Best Management Practices and Self-Assessment

Water and Fertilizer Use for Outdoor Container Production

Canada

Ontario

Contents

Getting Started

Water and nutrient management is fundamentally important to the profitable production of container-grown woody and herbaceous crops. Best management practices (BMPs) can help you to improve production efficiency and protect our environment by making the best use of water and nutrient resources.

BMPs are voluntary tools that can help you:

- scrutinize the current use of water and fertilizer at your production facility
- prioritize your water and fertilizer use
- determine where improvements can be made
- document ongoing improvements.

Every BMP will not be suitable for every operation and goal. Your completed Environmental Farm Plan (EFP) and this Self-Assessment can help you determine which BMPs to implement in your outdoor container production system.

Start by taking a comprehensive and critical overview of your production areas.

1. Map all source, stored and post-production water movement on and off your property.
2. Review all fertilizer and chemical storage and mixing areas to ensure proper containment.
3. Identify areas on your property where current production practices may impact surface or ground water.
4. Test all irrigation, container yard runoff, as well as collected and stored water for pH, EC, bicarbonates, sulphates and nutrients.
5. Calculate and record your current water and fertilizer use per unit area of production.
6. Describe how water and fertilizer are collected and stored for reuse.
7. Develop and review contingency plans for when irrigation water availability is restricted or quality reduced, and for post-production water storage.
8. Evaluate potential for effective conservation of water and nutrient inputs.
9. Know and comply with all local, provincial and federal bylaws and regulations.

In the following Self-Assessment, BMPs are grouped by production stage:

Irrigation Water Management: management of water and nutrients before application to the outdoor container production area

Crop Nutrient and Water Management: management of water and nutrients within the outdoor container production area

Runoff Management: management of water and nutrients after runoff intercepts the outdoor container production area

Each section is guided by the following key principles:

- Know your water quantity and quality throughout the system.
- Manage water and nutrient inputs efficiently.
- Maximize collection and reuse of post-production water.
- Maximize storage capacity and integrity to keep post-production water contained.

Implementation of the BMPs provided in this document does not remove the operator's responsibility to ensure compliance with applicable legislation, including municipal, provincial and federal requirements.

Container production farms must be managed in accordance with applicable legislation such as the *Conservation Authorities Act, Environmental Protection Act, Lakes and Rivers Improvement Act, Nutrient Management Act, Ontario Water Resources Act* and the *Pesticides Act.*

Self-Assessment

To help decide which BMPs to implement in your production system, start by completing the Self-Assessment.

How it Works

For most questions, there are four answers listed in separate columns. Each column has a number ranking: 4, 3, 2 or 1. In some instances, where the answer is either Yes-4 or No-1, only two columns are listed. Check the box ☑ that most accurately describes the current situation for your operation.

Practices described under Columns 4 and 3 (on left-hand side of tables) improve nutrient and water use by reducing the amount of water and nutrients requiring management post-production.

Practices identified in Columns 1 and 2 may be improved upon by implementing the BMPs listed under each Self-Assessment question.

After completing the Self-Assessment, review the practices you identified as candidates for improvement (ranked as 1 or 2). Document your Self-Assessment score and create a plan for improving your score. Consider the suitable BMPs that can be implemented to improve your management of water and nutrients, and choose those that you can apply in the next 1–3 years. Improving the management of water and nutrients in outdoor container production systems is a work in progress.

A IRRIGATION WATER MANAGEMENT

Management of water and nutrients *before* application to the outdoor container-grown crop or production area

Know your water quality before it becomes part of your production system. If you are aware of the undesirable attributes and nutrients in your source water, you can take pre-emptive measures to reduce the quantity of water and nutrients that will have to be managed post-production.

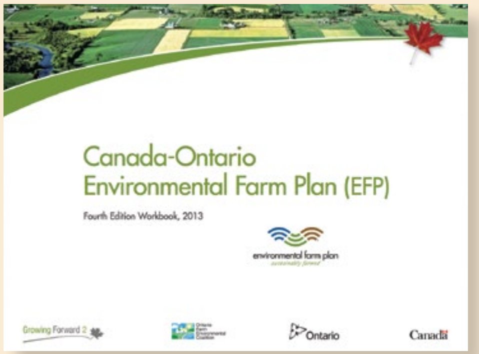
1. Do you have an up-to-date, completed and peer-reviewed Environmental Farm Plan (EFP)?

4	1
☐ Yes	☐ No

BMP: Complete an EFP for your container operation.

Attend an EFP workshop and create a peer-reviewed action plan.

The EFP is a voluntary education and awareness program designed to help Ontario farmers prepare confidential and self-administered risk assessments on their farms. Action plans are developed to address identified concerns. Check with the Ontario Soil and Crop Improvement Association (OSCIA) for the most current edition.



An Environmental Farm Plan (EFP) helps participating farmers verify their good production practices and identify areas requiring improvement. Having an up-to-date completed EFP may entitle farmers to cost share-based funding.

2. Do you have an up-to-date map or schematic of your farm showing all incoming and outgoing surface and subsurface water on and off your property?

4	1
☐ Yes	☐ No

BMP: Know where source water enters and drain water leaves your operation, as well as how water moves through your operation.

Begin by identifying all irrigation water inputs and outputs on a map of your operation:

- inputs from municipal water, wells, surface water, storm water recapture etc.
- outputs from irrigation runoff and surface and subsurface drainage* systems (pre-existing and ones you have installed), catch basins and driveways.

Ensure your map also indicates:

- all locations of surface and ground water
- all sources of runoff from surface and roofs
- surface and subsurface drains and collection areas (ponds, cisterns)
- how surface water moves through your farm, to collection areas and off your property
- water movement through subsurface drainage pipes* – including subsurface drain pipes installed prior to outdoor production area construction, and those installed as part of the outdoor production area
- fertilizer and chemical storage area(s), including fuel storage tanks.

* "Tile drainage" is now referred to as "subsurface drainage".

Create an aerial map or schematic of your farm property. Clearly label all places where fertilizer and water are stored. Using arrows, indicate the movement of water throughout the property, including all types of potential runoff.

3. How do you protect your water sources? (Give yourself a point for each practice you employ.)			
4	3 Any three of the practices in column 4	2 Any two of the practices in column 4	1 Any one of the practices in column 4
☐ Any runoff or spillage from fertilizer and/or pesticide mixing area is contained and dealt with appropriately ☐ On-farm wells protected from contamination ☐ Systems in place (e.g. berms, drainage ditches) to divert production runoff to a collection pond ☐ Anti-backflow devices used when taking water for pesticide or fertilizer-mixing			

BMPs: Only collect and store water suitable for irrigation purposes.

Construct lined ponds (e.g. synthetic liner, compacted clay) to reduce loss of the stored water and capture surface runoff and precipitation. Constructed systems (including drains, berms, catch basins or ditches) can be used to help collect additional clean water of suitable quality into storage for later irrigation needs.

Minimize erosion in surface collection by lining water pathways to slow water and catch sediment before it reaches the collection pond.

Prevent water contamination by nutrients and pesticides by managing and storing pesticides and fertilizers responsibly and safely. For more information on protecting water well quality, see BMP12E, *Water Wells.*

Inspect, monitor and maintain wells. Where necessary, slope the ground surface away from the well and mound the earth around it, so that any surface water quickly flows away from the casing. For more information on protecting water well quality, see BMP12E *Water Wells* or MOECC manual *Water Supply Wells: Requirements and Best Practices.*

Follow EFP guidelines for separation distances from potential contaminant sources and wells. Test well water regularly. Properly abandon (plug and seal) any unused wells according to the Wells Regulation [R.R.O. 1990, Regulation 903 (Wells) as amended made under the *Ontario Water Resources Act,* R.S.O. 1990, c.0.40.].

Equip all water-taking systems with anti-backflow devices to prevent unintentional contamination of the water source. Mix pesticides and fertilizers well away from natural watercourses or ground water systems.

Install safety fencing on all ponds near public areas, and equip with basic rescue devices such as ropes, flotation devices, etc. Check for any municipal regulations.

Take precautions to protect the integrity of irrigation water sources – such as wells, collection ponds and eaves-fed cisterns. Protected water sources are less likely to experience water quality issues.

4. Do you sample your irrigation source water for analysis?

4	3	2	1
☐ Irrigation water sampled monthly during the growing season	☐ Irrigation water sampled two or three times during the growing season	☐ Irrigation water sampled once during the growing season	☐ Irrigation water not sampled

BMPs: Take irrigation source water samples throughout the year or when changing water sources for a complete analysis. See Question 5 BMP for more detail.

Document sampling dates and keep test results accessible for review. Incoming source water can be compared against production and post-production water to see how much production practices are influencing water quality.

OMAFRA has educational videos on sampling and testing irrigation water here: www.omafra.gov.on.ca/english/crops/hort/videos.htm

Test irrigation water quality throughout the crop cycle and when changing water sources.

Be familiar with the chemistry of your irrigation water, and know the water quality class to determine whether the water source is appropriate for use on your crops (e.g. propagation).

5. What is your irrigation water quality class?

4	3	2	1
☐ Class 1	☐ Class 2	☐ Class 3	☐ Don't know
EC <0.5 mS/cm* Na <30 ppm** Cl <50 ppm SO_4 <100 ppm HCO_3 <60ppm	EC 0.5–1.0 mS/cm Na 30–60 ppm Cl 50–100 ppm SO_4 100–200 ppm HCO_3 60–150 ppm	EC 1.0–1.5 mS/cm Na 60–90 ppm Cl 100–150 ppm SO_4 200–300 ppm HCO_3 >150 ppm	

* mS/cm = mmhos/cm
** ppm = mg/L

Class 1: Used for all purposes

Class 2: Used in substrate or soil culture where adequate leaching can take place.

Class 3: Not recommended for salt-sensitive crops. If EC exceeds 1.5 mS/cm, it is marginally suitable for outdoor container irrigation

BMP: Test your irrigation water source for:

- macronutrients: nitrate-nitrogen (NO_3-N) phosphorus(P), potassium (K), magnesium (Mg), calcium (Ca)
- micronutrients : manganese (Mn), molybdenum (Mo), copper (Cu), boron (B), zinc (Zn), iron (Fe)
- other components: electrical conductivity (EC), pH, bicarbonates (HCO_3), sodium (Na), chloride (Cl), sulphates (SO_4).

6. Management of irrigation water used based on chemical makeup of water (see Question 5)

4*	3*	2*	1*
☐ Water quality acceptable (Class 1 or 2, or meets crop requirements throughout the growing season) and/or high quality water (e.g. rainwater) held separately and used for sensitive crops, such as propagation, small-volume containers, and other sensitive crops	☐ Water quality has some limitations – water is managed by matching water quality to plant tolerances and water is treated where necessary to meet crop needs	☐ Some water quality limitations based on chemistry – water use is managed by matching water quality to plant tolerances as best as possible	☐ Water quality not ideal but water is used in production system without treatment or management for different crop tolerances

BMPs: Test water after it has been treated to ensure that irrigation water quality objectives have been met.

Match irrigation water chemical makeup to crop requirements. Treat water where necessary.

* Treatment of water does not include sediment filtration

Acidification is a common pre-irrigation treatment for the production of young plants and pH-sensitive crops. This treatment process will lower the pH to increase the availability of micronutrients (e.g. iron) in the growing media solution. Some growers will use acidifying fertilizers, but their acidifying effect in the container media will be limited and short-lived.

Visual inspection of irrigation equipment and filters, together with a review of water test results, will help determine if filtering and filter maintenance are adequate, and if an additional treatment method is necessary for source water.

7. Physical water treatment: If you filter surface water sources before irrigation, which physical pre-treatment do you use?

4	3	2	1
☐ Macro screening and pre-treatment of clean irrigation water such as stainless-steel stationary screen with a sand filter and a fabric filter	☐ Macro screening and pre-treatment of clean irrigation water such as stainless-steel stationary screen with a sand filter	☐ Macro screening (e.g. >1 cm particles cannot pass through) at intake pipe and no other screening or filtration	☐ Other (list) or do not screen irrigation water before application

BMPs: Filtering or screening out debris and sediments will improve the functionality of irrigation equipment.

Remove debris* and sediments** to maintain integrity and delivery uniformity of irrigation system.

Filter water prior to pathogen or chemical treatment to increase the effectiveness of water treatment options.

*Debris can be anything that might plug your irrigation system such as algae, biofilm, fish, or frogs.
**Sediments include suspended silts and clays.

Note: that the disposal of debris and backwash from filtering must be managed in accordance with applicable legislation such as the Ontario Water Resources Act and the Environmental Protection Act.

8. Do you know your maximum daily volumes required to irrigate your entire crop on a peak use day (L/day)?
To calculate Total Maximum Daily Water Use, see Worksheet 1 on page 30.

4	3	2	1
☐ Yes, water meter records used to document actual water use	☐ Calculated by multiplying pumping rates (based on recorded operating pressure for each event) by actual time for irrigation event	☐ Estimated based on average length of irrigation cycle	☐ No, don't know how much water is used

BMPs: Know the actual maximum amount of water you need. Ensure that you have access to adequate volumes of water, from reliable sources.

If you take more than 50,000 L on any day from a surface or ground water source, you must have a valid Permit to Take Water (PTTW) from the Ontario Ministry of the Environment and Climate Change (MOECC). For more information about obtaining a PTTW, contact your local MOECC office or see:
www.ontario.ca/document/application-permit-take-water

Knowing volumes for maximum daily water:

install water meters and record volumes to document volumes used for irrigation and other purposes.

keep records of dates, length of irrigation events, operating pressure and volumes used as these can be used to calculate water use.

If you are not using water meters, record the time of each irrigation event and multiply it by the pump output based on the actual operating pressure (recorded at each irrigation event) to calculate volume used.

Knowing the maximum daily water used can help you prepare an effective contingency plan for times when irrigation water becomes limited or the quality compromised.

Design irrigation systems, production, collection and storage areas to provide and handle those predetermined volumes of water.

Knowing the irrigation volumes required per production area is crucial when designing irrigation systems, production layout, water storage and water treatment systems. These volumes are also used to develop contingency plans for source water.

If you take more than 50,000 L or more of water per day, you will need a PTTW. If seeking permit renewal, apply well in advance of permit expiry.

9. If you use off-farm surface water (lake, stream etc.) as your irrigation source, when do you take water to replenish ponds and store for future irrigation use (high flow vs low flow)?

4	3	2	1
☐ At high flow only (e.g. early spring, late fall) and store it for long-term future use	☐ Strategically to minimize impacts on water source and store it for long-term use	—	☐ Whenever I need it with no consideration to source levels

BMPs: Design, construct or modify storages (e.g. ponds) for irrigation water to accommodate the harvest of water during periods of high flow to minimize harvest from surface sources during low flows.

Harvest water after peak flows for best quality and minimal impact on environment.

Know your local conservation authority's low water response plan and how it may affect your water use plan during extended dry/low water periods.

If you use surface water to augment your irrigation water supply, harvest and store the surface water when levels or flow rates are high.

Have a contingency plan in place for low water conditions. Secure alternative source(s) of water in case primary supplies become inadequate in volume or quality. This photo depicts replenishing a pond by using the lined ditch to channel the trucked water efficiently into the irrigation pond.

10. Do you have a contingency plan if irrigation water access is restricted, inadequate, or water quality becomes poor?

4	1
☐ Yes	☐ No

BMP: Develop and update a contingency plan to ensure available water during periods of low water or poor water quality.

Note: A contingency plan should include: alternative water sources, logistics for delivery, backup storage, and permanent water storage capacity to compensate for variability in water quantity and quality.

Be familiar with your local conservation authority's Low Water Response Plan and the members of their Low Water Response Team. Grower participation in regional water management teams can benefit both the team and the agricultural sector.

B CROP AND NUTRIENT MANAGEMENT

Management of water and nutrients *within* the outdoor container-grown crop or production area

Your crop nutrient and water management practices during crop production cycles will affect the quantity and quality of runoff water.

Maintaining water quality, reducing excess irrigation water lost as runoff, and minimizing unnecessary nutrient applications within the facility will reduce the quantity of water and nutrients that need to be managed in the runoff water.

11. Which one of the following best describes the features of your container production area that are designed and constructed to reduce ground infiltration and maximize the capture of runoff?

4	3	2	1
☐ Containers placed on compacted ground surface Container bed and all runoff pathways covered with an impermeable barrier; beds are crowned	☐ Containers placed on compacted ground surface Container bed covered with a semi-permeable barrier	☐ Containers placed directly on un-compacted ground surface Container bed covered with a semi-permeable barrier	☐ Containers placed directly on un-compacted ground surface Container bed is not covered with a semi-permeable barrier

BMPs: Maximize surface runoff collection by diverting water to lined (e.g. clay) irrigation ponds.

Select the site or modify site as needed to help protect ground water and surface water. Prior to constructing the outdoor container yard, assess site features: soil texture, topography, depth to water table and bedrock, and all off-site water sources for water entering the production area.

Construct beds to attain a crowning effect, where the centre of the bed is higher than the sides to facilitate excess water to drain away from the production surfaces. Use a gradual slope, compacted ground, and impermeable or semi-permeable surfaces to maximize crop water runoff diversion and for re-capture, as well as reducing ground infiltration.

Design the production area to capture as much runoff as possible for reuse.

Use impermeable or semi-permeable surfaces (e.g. landscape fabric, polyethylene film) to reduce erosion and maintain integrity of compacted ground surfaces on container beds as well as all pathways that runoff travels after intercepting the crop.

Reduce surface erosion by using concrete blocks and straw/hay bales to slow surface runoff, increase the removal of debris, and direct water flow.

Vegetate or line open waterway collection systems, and/or install check dams/riprap to slow water down, prevent erosion, and promote sedimentation prior to entry into irrigation ponds.

Maximize subsurface water collection using subsurface pipe, and divert to a collection pond.

Construct settling ponds ahead of irrigation ponds, where practical, to reduce sediment load to surface water.

Note: that The Ontario Water Resources Act prohibits the discharge of any material that may impair the quality of water.

Lined container production beds protect soil and prevent erosion. Ground materials below the liner are machine-compacted to prevent infiltration and support overland flow of irrigation runoff to a collection point.

A well-designed container bed and runoff collection system – with suitable slopes and protected collection channels – will divert irrigation runoff for collection.

12. Which of the following best describes the subsurface drainage pipes located within the outdoor container production area?

4	3	2	1
☐ 67–100% of container production beds have subsurface diversion or capture	☐ 34–66% of container production beds have subsurface diversion or capture	☐ Up to 33% of container production beds have subsurface diversion or capture	☐ No subsurface diversion or capture in/between any container production bed

BMPs: Maximize subsurface runoff water collection using subsurface pipe and divert to a collection pond.

Know where subsurface pipe outfalls are located and monitor them to ensure they are working.

13. Which of the following best describes how your irrigation system was designed?

4	3	2	1
☐ 100% of the irrigation system designed by a qualified irrigation designer* to meet crop production requirements (e.g. different container sizes, media, crop architecture and water requirements)	☐ Greater than 50% of the irrigation system designed by qualified irrigation designer*	☐ Less than 50% of the irrigation system designed by qualified irrigation designer*	☐ None of the irrigation system designed by qualified irrigation designer* to meet production crop requirements (e.g. different container sizes or crops)

BMP: Use a qualified irrigation designer familiar with the irrigation delivery system you require.

Note: The irrigation delivery system design should optimize irrigation efficiency and conserve water through uniform application and optimal timing of irrigation events.

* A qualified irrigation designer has formal training and experience in the design and layout of irrigation systems. Expertise is required to ensure that the system applies water in appropriate volumes to all cropped areas and avoids non-cropped areas. Pumping and transmission piping is sized to ensure energy and cost efficiencies.

Qualified irrigation specialists can help design and size irrigation systems to meet crop needs while maximizing efficiency in uniformity and interception.

14. How often do you maintain your irrigation system and evaluate it for delivery uniformity?			
4	3	2	1
☐ Irrigation system is monitored every irrigation event; repairs completed immediately if necessary; regular irrigation maintenance completed at the start/end of each season	☐ Irrigation system is monitored twice a week; repairs completed immediately if necessary; regular irrigation maintenance completed at the start/end of each season	☐ Irrigation system is monitored weekly or monthly; regular irrigation maintenance completed at the start/end of each season	☐ Irrigation system is not regularly monitored; regular irrigation maintenance completed at the start/end of each season or only as required

BMPs: Monitor and visually inspect the irrigation system regularly during each irrigation event.

Ensure that your annual maintenance plan includes monitoring and repair of pumping equipment.

Repair and clean nozzles, emitters, filters and lines often or as needed.

Install monitoring equipment (water volumes/pressure gauges/flow meters) as an early warning tool to detect changes in water volumes and application rates.

Test individual nozzle/emitter output, pressure and catch-can volumes to assess application uniformity.

Keep maintenance and water use data records.

For more information, check out the OMAFRA nutrient and water BMP videos: www.omafra.gov.on.ca/english/crops/hort/videos.htm

Regular inspections of your irrigation system at each irrigation event can help detect mechanical problems early and minimize crop losses from over/under-watering.

15. Which of the following decision tools are used to schedule irrigation events?

4	3	2	1
☐ By comprehensive crop monitoring,* use of an irrigation scheduling model, and detailed record-keeping to calculate and initiate an irrigation event Irrigation scheduled using some of the following: • evapotranspiration data (sunlight, temperature, wind etc.) • moisture sensors • flow meters	☐ By comprehensive crop monitoring* and intuitive approach with record-keeping and tracking rainfall, selected pot moisture content (weight) etc.	☐ Intuitive approach by considering recent and forecasted weather, no comprehensive crop monitoring, scheduling or record-keeping	☐ System initiated on time schedule (e.g. management by calendar) with no consideration for environmental conditions, media, light etc.

* "Comprehensive crop monitoring" includes inspecting crops, roots and monitoring their moisture level

BMPs: Schedule irrigation events by monitoring weather conditions, crop needs, and container moisture levels (e.g. weight).

Use comprehensive crop monitoring* techniques. This includes physically reviewing each irrigation zone for plant visual clues (e.g. leaf or bloom wilting, pot weight). Several containers in each bed or zone are assessed to make decisions about irrigation event timing and duration.

Use models to schedule irrigation events. Evapotranspiration models help direct irrigation scheduling by estimating crop water loss. Collect and record climate data (e.g. wind speed, temperature, precipitation, relative humidity) and substrate moisture data (e.g. weights) for decision-making around irrigation scheduling.

When possible, time irrigation events for early morning to reduce evaporative losses and foliar disease, and irrigate during low to no wind conditions.

See also these BMP publications: *Water Management and Irrigation Management*.

Inspect the wetness level and moisture uniformity of the container media as well as crop root growth to make daily decisions regarding the frequency and length of an irrigation event.

Environmental data such as wind, relative humidity, temperature and precipitation can also be used alone or as part of an evapotranspiration model.

16. What time of day do you usually initiate overhead irrigation?

4	3	2	1
☐ Early morning (1–3 hours before/after sunrise), or cloudy days with low wind (<10 km/hr)	☐ Mid to late morning	☐ Irrigation timing, after 12:00 pm but before sunset	☐ No consideration of time of day, or wind speed

BMPs: When possible, time irrigation events for early morning to reduce evaporative losses and foliar disease, and irrigate during low wind conditions.

Know your local conservation authority's low water response.

To improve overhead irrigation uniformity, irrigate crops when windspeed is less than 5 km per hour.

Reduce water loss due to evaporation by irrigating 1–3 hours before/after sunrise.

See also these BMP publications: *Water Management and Irrigation Management*.

Where possible, irrigate with overhead sprinklers in the morning (within 1–3 hours of sunrise). Lower temperatures and low wind conditions mean less evaporative losses of water and greater application uniformity and interception by the crop.

Know the volume of water applied to each crop. Water use can be used to plan production area layout and also help make more informed decisions around crop proximity to environmentally sensitive areas.

17. Do you know how much water is required to irrigate each crop type (e.g. deciduous shrubs) for each irrigation event (L/ha)?

4	1
☐ Yes	☐ No

BMP: Determine how much water you require to irrigate your crops each day for all of your production areas so that you can plan ahead. Place plants needing the most water and nutrients farthest away from surface water and ground water sources to reduce risk of any impact.

Knowing the total volume of water required for each crop type will give you a sense of relative water use for each of your crops, and can help when planning production layout in relation to irrigation pressure needs, nutrient use, runoff collection and proximity to environmentally sensitive areas.

Knowing these volumes will also help you determine whether current water supplies are adequate, and help you develop an effective contingency plan in case water sources become unavailable or quality is impaired.

You will need to know:

- types and sizes of crops and their production area size (ha)
- water output per nozzle (gpm)
- number of nozzles per ha, and
- average irrigation cycle length (minutes).

For each crop type (e.g. 2 gallon evergreens), calculate:

water output per nozzle (gpm) × number of nozzles per ha × total area irrigated (ha) × average irrigation cycle length (minutes) = total volume required

The Total Maximum Daily Water Use you calculate in Worksheet 1 on page 30 will help with calculations.

18. What is the average % leaching fraction for crops receiving overhead irrigation?
For help with determining % leaching fraction, see Worksheet 2 on page 31.

4	3	2	1
☐ 0–15%	☐ 16–25%	☐ 26–40%	☐ >40% or don't know

BMPs: Ensure that the amount of water applied in an irrigation event does not significantly exceed the water-holding capacity of the substrate.

Note: "Leaching fraction" (LF) is the volume of water leached from the bottom of the pot divided by the total water irrigated on the pot. "Percent LF" is the LF multiplied by 100. An ideal LF is when less than 15% of water applied to substrate passes through the container.

Measure the volume of leachate that occurs in different production zones for different container volumes or substrates. Without actually measuring LF, the tendency is to underestimate leachate volumes, which may lead to excessive leaching – wasting water and nutrients.

Maintain a consistent, moist root ball. Irrigate to the point where only a little water trickles out from the bottom of the pot.

Use plastic-lined pots to measure % leaching fraction in each crop group. When combined with physical examination of media wetting front and root growth, %LF can be used to evaluate whether the volume of water applied at each irrigation event is too much or not enough.

19. How do you optimize irrigation efficiency in your overhead sprinkler irrigated systems?
For help with determining Interception Efficiency, see Worksheet 3 on page 33.

4	3	2	1
☐ Containers placed in a triangular, or staggered pattern as shown in the figure B below or minimal distances between the containers are maintained for maximum interception efficiency Plants grouped according to water/nutrient requirements Irrigation water distribution uniformity evaluated regularly or at least monthly Overhead sprinklers can be shut off when no crops are in the growing area	☐ Containers placed in a triangular, or staggered pattern as shown in the figure B below OR minimal distances between the containers are maintained for maximum interception efficiency Plants grouped according to water/nutrient requirements Irrigation water distribution uniformity (nozzle output, nozzle pressure, catch cans) evaluated at least once a year	☐ Containers placed in a triangular, or staggered pattern as shown in the figure B below OR minimal distances between the containers are maintained for maximum interception efficiency Plants not grouped according to water/nutrient requirements Irrigation water distribution uniformity (nozzle output, nozzle pressure, catch cans) not evaluated since installation	☐ Containers placed in a rectangular pattern as shown in figure A or random and not a triangular, or staggered pattern Plants not grouped according to water need or container size Irrigation water distribution uniformity (nozzle output, nozzle pressure, catch cans) never evaluated

BMPs: Tighten pot spacing, where canopies allow, to increase interception efficiency and adjust sprinklers to apply water only to areas where plants are standing.

Maintain irrigation nozzle pressure to ensure proper and uniform output (gpm) throughout the container bed.

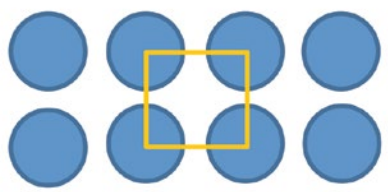
Evaluate nozzle pressures with a pressure gauge and measure actual volume output for each nozzle throughout the bed. Maintain a <10% pressure differential between nozzles. This can be achieved through the use of uniform nozzle type use, check valves and pipe diameters as required.

To help assess distribution uniformity, place catch cans (e.g. 20 L pails) throughout the production block. Measure volumes in catch cans over a known irrigation event length and map out volumes visually to better understand the distribution uniformity of the irrigation system and its limitations (e.g. dry spots).

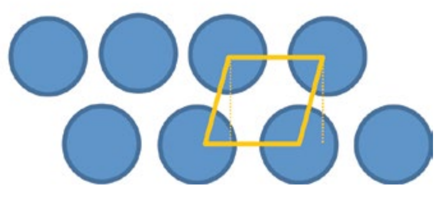
Use a low-volume irrigation system for high-value or large, widely spaced containers where practical.

Create management zones for crops based on similar water and fertilizer requirements, crop size and canopy architecture, e.g. plants grouped by age, type (conifer, broadleaf evergreen, deciduous), pot size, soilless mix, water and nutrient requirements. Place plants needing the most water and nutrients farthest away from natural surface water and ground water systems.

Where canopies allow, place pots as close together as practical. For round pots, a staggered arrangement is best.



A. Rectangular pot spacing



B. Staggered pot spacing

Container placement arrangements can be configured to maximize the proportion of irrigated water captured by the crop. Triangular (or staggered) container spacing will improve interception efficiency of the overhead irrigation.

20. Do you use pulse or cyclic irrigation (two or three applications of water with time off in between each) as your method of overhead irrigation?

4	3	2	1
☐ Yes, greater than 75% of the irrigation is applied by pulse irrigation	☐ Yes, 25–75% of the irrigation is applied by pulse irrigation	☐ Yes, less than 25% of the irrigation is applied by pulse irrigation	☐ No, all overhead irrigation is carried out in one uninterrupted application

BMP: Practise cyclic/pulse irrigation where possible to reduce the overall amount of water applied in an irrigation event.

Pulse or cyclic irrigation is the practice of splitting a long irrigation event into smaller, shorter, incremental applications. The shorter applications are separated by a period with no water being applied. Pulsed cycles reduce total water used and significantly improve thorough wetting uniformity of the substrate throughout the pot. The goal is to apply water in smaller amounts that can be more effectively used by the plants, rather than in one large application that produces more deflection of water, higher leaching fraction percentages and the potential for greater runoff volumes.

For example, instead of an irrigation event consisting of 60 minutes of uninterrupted water application, the irrigation events consists of two or three shorter cycles of 10–15 minutes with 30–60 minutes intervals of no irrigation in between. The break between irrigation applications allows for better infiltration of the media and more even wetting of the soilless mix. The use of pulse or cyclic overhead irrigation can reduce total volume of water applied by up to 33%. Monitor EC levels of media and/or pour-through leachate to ensure nutrient salts are not accumulating in the pots. Fertilizer rates may need to be reduced with the use of pulse or cyclic irrigation.

Cyclic irrigation is the total daily application of water broken up into two or three smaller applications, with periods of no irrigation in between. This technique results in more even wetting of the media and significantly reduces the total volume of water required (by as much as 33%).

21. How often do you test nutrients (N-P-K), pH and EC (soluble salts) in growing media and/or pour-through solution?
For more information, see Worksheet 4 – Nutrient Testing for Container Media on page 35.

4	3	2	1
☐ At least four times during the growing season (May–Oct.) or cropping cycle	☐ Two or three times per growing season (May–Oct.) or cropping cycle	☐ Once during the growing season (May–Oct.) or cropping cycle	☐ Never

BMPs: Analyze growing media for nutrient levels throughout the production/cropping cycle to detect nutrient issues early.

Test media nutrient (N-P-K and micronutrients), pH and soluble salt levels every two to four weeks, especially when changes are made to irrigation water or media sources

Test growing media EC (pour-through method appropriate for in-house testing), pH and crop development stage to determine fertilizer application rates or by using a commercial soil laboratory.

Analyze each crop group separately, e.g. conifer, broadleaved evergreen and deciduous crops have different nutrient requirements depending on crop age, media and irrigation method.

Review results and interpretations for salts, bicarbonates, pH and EC, and compare to crop growth and quality. Keep records and refer back to results often to assist in improving crop quality and management. Use these results in conjunction with crop health monitoring to detect any correlations that might be corrected through modifying crop management methods.

Take substrate samples throughout the crop cycle and have them analyzed for nutrients to ensure proper levels of nutrients for plant uptake. High levels of nutrients in the media may indicate underwatering, excessive heat or overapplication of fertilizer.

Key media and water parameters to measure:

Do-it-yourself pour-through and media	pH, EC
Media lab test	pH, EC, NO_3-N, NH_4-N, P, K, Mg, Ca, Cl, Cu, Fe, Mn, Na, SO_4, Zn
Leachate lab test	pH, EC, NO_3-N, NH_4-N, P, K, Mg, Ca, HCO_3, SO_4, Cl, Na, B, Fe

22. Are the physical and chemical properties of each component considered when preparing container media for potting?			
4	**3**	**2**	**1**
☐ Media components selected based on crop requirements and production cycle length, and customized per crop type (drainage and water retention properties are measured prior to use)	☐ Media components selected based on crop requirements and production cycle length, and customized per crop type (drainage and water retention properties are not measured prior to use)	☐ Media components selected based on average needs of all crops and container sizes/volumes (drainage and water retention properties are not measured prior to use)	☐ Media component properties not verified and selection is based only on economics

BMPs: Match media components to growing needs of crop and the length of the cropping cycle.

Conduct trials or verify specifications from supplier to assess the suitability of the physical and chemical characteristics of candidate media components (EC, pH, and porosity, water retention).

Optimize growing media materials to increase air pore space retention and structural properties throughout the duration of the crop cycle (aeration porosity). Growing media should have a total porosity of 50%. Total porosity of a media is the space between substrate components that can be filled with water and air. Media aeration porosity should be 15–30% to give adequate pore space for root growth. Aeration porosity is the percentage of space filled by air after water has drained. See OMAFRA Publication 841 *Guide to Nursery and Landscape Plant Production and IPM* for how to determine media porosity.

Check chemical properties of media components separately using a greenhouse media analysis lab test prior to use.

Check potential organic media components for contaminants such as weed seed, pathogens, heavy metals and salts (e.g. municipal yard waste and composts).

Ensure soilless media has a C:N ratio (carbon:nitrogen) that is less than 25:1. If the C:N ratio is greater than 25:1, the bacteria in the media may use some of the fertilizer nitrogen to break down the carbon in the media. This is a common problem in bark-based media where the bark is not adequately aged or composted.

Container media should be selected and mixed in ratios that provide the best physical properties to support crop growth, such as even wetting, water retention, aeration porosity and structure throughout the crop cycle.

23. What fertilizer type and formulation do you use?			
4	3	2	1
☐ In overhead irrigated crops, the only source of N-P-K is Controlled Release Fertilizer; no other pre-incorporated N-P-K fertilizers (e.g. super phosphate) used Soluble fertilizer formulations not used in outdoor container production	☐ In overhead irrigated crops, the only source of N-P-K is Controlled Release Fertilizer; no other pre-incorporated N-P-K fertilizers (e.g. super phosphate) used Soluble fertilizer formulations only used in micro-irrigation systems (e.g. trickle, spray or drip irrigation systems) applied directly onto growing media surface in outdoor container production	☐ In overhead irrigated crops, sources of N-P-K include Controlled Release Fertilizers, with other pre-incorporated N-P-K sources (such as ammonium nitrate, 34-0-0 or triple super phosphate,0-46-0) Soluble fertilizer formulations only used in micro-irrigation systems (e.g. trickle, spray or drip irrigation systems) applied directly onto growing media surface in outdoor container production	☐ In overhead irrigated crops, sources of N-P-K include Controlled Release Fertilizers, with or without the pre-incorporation of N-P-K sources (such as ammonium nitrate, 34-0-0 or triple super phosphate, 0-46-0) and water-soluble fertilizer formulations

BMPs: Choose fertilizers with an analysis and formulation that reflect the crop's needs but will not leach quickly or completely.

Choose fertilizer analyses having a ratio similar to 3:1:2 that are formulated to release nutrients gradually over the crop cycle. Choose fertilizer formulations that are between 6 and 9% P_2O_5 to reduce phosphorus losses in leachate.

Do not use fertilizers that have equal N-P-K nutrient analysis (e.g. 20-20-20), as they do not efficiently reflect crop needs and can result in the over-application of nutrients. Analyses such as 10-52-10 will lead to the over-application and loss of phosphorus through leachate.

Do not use pre-incorporated or topdressed rapidly soluble farm-grade fertilizers or triple super phosphate in open, outdoor container irrigation systems.

Do not use water-soluble fertilizer in overhead irrigation systems.

Use Controlled Release Fertilizers (CRF) in outdoor container production crops, especially in overhead irrigation systems. CRF products are specially formulated to provide a more gradual release of nutrients throughout the crop cycle, which reduces nutrient content in container leachate and irrigation runoff.

24. How is Controlled Release Fertilizer (CRF) placed in the container?			
4	3	2	1
☐ A combination of targeted surface-applied directly to each pot and subsurface, e.g. dibbling	☐ Targeted surface-applied directly to each pot	☐ A combination of surface-applied and preplant incorporated	☐ Surface-applied by broadcast application
BMP: Place CRF within the container media, wherever possible, to allow gradual release of nutrients and decrease fertilizer losses due to container blow-over.			

Application Methods

Pre-incorporated fertilization: Add CRF by mixing it consistently into growing media prior to potting. This method may lead to increased loss of nutrients through leachate.

Dibble applications: Add a premeasured amount of CRF into multiple, small augured holes in the container media around the plant.

Topdressing and broadcast: Surface-applied CRF can be lost if pots are blown over. This means lost nutrients and fertilizer dollars. Minimize pot blow-down to keep CRF in place by securing outside rows or some other method. Apply CRF as a topdress directly onto individual pots. Only broadcast if containers are placed tightly together and there is no canopy to deflect the fertilizer away from the pot.

Dibble or subsurface apply CRFs under the weed barrier to reduce fertilizer losses from container blow-down.

25. How is the rate of Controlled Release Fertilizer determined?

For more information, see Worksheet 4 – Nutrient Testing for Container Media on page 35.

4	3	2	1
☐ Fertilizer rate decision based on extensive growing experience and validation or results from regional or on-farm field trials Fertility levels monitored using foliar nutrient and media/pour-through nutrient testing regularly for N-P-K and EC, and crop quality observations including root development	☐ Fertilizer rate applied at the manufacturer's recommended rate for your growing region and your crop Fertility levels monitored using media/pour-through nutrient testing periodically (e.g. every 2 months) for N-P-K and EC, and crop quality observations including root development	☐ Fertilizer rate applied at the manufacturer's recommended rate for your growing region and your crop Fertility levels monitored by measuring EC of media/ pour-through periodically (e.g. every 2 months), and crop quality observations including root development	☐ Fertilizer rate exceeds recommended manufacturer's rates for growing region No measurement of foliar nutrient or media/pour-through N-P-K or EC testing

BMPs: Monitor fertility levels by using foliar tissue analysis or media/pour-through nutrient testing on a regular basis.

Match the rate of fertilizer to expected crop growth response, climate, crop type, growth stage, irrigation volume applied, and crop cycle length to minimize leaching losses.

Verify that the CRF manufacturer's recommended rates are appropriate for the crops being grown by testing rates at and below the recommended rate. Choose a rate that promotes adequate growth and colour, below which the crop growth response is inadequate.

Complete a growing media or pour-through nutrient analyses regularly during the growing season to ensure adequate but not excessive nutrient levels in the root zone.

Reduce CRF application rates to account for available nitrogen, phosphorus and potassium from the organic sources.

High volumes of irrigation (e.g. hot, windy conditions) or excessive natural precipitation can result in increased leaching fractions and loss of nutrients. If irrigation/precipitation volumes are high and cannot be reduced, consider a supplemental application of fertilizer to prevent nutrient deficiency later in the growing season. In situations like this, capture runoff/nutrients and recycle.

The pour-through method of sampling substrate solution for nutrient analysis is a reliable and practical way to verify the availability of nutrients to the crop. High levels of nutrients in the pour-through solution may indicate overwatering or over-application of fertilizer, high media temperatures or poor root growth.

26. If water-soluble fertilizer is used in the micro-irrigation system (drip, spray stakes etc.) in outdoor containers, what is the % leaching fraction?
For help with determining % leaching fraction, see Worksheet 2 on page 31.

4	3	2	1
☐ 5–10 %	☐ 11–20 %	☐ 21–30%	☐ >30% leaching fraction or ☐ % leaching fraction unknown

BMPs: Measure the leaching fraction for micro-irrigated crops over multiple irrigation events over the cropping cycle. Adjust irrigation volumes accordingly to minimize leaching.

Pulse the irrigation event into several (e.g. greater than 2) applications per day. This will improve horizontal substrate wetting and prevent irrigation water from moving quickly through the wet column below the emitter.

Soluble fertilizers should only be used with micro-irrigation systems or other low-volume irrigation systems where leaching volumes are very low and/or captured for re-use.

27. How often do you test nutrients, pH and EC (soluble salts) in runoff collection points and irrigation ponds?

4	3	2	1
☐ At least four times (April–Oct.)	☐ Up to three times (April–Oct.)	☐ Once (April–Oct.)	☐ Rarely

BMPs: Analyze water at runoff collection points and irrigation pond to detect any issues with water quality and crop performance. Have management plans in place to take appropriate action when required.

Collect samples at least monthly for analyses of macronutrients (nitrate-nitrogen [NO_3-N] phosphorus [P], potassium [K], magnesium [Mg], calcium [Ca]), micronutrients (manganese [Mn], molybdenum [Mo], copper [Cu], boron [B], zinc [Zn], iron [Fe]), and other water quality parameters such as electrical conductivity (EC), pH, bicarbonates (HCO_3), sodium (Na), chloride (Cl), and sulphates (SO_4).

Maintain records of the results, and be aware of the quality of water you have on your farm and the potential for offsite movement.

28. How and where are fertilizer products stored?

4	3	2	1
☐ *Storage:* Locked and stored in building and on an impermeable surface	☐ *Storage:* In building on permeable surface	☐ *Storage:* Outdoors on soil with temporary cover	☐ *Storage:* Outdoors on soil with no cover

BMPs: Maintain an inventory of the amount of fertilizer purchased and used, and have a proper storage facility in place.

Safely store all fertilizer material in a facility where a spill can be contained and would not be able to seep into surface and ground water systems.

Keep CRF bags intact and protected from elements to prevent them from breaking down. Keep substrate mixed with fertilizer dry and protected from elements on an impermeable surface. Use it as soon as possible.

Conduct regularly scheduled inspections of all fertilizer storage and application equipment, and document these inspections.

Ensure no floor drains from any fertilizer or pesticide storage or mixing areas lead to the outside environment. Close off floor drains or direct them to a separate, isolated containment.

Contain and clean up any fertilizer spills during all phases of transport, storage and application immediately. Use appropriate technology and techniques (e.g. spill kits with portable barrier) to clean up solution spills.

Fertilizer storage should be located no less than 30 metres to surface water, no less than 15 metres from a drilled well and no less than 30 metres from a bored well.

Write and post a contingency plan for fertilizer spills.

Keep stored fertilizer away from vulnerable water sources. Check EFP and BMP information for specifications regarding separation distances.

29. Do you know total amount of fertilizer – actual nitrogen, phosphorus (as P_2O_5) and potassium (as K_2O) – applied per crop type or zone per area (hectares) over one year of production?

For help with calculating Total Nitrogen, Phosphorus and Potassium Applied per Area, see Worksheet 5 on page 38.

4	1
☐ Know nitrogen/ha, phosphorus (P_2O_5/ha), and potassium (K_2O/ha) or per crop group (e.g. evergreens), or container size per growing season	☐ Do not know

BMP: Determine and keep records of fertilizer use per area (e.g. hectare). This will help to relocate high water- and nutrient-requiring crops away from production zones that are closest to sensitive environmental areas.

The total amount of nutrients applied is also valuable to know per crop group (e.g. evergreens), or container size per year.

Calculate the amount of fertilizer (total nitrogen, phosphorus as P_2O_5 and potassium as K_2O) used per hectare of production from all nutrient sources. Divide crop into groups based on container sizes and crop types such as evergreens, deciduous, and perennials.

Fertilizer application rates depend on the crop grown, the growth stage, and the irrigation management (e.g. cyclic irrigation requires less fertilizer). Where possible, reduce the fertilizer application rate to the lowest level where crop growth and quality are not negatively impacted.

C RUNOFF MANAGEMENT PRACTICES

Management of water and nutrients *after* runoff intercepts an outdoor container-production area.

Because container nursery production systems are outdoors, precipitation is an important source of water for irrigation and is routinely collected in large ponds. This water is often combined with container yard runoff water for reuse as irrigation water. In an effort to minimize water-taking from other surface and ground water sources, Ontario container nursery production systems are designed to collect and reuse as much precipitation, irrigation and runoff water as possible.

Note that water leaving the farm must be managed in accordance with applicable legislation such as the *Ontario Water Resources Act*, the *Environmental Protection Act*, the *Drainage Act and Common Law Drainage*.

30. How do you collect and store runoff water from container production area?			
4	**3**	**2**	**1**
☐ Runoff water efficiently diverted from container beds by engineered surface channels and subsurface drainage to collection pond for storage and reuse	☐ Runoff water diverted from container beds by overland flow via engineered channel system (e.g. vegetated or riprap-lined) and diverted to collection pond for storage and reuse	☐ Runoff water diverted from container beds by overland flow (no engineered channel) and passively diverted to collection pond for storage and reuse ☐ No subsurface collection	☐ Runoff water is not collected for storage and reuse

BMPs: Collect runoff and reuse for irrigation to minimize water-taking from other surface and ground water sources.

Design production areas with sloping, compacted or lined production beds with subsurface drain pipes, surface inlets and/or lined or vegetated runoff channels to maximize diversion and collection of post-production water.

Use impermeable or semi-impermeable production surfaces such as polyethylene, polypropylene (e.g. geotextile fabric), gravel or concrete on compacted subsoil to maximize capture of irrigation water runoff. The soil should be mechanically compacted to minimize infiltration. All growing beds and channels should be lined.

Vegetate or line open waterway collection systems, and/or install check dams or settling ponds to slow water down to prevent erosion and promote sedimentation prior to irrigation pond.

Construct irrigation ponds or basins, where practical, to reduce sediment loads to irrigation water.

Filter collected runoff to reduce sediment and available nutrients. This will improve water quality in irrigation storage ponds.

Use aeration to help reduce available nutrients and suppress algae growth.

Where possible, filter water through plants and soil to reduce nutrient levels (e.g. vegetated buffers).

There are several treatment options to reduce sediment and nutrients in runoff water (e.g constructed wetland, bio-retention swales, wood chip biofilter).

Most modern container nursery operations are designed and managed to divert and collect runoff into irrigation ponds. Techniques used include sloped beds and conveyance channels with bank protection such as riprap or vegetation strips.

31. What is the capacity of the storage structure (e.g. irrigation pond) to contain runoff water from your container production area during the growing season?

4	3	2	1
☐ My pond never overflows following a rain event or snow thaw	☐ My pond seldom overflows following a rain event or snow thaw	☐ My pond sometimes overflows following a rain event or snow thaw	☐ My pond often overflows following a rain event or snow thaw

BMPs: Store runoff water in storage structures that are sized to reduce the chance of overflow events.

During the growing season, contain as much runoff water from production area as possible by constructing storage structures that are lined (e.g. clay) and not connected to continuous surface water or ground water sources.

When you build a runoff water storage structure above grade, engineer the structure correctly to ensure the integrity under the gravitational pressure of the water.

Irrigation ponds should be dredged as needed to remove sediment. Care must be taken not to disturb the lining at the bottom of the pond.

Irrigation ponds should be sized and constructed to be large enough to meet your design requirements (e.g. irrigation needs, runoff from production area during the growing season).

Nutrient and sediment levels in runoff can be reduced using treatment BMPs such as constructed wetland biofilters with settling ponds as the first step in filtration.

Appendix

WORKSHEET 1. TOTAL MAXIMUM DAILY WATER APPLIED

This worksheet explains how to estimate peak water use to irrigate your entire production area in one day. A peak use day is a day with high solar radiation, low relative humidity, moderate-high winds and high temperatures. The same calculation can be used to determine Average Daily Water Applied. It is important to know the total maximum daily water use when:

- designing an irrigation system
- designing an irrigation/storm water recycling pond
- recording and estimating daily water use for reporting

To calculate total maximum daily water applied, you need to know:

- output of irrigation nozzles (volume per minute)
- number of nozzles in one acre/hectare of container production (including driveways)
- total time to irrigate one acre/hectare on peak use day (can give low-med-high or take an average of all crops)
- total number acres/hectares to be irrigated on peak use day
- to convert 1 acre to hectares ➔ multiply by 0.40
- to convert 1 US gallon to litres ➔ multiply by 3.785
- 1 acre = 209 feet x 209 feet (43,560 ft^2)
- 1 hectare = 100 metres x 100 metres (10,000 m^2)

Example

Based on a typical operation with nozzle spacing of 30 feet, we can fit about 33 nozzles in one acre of container production polyhouses (including driveways and walkways).

Each nozzle output is about 3.7 US gpm (gallons per minute) = 14 lpm (litres per minute)

At the most, we would irrigate for a total of 60 minutes per day.

33 nozzles/acre x 14 lpm/nozzle x 60 minutes = 27,720 litres/acre

Max Water Applied per Area = 27,720 L/acre OR 69,300 L/ha

To convert litres/acre to litres per hectare: L/ac ÷ 0.4 = L/ha

To calculate the *Total Max Water Applied* for your farm, multiply this water volume by the total number of acres/hectares under container production with overhead i sprinkler irrigation.

Note: when calculating the volume required for an irrigation/storm water collection pond, take into consideration the average annual precipitation and historical storm events in your area.

Gallons referenced in this document are US gallons.

WORKSHEET 2. LEACHING FRACTION FOR CONTAINER NURSERY PRODUCTION

Percent leaching fraction (or %LF) is commonly used to assess the irrigation efficiency of container crop production. Specifically, it helps to measure whether too much or not enough irrigation water is being applied to the crop. The lower the number, the lower the volume of water being lost out the bottom of the pot.

Periodically, growers may need to leach their crops (e.g. high heat in the spring/early summer causing accumulation of fertilizer salts in the media). But on average, growers are working towards minimizing % leaching fraction.

Several unrelated factors can affect the leaching fraction data. For instance, media that is not evenly or regularly moistened tends to have dry "cracks" that channel irrigation water rapidly through the pot, exaggerating the leachate volume. Container crops with dense or tall canopy architectures can deflect irrigation water, preventing it from landing on the surface of the media of some of the pots within the irrigation zone. Proximity and direction from the nearest sprinkler, as well as wind speed, can have a significant effect on % leaching fraction throughout the bed.

By knowing and paying attention to these limitations, growers can use % leaching fraction to help make decisions about irrigation scheduling in order to help conserve water and nutrients lost through leaching.

Example

For this exercise, try to choose overhead sprinkler-irrigated container beds that have crops that are similar in age, size and canopy architecture. Use 10–20 pots each for both the "interception" and the "leachate" pots in each bed. Larger beds (>300 feet) may require more than 20 pots to accurately assess average leaching fraction %.

You will need the following for each bed:

- 40–60 clean, empty pots identical to those used to grow crops in each bed
- 40–60 small plastic bags (e.g. small garbage bags)
- 40–60 large elastic bands
- 20–30 medium-sized stones (5–10 cm in diameter) or pieces of 2x4 wood (e.g. 5x15 cm)
- wide-mouth 1–2 L jug, graduated cylinder, flagging tape, clip board with chart paper, mechanical pencil and eraser.

Step 1

Place 10–20 empty pots lined with an impermeable barrier (e.g. plastic bag) throughout the container bed at different distances and directions from the irrigation nozzles. These empty, lined pots are the "interception" pots. Only use pots identical to those used in the crop you are testing. The "interception" pot approximates how much of the overhead irrigation water actually makes it onto the surface of the media. (*Tip:* Use elastic bands to secure the impermeable barrier to the top rim of the pot.)

WORKSHEET 2. LEACHING FRACTION FOR CONTAINER NURSERY PRODUCTION (cont'd)

Step 2

Place 10–20 empty, lined pots directly underneath the crop plant pots. Place a 5 cm stone inside to give room for drainage. These pots are the "leachate" pots, and will catch the volume of water that drains from the crop pots. The "leachate" pots are identical to the crop pots and fit tightly under the crop pot. Place these crop plant + "leachate" pots beside the empty "interception" pots. (*Tip:* Attach flagging tape to the plants and number them so you can find them more easily after the irrigation event.)

Step 3

After an average irrigation event, collect and measure all "leachate" and "interception" pot water volumes, and record them in a chart so you can refer back to individual pot volumes and their location in the bed, in relation to the sprinklers. A quick sketch of the Leaching Fraction pot layout in the bed will be valuable for interpreting results later. (*Tip:* Hold the plastic liner to allow water to drain smoothly. Collect water into a wide-mouthed vessel before pouring into the graduated cylinder for measurement.)

Record temperature, wind speed, wind direction and relative humidity at the time of the irrigation event (e.g. at the beginning and at the end).

Step 4

Use the water volumes collected to calculate % leaching fraction.

$$\text{\% Leaching Fraction} = \frac{\text{"leachate" pot volumes}}{\text{"interception" pot volume}} \times 100$$

$$\text{Average \% Leaching Fraction for the Bed} = \frac{\text{Avg ("leachate" pot volumes)}}{\text{Avg ("interception" pot volumes)}} \times 100$$

Interpreting the results

Review the individual %LF for various pots throughout the bed. Do they differ in relation to distance and direction from sprinkler? Does wind speed play a role in Leaching Fraction? Does canopy architecture play a role in deflecting water off the plant foliage? Can you think of any other factors that could affect the results?

Guidelines for Interpreting Average Leaching Fraction:

%LF = 0–15%	%LF = 16–25%	%LF = 26-40%	%LF = >40%
Very Good	Good	Inefficient	Excessive
This indicates a conservative use of irrigation water.	Review crop quality, wetting front in the media and any other factors that could be exaggerating %LF. Then consider reducing the length of the irrigation cycle.	Review crop quality, wetting front in the media and any other factors that could be exaggerating %LF. Then consider reducing the length of the irrigation cycle.	Review crop quality, wetting front in the media and any other factors that could be exaggerating %LF. Most likely there is an error in the procedure somehow. Try evaluating the volume of water with alternative devices (e.g. rain gauges) placed at the top of the canopy. Strongly consider reducing the length of the irrigation cycle.

WORKSHEET 3. INTERCEPTION EFFICIENCY

Percent interception efficiency (%IE) is commonly used to describe the spacing and configuration of container crops. It indicates the pot surface area in relation to the area of bed they are growing on. However, the true value of this measurement is to quantify the effective use of the production area and the efficient use of overhead-applied irrigation water. The higher the % interception efficiency, the lower the volume of water being lost between the pots.

%IE is a simple calculation based on container spacing in two directions. Container crop spacing will depend on several key crop and management factors.

Container crops with tall or wide canopy architectures will deflect irrigation water and prevent it from landing on the surface of the media, and may require pots to be placed farther away from each other to achieve adequate wetting of the media. Many nursery crops are susceptible to foliar diseases that can be reduced by using wider pot spacing patterns. Some growers space pots in the spring at the maximum spacing distance they will require months later to allow for seasonal canopy growth. Other growers prefer to space the crop multiple times throughout the growing season, incrementally larger as the crop canopy expands.

By measuring %IE throughout the growing season for various types of nursery container crops, growers can use the data to help make decisions about irrigation systems and scheduling in order to help conserve water and nutrients lost through leaching. Also, crops that are grown with a low %IE (e.g. <40%), and that require a moderate to high amount of fertilizer and irrigation volumes, may be placed farther from environmentally sensitive areas and surface or ground water sources.

What you will need:

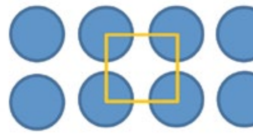
- a 30-cm ruler, a measuring tape
- clipboard with chart paper, mechanical pencil and eraser.

Step 1. Pick your sites.

For this exercise, try to choose overhead sprinkler-irrigated container beds that have crops that are similar in pot size, age and canopy architecture. By organizing %IE data into groups, growers can gain more meaningful data to help manage their different crops. Many growers prefer to organize their groups by pot size and canopy architecture (e.g. 1 gallon upright evergreens).

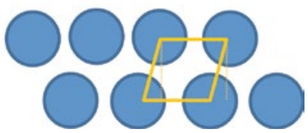
Step 2. Calculate your areas.

Start by envisioning a rectangle or square that includes one quarter of each of 4 containers (see Fig. A). Measure the length and width of the rectangle that intersects with the centres of the 4 containers and record it as ground area.



A. Rectangular pot spacing

In staggered pot spacing, you will need to draw an imaginary vertical line to make the parallelogram into a rectangle and measure length and width (see Fig. B). These length and width dimensions will be used to calculate the area of the rectangle that reaches the centre of 4 pots.



B. Staggered pot spacing

There are 4 quarters of a container surface in each rectangle, which adds up to one full container surface area. Calculate surface area (A) of one container ($A= \pi r2$) by measuring the diameter of the pot. The radius is one-half of the diameter and is used to calculate the pot surface area. If the container is square or a rectangle, simply calculate the area of the container using length x width.

WORKSHEET 3. INTERCEPTION EFFICIENCY (CONT'D)

Step 3. Do the calculations.

$$\%IE = \frac{\text{Surface area of 1 container}}{\text{Rectangle area}} \times 100$$

Sample calculation:

1 gallon container (pot)
(Container diameter = 15.24 cm) (Radius = ½ diameter = 7.62 cm)
Container area: $A = \pi r^2 = \pi (7.62)^2 = 182.41\ cm^2$

$$\%IE = \frac{182\ cm^2}{19.2 \times 18\ cm} \times 100 = \frac{182\ cm^2}{346\ cm^2} \times 100 = 53\%$$

Table 1. Sample Calculations for Actual % Interception Efficiency in a Typical Nursery

Pot Size, Diameter	Pot/Tray Surface Area	Ground Area (Measured)	Calculated %IE
Liner tray (26.7 x 49.5 cm)	1321 cm^2	26.7 cm x 54.6 cm = 1457.8 cm^2	91%
1 gallon (15 cm)	182 cm^2	19.2 cm x 18 cm = 346 cm^2	53%
2 gallon (20 cm)	314 cm^2	28.2 cm x 21.1 cm = 595 cm^2	53%
3 gallon (25.4 cm)	508 cm^2		

Because nursery containers are round, there is already a significant loss in interception, even when the crop is grown 'pot-to-pot' tight. The following table lists the maximum %IE when a crop is grown in round containers that placed out pot-pot tight in all four directions.

Table 2. Maximum % Interception Efficiency Possible for Typical Round Containers used in Commercial Nursery Production

Pot Size, Diameter	Pot/Tray Surface Area	Rectangle Area (pot–pot tight)	Maximum Potential %IE
1 gallon (15 cm)	182 cm^2	15 cm x 15 cm = 225 cm^2	81
2 gallon (20 cm)	314 cm^2	20 cm x 20 cm = 400 cm^2	79
3 gallon (25.4 cm)	508 cm^2	25.4 cm x 25.4 cm = 645 cm^2	79

Step 4. Complete this several times during the growing season for several different production zones and crops. Use the data to optimize irrigation interception efficiency.

WORKSHEET 4. NUTRIENT TESTING FOR CONTAINER MEDIA

Most growers these days are using controlled-release fertilizers (CRFs) because they release quantities of nitrogen, phosphorus, potassium and other nutrients over the growing season. The nutrient release is dependent on media temperature and to a lesser extent, moisture. As we all know, temperature and moisture are highly variable from growing season to growing season. How do we know if there are enough nutrients to supply the plant through its entire growth period?

Some growers measure the electrical conductivity (EC) of the media to get a quick and reasonably good indication of media fertility. However, EC determination only gives the total salts content and not the concentrations of individual nutrients in the media solution. Without further analysis, you don't know if the EC reading reflects the necessary N, P, K, or the less essential ions (e.g. sulphates). This can lead to a false impression of media fertility, especially later in the growing season. In addition, the N supplied in some CRF productions is provided as urea, which does not register a charge and therefore does not contribute to the EC.

To test media fertility, samples can be sent to an OMAFRA-accredited laboratory[a] monthly throughout the growing season. **Complete analysis packages should include: pH, EC, nitrogen (nitrate and ammonium), phosphorus, potassium, calcium, magnesium, iron, manganese, zinc, copper, boron, molybdenum, sodium, chloride, and sulphates.** The results will give not only the EC and pH of the media, but all of the necessary macro and micronutrients – everything needed to determine if your crop is being fertilized correctly. To save money, you may want to get a complete test done monthly and a basic test (pH, EC, nitrate nitrogen, phosphorus, potassium, calcium, magnesium) during the two weeks in between.

If a decline in an essential nutrient is detected, growers have the ability to correct the problem by supplemental fertilizer application. This can include topdressing or subsurface placement with a reduced amount of a CRF to the affected plants. Costs for a complete nutrient analysis of your growing media are modest and a small price to pay compared to the possible losses in plant sales due to nutrient deficiencies or toxicities. Here's what you can do to make the most out of your container growing nutrient status:

Table 1. Sampling Procedures for Soilless Media Fertility

Sampling Technique	Procedure	Notes	Comparison of Results
Soilless Media Core Sample	Use a small-diameter probe to extract a core of media from each pot. Sample midway between top and bottom, halfway between stem and pot edge. Sample 10 pots and mix samples to get one pooled sample of media (about 2 cups). Refrigerate sample until delivered to lab.	Avoid breaking CRF prills when sampling. Procedure may disturb roots. Most labs will conduct a "saturated paste" analysis on media.	Compare results to Table 2 (based on saturated paste analysis).
Pour-Through Technique for Leachate	Sample 30 minutes after irrigation has finished. Pour 200 ml deionized water over media surface (or enough water to collect 50 ml leachate). Let pot drain long enough to collect 50 ml leachate. Repeat for at least 10 pots and mix sample (roughly 500 ml). Refrigerate sample until delivered to lab.	Does not disturb roots. Try testing pH and EC with your own equipment and compare with lab results.	Compare results to Table 3 (based on Virginia Tech Extraction Method).

[a] See OMAFRA Publication 841, *Guide to Nursery & Landscape Plant Production and IPM* for a list of OMAFRA-accredited labs as well as more information on nutrition for nursery production. www.omafra.gov.on.ca/english/crops/pub841.pdf

WORKSHEET 4. NUTRIENT TESTING FOR CONTAINER MEDIA (CONT'D)

Always sample from at least 10 pots for a good representation of your containers. Sample from an entire block – from centre to outside edge. For media samples, take small amounts from numerous pots to give a better representative sample with less impact on the root system. Mix the sample well.

You should test your media and/or pour-through leachate at least monthly. It would be useful to send a corresponding sample of irrigation source water, since it has a huge impact on soilless media. Compare these test results with previous samples and to the ranges in Table 2, to determine trends in pH, EC and nutrient status. Analysis results can then be correlated with plant growth and health symptoms to help establish your own thresholds for irrigation water and media properties. We guarantee that the results will help you gain more insight into growing better container crops.

Table 2. Media Nutrient Levels for Most Container Crops[b]

Nutrient	Low	Moderate	Excessive
pH	<5.0	5.0–6.5	>7.0
Electrical Conductivity (mS/cm), (mmho/cm), (dS/m)	<0.75	1.0–3.5	>3.5
Ammonium nitrogen (NH_4-N, ppm)	Generally, NH_4-N should not exceed NO_3-N		
Nitrate nitrogen (NO_3-N, ppm)	0–39	100–199	>250
Phosphorus (P, ppm)	0–2	6–9	>50
Potassium (K, ppm)	0–59	150–250	>350
Calcium (Ca, ppm)	0–79	200–300	>400
Magnesium (Mg, ppm)	0–29	70–200	>200
Chloride (Cl, ppm)	–	0–50	>50
Copper (Cu, ppm)	–	0.3–3.0	–
Iron (Fe, ppm)	–	0.3–3.0	–
Manganese (Mn, ppm)	–	0.3–3.0	–
Sodium (Na, ppm)	–	0–50	–
Sulphate (SO_4, ppm)	–	–	>300
Zinc (Zn, ppm)	–	0.3–3.0	–

[b] See OMAFRA Publication 841, *Guide to Nursery and Landscape Plant Production and IPM*. www.omafra.gov.on.ca/english/crops/pub841/pub841.pdf

Use a soil probe to sample media cores from container production crops.

WORKSHEET 4. NUTRIENT TESTING FOR CONTAINER MEDIA (cont'd)

Table 3. Pour-through Leachate Nutrient Levels for Most Container Crops[c]

Nutrient	Liquid Fertilizer or CRF and Liquid	CRF Fertilizer Only
pH	5.0–6.0	5.0–6.0
Electrical Conductivity (mS/cm), (mmho/cm), (dS/m)	0.5–1.0	0.2–0.5
Ammonium nitrogen (NH_4-N, ppm)	Generally, NH_4-N should not exceed NO_3-N	
Nitrate nitrogen (NO_3-N, ppm)	50–100	15–25
Phosphorus (P, ppm)	10–15	5–10
Potassium (K, ppm)	30–50	10–20
Calcium (Ca, ppm)	20–40	20–40
Magnesium (Mg, ppm)	15–20	15–20
Chloride (Cl, ppm)	–	–
Copper (Cu, ppm)	0.02	0.02
Iron (Fe, ppm)	0.5	0.5
Manganese (Mn, ppm)	0.3	0.3
Sodium (Na, ppm)	–	–
Sulphate (SO_4, ppm)	–	–
Zinc (Zn, ppm)	0.2	0.2
Boron (B, ppm)	0.05	0.05

[c] Southern Nurseryman's Assoc. 2013. *Best Management Practices; Guide for Producing Container-Grown Plants*. S.N.A., Marietta, GA.

Other references: Davidson, H., R. Mecklenburg and C. Peterson. 2000. *Nursery Management Administration and Culture.* Prentice-Hall Inc. NJ.

This infosheet was authored by Jen Llewellyn, OMAFRA Nursery Crops Specialist and Peter Purvis, Nursery Technician, University of Guelph.

Use a soil probe to sample media cores from container production crops.

Apply enough water to the surface of media to collect a known quantity of leachate for sampling.

WORKSHEET 5. TOTAL NITROGEN, PHOSPHORUS AND POTASSIUM APPLIED PER AREA

This worksheet explains how to calculate annual nitrogen (N), phosphorus (P) and potassium (K) application per production area unit (e.g. hectares) for each crop type or container size.

Knowing the actual amount applied per area will be helpful when decisions are being made regarding where to grow certain crops in relation to distance to natural surface and ground water sources.

These calculations are relatively easy to complete, and are very important when assessing the impact of fertilizer practices on the environment and on the cost of production.

To calculate total maximum daily water applied, you will need to know the following:

- number of containers per acre/hectare of production, for each container size (including driveways) – see the bottom of this worksheet for examples
- total grams of fertilizer product(s) applied to each plant per year, for each container size or crop type
- N-P-K analysis of all fertilizer products applied in a season
- 1 acre = 209 feet x 209 feet (43,560 ft^2)
- 1 hectare = 100 metres x 100 metres (10,000 m^2)
- 1 acre to hectares ➔ multiply by 0.40
- 1 hectare to acres ➔ multiply by 2.47
- $P_2 0_5$ to actual Phosphorus ➔ multiply by 0.44
- $K_2 0$ to actual Potassium ➔ multiply by 0.83.

Example

A 3-hectare container nursery produces 1.5 hectares of 1-gallon containers, 1 hectare of 3-gallon containers and 0.5 hectares of 2-gallon containers.

All of the containers are fertilized with a slow release fertilizer product (17-6-12), which is 17% nitrogen (N), 6% phosphorus (as $P_2 0_5$) and 12% potassium (as $K_2 0$). The 3 gallon containers receive 32 g per pot, the 2 gallon containers receive 18 g per pot, and the 1 gallon containers receive 9 g per pot of the fertilizer product.

Unless you have accurate inventory averages for your operation, you may assume there are:

- 158,080 1-gallon pots per hectare (64,000 1-gallon pots per acre)
- 79,040 2-gallon pots per hectare (32,000 2-gallon pots per acre)
- 59,282 3-gallon pots per hectare (24,000 3-gallon pots per acre)

1-gallon pots take up 1.5 hectares = 158,080 pots/ha. x 1.5 hectares
= 237,120 1-gallon pots per 1.5 hectares x 9 g fertilizer/pot = **2,134 kg fert/1.5 ha**

2-gallon pots take up 0.5 hectares = 79,040 pots/ha. x 0.5 hectares
= 39,520 2-gallon pots per 0.5 hectares x 18 g fertilizer/pot = **711 kg fert/0.5 ha**

3-gallon pots take up 1 hectare = 59,282 pots/ha
= 59,282 3-gallon pots per 1 hectare x 32 g fertilizer/pot = **1,897 kg fert/ha**

How to estimate Nitrogen (N) used per area:

$$\frac{\text{Total weight of fertilizer product}}{\text{Total production area}} \times \text{\% Nitrogen in analysis} = \text{Total N applied per area}$$

1-gallon pots (1.5 ha): 2134 kg x 17% actual nitrogen = **363 kg nitrogen per 1.5 ha**
- N applied per ha = 363 kg N/1.5 ha = 242 kg/ha (1 gallon)

2-gallon pots (0.5 ha): 711 kg x 17% actual nitrogen = **121 kg nitrogen per 0.5 ha**
- N applied per ha = 121 kg N/0.5 ha = 242 kg/ha (2 gallon)

WORKSHEET 5. TOTAL NITROGEN, PHOSPHORUS AND POTASSIUM APPLIED PER AREA (CONT'D)

3-gallon pots (1 ha): 1897 kg x 17% actual nitrogen = **323 kg nitrogen per 1.0 ha**

- N applied per ha = 323 kg N/1 ha = 323 kg/ha (3 gallon)

How to estimate Phosphorus (P) used per area:

$$\frac{\text{Total weight of fertilizer product}}{\text{Total production area}} \times \%\ P_20_5 \text{ in analysis} = \text{Total } P_20_5 \text{ applied per area}$$

1-gallon pots (for 1.5 ha): 2134 kg x 6% P_20_5= 128 kg P_20_5 per 1.5 ha

- P_20_5 applied per ha = 128 kg P_20_5/1.5 ha = 85 kg P_20_5/ha (1 gallon)
  *CONVERT P_20_5 to actual P: 85 x 0.44 = **37 kg actual P/ha**

2-gallon pots (for 0.5 ha): 711 kg x 6% P_20_5= 43 kg P_20_5 per 0.5 ha

- P_20_5 applied per ha = 43 kg P_20_5/0.5 ha = 86 kg P_20_5/ha (2 gallon)
  *CONVERT P_20_5 to actual P: 86 x 0.44 = **38 kg actual P/ha**

3-gallon pots (for 1.0 ha): 1897 kg x 6% P_20_5= 114 kg P_20_5 per 1.0 ha

- P_20_5 applied per ha = 114 kg P_20_5/1.0 ha = 114 kg P_20_5 /ha (3 gallon)
  *CONVERT P_20_5 to actual P: 114 x 0.44 = **50 kg actual P/ha**

* Phosphorus is represented as %P_20_5 (phosphorus pentoxide) in fertilizer formulations. P_20_5 contains phosphorus, but is not 100% phosphorus. To convert P_20_5 to P, multiply by 0.44.

How to estimate Potassium (K) used per area:

$$\frac{\text{Total weight of fertilizer product}}{\text{Total production area}} \times \%\ K_20 \text{ in analysis} = \text{Total } K_20 \text{ applied per area}$$

1-gallon pots (for 1.5 ha): 2134 kg x 12% K_20 = 256 kg K_20 per 1.5 ha

- K_20 applied per ha = 256 kg K_20 /1.5 ha = 170 kg K_20 /ha (1 gallon)
  CONVERT K_20 to actual K: 170 x 0.83 = **141 kg actual K/ha

2-gallon pots (for 0.5 ha): 711 kg x 12% K_20 = 85 kg K_20 per 0.5 ha

- P_20_5 applied per ha = 85 kg K_20 /0.5 ha = 170 kg K_20 /ha (2 gallon)
  CONVERT K_20 to actual K: 170 x 0.83 = **141 kg actual K/ha

3-gallon pots (for 1.0 ha): 1897 kg x 12% K_20 = 228 kg K_20 per 1.0 ha

- K_20 applied per ha = 228 kg K_20 /1.0 ha = 228 kg K_20 /ha (3 gallon)
  CONVERT K_20 to actual K: 152 x 0.83 = **189 kg actual K/ha

** Potassium is represented as %K_20 (potash) in fertilizer formulations. Potash contains potassium, but is not 100% potassium. In order to reveal the amount of actual potassium, the amount of K_20 needs to be multiplied by 0.83.

Example Results

Container Size	Actual Nitrogen/ha	Actual Phosphorus/ha	Actual Potassium/ha
1 gallon	242	38	141
2 gallon	242	38	141
3 gallon	323	50	189

By comparing the amount of actual N, P and K used per hectare of production for each crop size or type, it is easy to see that in this case, the 3-gallon containers require greater nutrient inputs per unit area than the other container sizes.

These same calculations can be used when selecting fertilizer formulations.

Use these charts to record your results for the Self-Assessment (Questions 1–31) and the Appendix Worksheets 1, 2, 3 and 5.

Be as descriptive as possible. Fill in the Year that the data was collected.

For Crop Type/Area, describe the crop (e.g. *perennials*), size (e.g. *1 gallon*) and location (e.g. *Home Farm, House #32–36*).

For Area, describe the number of acres or hectares that the measurement refers to, where appropriate.

Refer to these charts to show progress in the years that follow.

Self-Assessment Questions

Questions	Year				
1					
2					
3					
4					
5					
6					
7					
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9					
10					
11					
12					
13					
14					
15					
16					
17					
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19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
31					
My Total					

Self-Assessment Questions

Questions	Year				
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
31					
My Total					

Appendix – Worksheets 1, 2, 3 and 5

Record	Crop Type/Area	Year				
Total Max Daily Water Applied	Area 1					
	Area 2					
	Area 3					
	Area 4					
	Area 5					
	Area 6					
	Area 7					
	Area 8					
	Area 9					
	Area 10					
Leaching Fraction	4 in.					
	1 g					
	1 g					
	2 g					
	2 g					
	3 g					
	3 g					
Interception Efficiency	4 in.					
	1 g					
	1 g					
	2 g					
	2 g					
	3 g					
	3 g					
Total N/P/K Applied per Area	4 in. per ha					
	1 g per ha					
	1 g per ha					
	2 g per ha					
	2 g per ha					
	3 g per ha					
	3 g per ha					

Appendix – Worksheets 1, 2, 3 and 5

Record	Crop Type/Area	Year				
Total Max Daily Water Applied	Area 1					
	Area 2					
	Area 3					
	Area 4					
	Area 5					
	Area 6					
	Area 7					
	Area 8					
	Area 9					
	Area 10					
Leaching Fraction	4 in.					
	1 g					
	1 g					
	2 g					
	2 g					
	3 g					
	3 g					
Interception Efficiency	4 in.					
	1 g					
	1 g					
	2 g					
	2 g					
	3 g					
	3 g					
Total N/P/K Applied per Area	4 in. per ha					
	1 g per ha					
	1 g per ha					
	2 g per ha					
	2 g per ha					
	3 g per ha					
	3 g per ha					

ACKNOWLEDGEMENTS

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FOR MORE INFORMATION

Many sources of supplementary information are available from the Ministry of Agriculture, Food and Rural Affairs. Most can be found online at **ontario.ca/omafra** or ordered through ServiceOntario.

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Published 2016
BMP28

ISBN 978-1-4606-9210-3 (Print)
ISBN 978-1-4606-9211-0 (HTML)
ISBN 978-1-4606-9212-7 (PDF)