excess use of pesticides. Some diseases that attack nursery crops are in what is known as the "water mold" group of fungi, such as *Pythium* and *Phytophthora*. These pathogens thrive in high moisture. Therefore, when environmental conditions favor the development of water-mold fungi, carefully manage your irrigation to avoid excessive or poorly timed irrigation. In addition, recycled irrigation water that may contain disease organisms, should be decontaminated before application to reduce spread of water mold pathogens to nursery crops.

Management of recycled water. Decontamination practices can be implemented to treat water for disease organisms by retention and dilution, filtration, chlorination, ozonation, and/or UV light. For more information about water sampling and analysis for Phytophthora spp, and treating strategies of recycled water in nursery operations, visit the website: *www.ento.okstate.edu/zoospore/phytophthora/monitor/index.html*.

Water samples from recycled irrigation water should be done at different points to determine pathogen presence and levels. Additionally, it is recommended to check the pH of recycled water, before it is used for mixing and spraying pesticides, to ensure pesticide effectiveness. Recycled water may have a pH range between 7and 9. Many pesticides undergo hydrolysis in water with pH of 9.0 or above. Many pesticides, that commonly use organophosphate and carbamate insecticides, undergo a chemical reaction in the presence of alkaline water. This reaction is called **alkaline hydrolysis**. The pesticide is hydrolyzed and rendered ineffective in water with a pH greater than 7. You can adjust your spray solutions to the 4–7 pH range with commercially available buffering agents. General information on half-lives of selected pesticides at different pH values, and methods for testing and adjusting the pH of alkaline water used for mixing pesticides can be found at the website: *www.ag.unr.edu/wsj/Factsheets/96-18h20.pdf*.

Storing, mixing and rinsing stations. Use proper safety equipment and protective clothing when you apply and handle pesticides. Safety equipment should at least consist of unlined neoprene or rubber boots and gloves; waterproof hat, coat, and coveralls; an approved respirator, and proper measuring equipment. For more information refer to RCRE bulletin, E261, 11 pp. *www.rcre.rutgers.edu/pubs/pdfs/e261.pdf*.

Store protective clothing used for spraying in a location separate from the pesticides. Store equipment used for measuring and mixing pesticides in the pesticide storage room/building. Follow all federal, state, and local laws and regulations governing the use, storage, and disposal of pesticides, and the training of applicators and pest control advisors. Pesticides should be stored in a cool, dry, well-ventilated facility with an impermeable floor. There should be no floor drain situated 100 feet or less from any well, stream, or pond. Do not store pesticides in underground tanks. Mix pesticides at least 100 feet from any well, stream, or pond. After spraying, unused or excess pesticides should be sprayed over a production area and should not be dumped by washing the pesticide containers down drains. Disposal of empty pesticide containers should follow instructions provided on the container. Utilize hazardous chemical collection days to get rid of old chemicals.

Keeping records of pesticide uses and tests. All applications of pesticides must be recorded by the applicator. Records are useful when runoff, drift, or leaching occurs. Records should include: date of application, chemical applied (trade name and formulation), rate per acre (or square feet), total amount of spray and active ingredient applied, method of application, plant material treated, size of the area treated with pesticides, purpose of application (target pest(s)), weather and soil conditions at time of application, most recent date of calibration, and name and license number of applicator. Evaluate and record the effectiveness of previous control strategies during weekly inspections. Keep records of soil and water tests as a reference for making future pesticide application decisions.

Containment and clean up of spills. Train personnel to manage pesticide spills in mixed and storage areas and to clean up pesticide spills in production areas. Have supplies for the clean-up of pesticide spills readily available. These include kitty litter, sawdust, and buckets. A fire extinguisher approved for chemical fires should also be readily accessible. Have emergency telephone numbers visibly posted, and first aid equipment readily available.

Summary

Selection of the appropriate pesticide should first be based on the type of pest which needs to be controlled. If more than one pesticide can be used to control the pest, choose the pesticide that will yield the desired control results and have the lowest potential to cause any adverse environmental impacts. Choose the pesticide that fits into your pest management strategy and is the least toxic alternative. Including non-chemical practices in a management program reduces cost, resistance to chemicals, and enhances beneficial organisms' populations. Selection of pesticides with low leachability, low runoff potential, low persistence value, low water solubility, and high soil adsorption capacity lower chances to contaminate ground water.

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Table 1. Potential impact on groundwater and surface water using pesticide persistence and sorption properties[†].

Persistence	Sorption	Potential Impact	
		Groundwater	Surface Water
Nonpersistent	Low-Moderate	Low	Low
Nonpersistant	Moderate-High	Low	Moderate
Moderately persistent	Moderate-High	Moderate	Moderate
Moderately persistent	Low-Moderate	High	High
Persistent	Moderate-High	Moderate	High
Moderately persistent and persistent	Low-High	Site-specific conditions determine ground water or surface water impacts	

[†]Adopted from Rao, P.S.C., and A.G. Hornsby. 2001. Behavior of pesticides in soils and water. Soil Science Fact Sheet SL40, University of Florida, Gainesville, FL. *http://edis.ifas.ufl.edu/SS111#footnotes*.

Table 2. Properties† of commonly used pesticides in nursery operations.

Common Name	Pesticide Movement Rating	Soil Half-life, $T_{1/2}$ (days)	Water solubility (mg/L)	Sorption coefficient, K_{oc} (ml/g OC)
acephate	Low	3	818,000	2
alachlor	Moderate	15	240	170
ancymidol	High	120	650	120
atrazine	High	60	33	100
azinophos-methyl	Low	10	29	1,000
bifenthrin	Extremely Low	26	0.1	240,000
captan	Very Low	2.5	5.1	200
chloropicrin	Extremely Low	1	2,270	62
chlorothalonil	Low	30	0.6	1,380
chlorpyrifos‡	Very Low	30	0.4	6,070
clopyralid	Very High	40	300,000	6
dazomet	Moderate	7	3,000	10
diazinon‡	Low	40	60	1,000
dichlobenil	Moderate	60	21.2	400
dicofol	Very Low	45	0.8	5,000
diflubenzuron	Extremely Low	10	0.08	10,000
dimethoate‡	Moderate	7	39,800	20
diquat dibromide	Extremely Low	1,000	718,000	1,000,000
diuron	Moderate	90	42	480
eptc	Low	6	344	200
endosulfan‡	Extremely Low	50	0.32	12,400
esfenvalerate	Very Low	35	0.002	5300
ethophon	Extremely Low	10	1,239,000	100,000
ethoprop	High	25	750	70
etridiazole	Moderate	103	50	1,000
fenamiphos	High	50	400	100
fenbutatin-oxide	Low	90	0.0127	2,300
fenpropathrin	Very Low	5	0.33	5,000
fluvalinate	Extremely Low	7	0.005	1,000,000
fosetyl-aluminum	Extremely Low	0.1	120,000	20
glyphosate	Extremely Low	47	900,000	24,000
hexythiazox	Very Low	30	0.5	6,200
iprodione	Low	14	13.9	700
isoxaben	Low	100	1	1,400
malathion	Extremely Low	1	130	1,800
mancozeb	Low	70	6	2,000
metalaxyl	Very High	70	8,400	50
metaldehyde	Low	10	230	240
methiocarb	Very Low	30	24	3,000
methyl bromide	Very High	55	13,400	22
myclobutanil	Moderate	66	142	500
napropamide	Moderate	70	74	700
norflurazon	Low	30	28	700
oxadiazon	Very Low	60	0.7	3,200
oxydemeton-methyl	High	10	1,000,000	10
pyrethrin	Extremely Low	12	0.001	100,000
resmethrin	Extremely Low	30	0.01	100,000
simazine	High	60	6.2	130
thiodicarb	Low	7	19	350
thiophanate-methyl	Very Low	10	3.5	1830
thiram	Low	15	30	670
triadimefon	Moderate	26	71.5	300
trifluralin	Very Low	60	0.3	8,000

†Adopted from Augustijn-Beckers, P. W. M., A. G. Hornsby, and R. D. Wauchope. 1994. The SCS/ARS/CES pesticide properties database for environmental decision making II. Additional compounds. Reviews of Environ. Contamin. Toxicol. 137:1-82. Wauchope, R. D., T. M. Buttler, A. G. Hornsby, P. M. Augustijn-Beckers, and J. P. Burt. 1992. The SCS/ARS/CES pesticide properties database for environmental decision making. Reviews of Environ. Contamin. Toxicol. 123:1-155. Vogue P.A., E.A. Kerle, and J.J. Jenkins. 1994. OSU Extension Pesticide Properties Database *http://npic.orst.edu/ppdmove.htm*.

‡EPA has phased or in process of phasing out insecticides due to safety concerns.

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