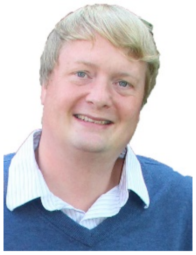
e-GRO Edible Alert



Neil Mattson
nsm47@cornell.edu

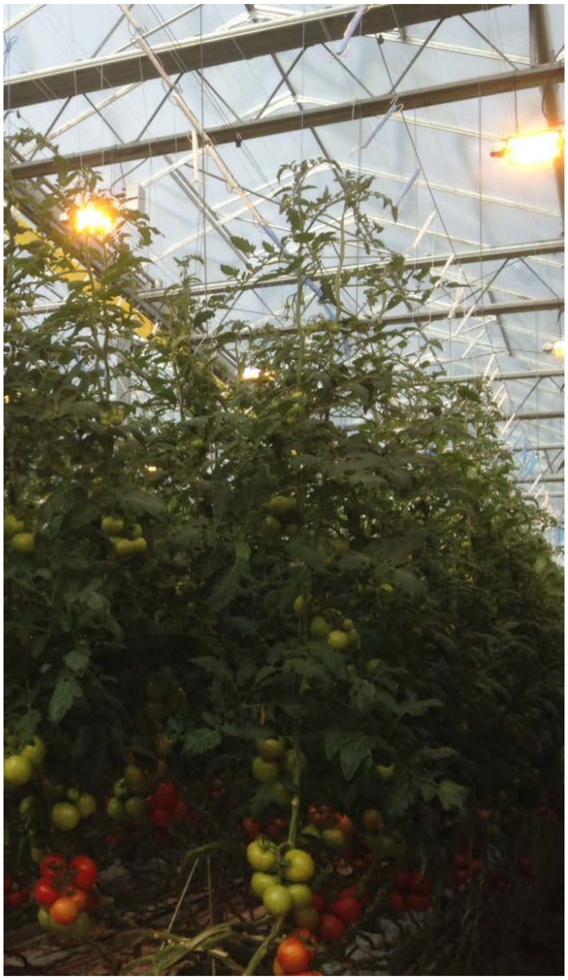
Volume 3 Number 5 March 2018

# Fertilizer Calculation Basics for Hydroponics

I'm often asked by growers and students alike to walk them through the calculations for setting up a hydroponic fertilizer recipe. While the math itself is pretty straightforward, there are several key points to take into account, including: percent elemental composition of a fertilizer, injector ratios, size of stock tank, and compatibility of fertilizer salts in stock tanks. This alert will cover the basics of fertilizer calculations when using dry fertilizers

**Step one how much fertilizer to achieve a ppm target?**

We're going to begin using metric units (milligrams, grams, liters) but I'll show how to convert to U.S. standard units. Let's say we want to use commercial calcium nitrate to supply 100 ppm nitrogen (N). There are different forms of calcium nitrate but let's assume the form we are using contains 19% calcium (Ca) and 15.5% nitrogen (N) (these values come from the product label). Let's calculate how many milligrams (mg) of calcium nitrate we need to achieve 100 ppm N in 1 liter (L) of water.



The basic principle we follow is that 1 ppm equals 1 mg/L. (This is an inherent property of physics. 1 L of water at room temperature weights 1 kg or 1,000,000 mg, therefore 1 mg of a given element in 1,000,000 mg of water becomes 1 ppm). Then we have to take into account that a given fertilizer contains only some fraction of element. In our case calcium nitrate contains 15.5% nitrogen. To calculate how many mg needed per 1 L of water divide the target value by the percent of the element.

Example: use commercial calcium nitrate to supply 100 ppm N.

100 mg/L (ppm) N / %N → 100 mg/L N / 0.155 [this is the percent N in calcium nitrate]
= **645** mg of calcium nitrate in 1 L of water

Great! Now, remember the fertilizer salts we use contain two elements of interest. In our case, the fertilizer also contains calcium, so let's calculate the ppm (or mg/L) of calcium supplied by using 645 mg of calcium nitrate in 1 L of water. This is calculated by multiplying the total mg/L of fertilizer salt used by the percent calcium (19% Ca):

645 mg/L calcium nitrate x 0.19 (% Ca) = 122.6 mg/L (ppm) Ca.

Therefore using 645 mg of calcium nitrate in 1 L of water, provides 100 ppm N and 122.6 ppm Ca.

Let's try one more practice example. How many mg of magnesium sulfate (9.7% Mg, 13% S) do you need to provide 40 ppm Mg? And how many ppm S does this also supply?

40 mg/L Mg / 0.097 = **412 mg** of magnesium sulfate in 1 L of water

How much S does this supply? 412 mg/L magnesium sulfate x 0.13 = 53.56 mg/L S (ppm S)

## Conversions

1 gallon = 3.785 Liters

1 ounce = 28.35 grams

1 gram = 0.03527 ounces

1 pound = 454 grams

1 pound = 0.45 kilograms

1 kilogram = 1,000 grams

1 gram = 1,000 milligrams

1 ppm = 1 mg/L

**Conversion factors**

Now let's say we want to know how many ounces of magnesium sulfate we need to prepare 100 gallons of water with the above target of 40 ppm magnesium. We start by doing the above math, which tells us we need 412 mg of magnesium sulfate per liter of water. Then we just take into conversion factors.

For convenience let's start by converting 412 mg to grams. Remember 1 gram has 1,000 mg. So, 412 mg = 0.412 g. Next, remember 1 gallon of water contains 3.785 liters. Therefore 100 gallons of water contains 100 x 3.785 = 378.5 L. So the amount of magnesium sulfate we need for 378.5 L of water is:

0.412 g magnesium sulfate per liter x 378.5 L = 155.9 grams

Finally to convert to ounces, note that 1 ounce = 28.35 grams. So we divide the number of grams by 28.35 to calculate the number of ounces of fertilizer required.

155.9 grams magnesium sulfate / 28.35 g/oz. = 5.5 oz. of magnesium sulfate per 100 gallons of water

**Note! Beware P and K**

By convention in the U.S. the fertilizer label lists the percentage $P_2O_5$ instead of the percent P (phosphorus). And similarly the labels lists the percentage $K_2O$ instead of the percent K. Sadly this means we have to take into account conversion factors to calculate the percent elemental P and K.

To convert $P_2O_5$ to P multiply by 0.4364
To convert P to $P_2O_5$ multiply by 2.2915

To convert $K_2O$ to K multiply by 0.8301
To convert K to $K_2O$ multiply by 1.2047

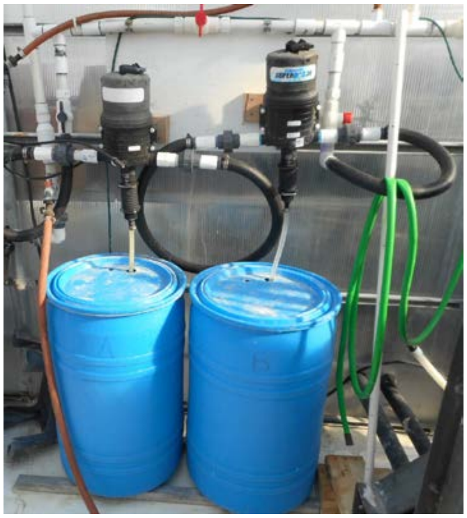
For example, let's assume we are using a common hydroponic fertilizer 5-12-26 which is used to provide most of the macronutrients and micronutrients except for Ca and enough N (therefore, it is typically used in conjunction with calcium nitrate).

Let's calculate the percentage P and K in 5-12-26. Remember the 3 numbers mean %N - %$P_2O_5$ and % $K_2O$

Since the percent $P_2O_5$ is 12%, then we multiply 12% by 0.4364 → 5.24% P
And, since the percent $K_2O$ is 26%, then we multiply 26% by 0.8301 → 21.58% K

**Injectors and Stock Tanks**

Most commercial hydroponic facilities prepare fertilizers in concentrated stock tanks and then use fertilizer injectors to dilute fertilizer down to the level needed by the plants. This allows the liquid fertilizer stocks to be stored in relatively low volume tanks. A common injector ratio is 1:100, meaning the fertilizer in the concentrated stock tank is at a 100 times higher concentration than what the plant receives. The fertilizer injector then takes 1 part fertilizer stock and adds 99 parts tap water to prepare the dilute fertilizer that plants receive. Injector ratios in the range of 1:50 to 1:200 are commonly used. A ratio of 1:200 means that are stock solution needs to have twice as much fertilizer as when using a 1:100 ratio, because in this case the fertilizer injector takes 1 part fertilizer and adds 199 parts tap water.



Two fertilizer stock tanks each with their own fertilizer injector are used because some fertilizer are incompatible with each other in concentrated amounts.

This means when we are conducting fertilizer calculations we will need to multiply the mg of fertilizer salt per 1 L of water times the volume of the stock tank and times the injector ratio.

**Injectors and Stock Tanks**

Most commercial hydroponic facilities prepare fertilizers in concentrated stock tanks and then use fertilizer injectors to dilute fertilizer down to the level needed by the plants. This allows the liquid fertilizer stocks to be stored in relatively low volume tanks. A common injector ratio is 1:100, meaning the fertilizer in the concentrated stock tank is at a 100 times higher concentration than what the plant receives. The fertilizer injector then takes 1 part fertilizer stock and adds 99 parts tap water to prepare the dilute fertilizer that plants receive. Injector ratios in the range of 1:50 to 1:200 are commonly used. A ratio of 1:200 means that are stock solution needs to have twice as much fertilizer as when using a 1:100 ratio, because in this case the fertilizer injector takes 1 part fertilizer and adds 199 parts tap water.

| Element | Tomato Stage 1 (ppm) | Tomato Stage 2 (ppm) | Tomato Stage 3 (ppm) |
|---|---|---|---|
| $NO_3$-N | 90 | 120 | 190 |
| $NH_4$-N | 0 | 0 | 0 |
| P | 47 | 47 | 47 |
| K | 144 | 350 | 350 |
| Ca | 144 | 160 | 200 |
| Mg | 60 | 60 | 60 |
| S | 116 | 116 | 116 |
| Cl | 89 | 89 | 89 |
| Fe (EDTA) | 2 | 2 | 2 |
| Mn | 0.55 | 0.55 | 0.55 |
| Zn | 0.33 | 0.33 | 0.33 |
| Cu | 0.05 | 0.05 | 0.05 |
| B | 0.34 | 0.34 | 0.34 |
| Mo | 0.05 | 0.05 | 0.05 |

Table 1. Nutrient targets for tomato at stage 1 (seedling to 2nd truss anthesis), stage 2 (2nd truss to 5th truss anthesis), and stage 3 (after 5th truss anthesis). Recipe comes from the University of Arizona Controlled Environment Agriculture Center (CEAC)

| Tank A | Tank B |
|---|---|
| • Calcium nitrate<br>• ½ of potassium nitrate<br>• Iron chelate<br>• (Nitric acid) | • ½ of potassium nitrate<br>• Potassium sulfate<br>• Monopotassium phosphate<br>• Magnesium sulfate<br>• Monoammonium phosphate<br>• Ammonium nitrate<br>• All micronutrients except iron chelate<br>• (sulfuric acid)<br>• (phosphoric acid) |
| **Tank C**<br>• Acid, used to drive down pH (sulfuric, nitric, phosphoric, citric, etc.) | |

Table 2. Commonly used procedure for separating fertilizer salts in 2-3 stock tanks to avoid incompatibility.

This means when we are conducting fertilizer calculations we will need to multiply the mg of fertilizer salt per 1 L of water value times the volume of the stock tank and times the injector ratio.

**Beware Fertilizer Incompatibility!**
When prepared in stock tanks in a concentrated form, many fertilizer components are not compatible – meaning that when combined they form a precipitate (or a water insoluble sludge) that will not dissolve in water or be taken up by the fertilizer injector. The most common incompatibilities involve calcium nitrate, which cannot be combined with fertilizers container sulfates or phosphates. **Note!** Always check with the fertilizer manufacturer/supplier to check for incompatibility issues before preparing concentrated stock solution.

Because of the incompatibility issues, commercial growers typically use 2-3 fertilizer injectors (each with their own stock tank) connected in series. By convention Tank A contains calcium nitrate (and any fertilizers compatible with calcium nitrate) and Tank B contains the fertilizers not compatible with calcium nitrate. A third stock tank (Tank C) is sometimes used and typically contains an acid which is used to decrease pH. (Most often we have to worry about decreasing pH in the hydroponic root-zone due to the alkalinity in tap water and the majority of N used in the in nitrate form which drives pH up over time).

**Steps to Calculate a Complete Nutrient Solution**
Now let's put the pieces together to discuss how to calculate the components required to put together a complete nutrient solution. This is somewhat complex because each of the fertilizer salts that we used contains two different elements of interest. That means if we want to add say calcium, that depending on the fertilizer source we use we will also be adding chloride, nitrate, sulfate, etc. that we also need to account for. Therefore, a fairly specific order is followed to make sure we do not add an excess of

one nutrient when trying to reach the target value for another nutrient. The order given below has been adapted from Nutrient Solutions for Greenhouse Crops, 2016 which is an excellent 94-page manual available for download by pdf. The manual contains nutrient solution recipes for many hydroponic crops. https://www.eurofins.com/agro/news/new-manual-nutrient-solutions-for-greenhouse-crops-available/ Here's the process to work through. And then I'll provide a comprehensive example!

Identify the target elemental values
Subtract nutrients in raw water from the target (typically only Ca and Mg are in high enough concentration in the water to be of interest)
For each nutrient source, follow this order

1. Choose calcium chloride or potassium chloride to add Cl (if required by the target elemental values, commonly used for tomatoes and vine crops).
2. Use calcium nitrate for Ca.
3. Use ammonium nitrate or MAP (monoammonium phosphate) or DAP (diammonium phosphate) to complete the $NH_4$ demand.
4. Choose monopotassium phosphate to complete the P demand.
5. Use magnesium sulfate to complete the Mg or S demand.
6. Add magnesium nitrate if more Mg is needed, or replace magnesium sulfate with magnesium nitrate if less sulfate is required.
7. Choose potassium sulfate as a sulfate source in case the sulfate demand is not completed with magnesium sulfate.
8. Use potassium nitrate to complete the $NO_3$ and K demand.
9. Select the appropriate fertilizer ingredient to supply each micronutrient.

Within each fertilizer salt:

1. Calculate the fertilizer amount required
2. Calculate fertilizer value of any other element added
3. Adjust for injector ratio (stock solution concentration) and stock tank volume

Example, we are preparing stage 1 tomato nutrient solution from UA CEAC, our water has 40 ppm Ca and 20 ppm Mg. Our stock tank is 100 L and injector ratio is 1:200. The example assumes we are using commonly available forms of fertilizer salts, but always check your own labels for their specific percent nutrient value.

| Element | Stage 1 Target (ppm) | Target after accounting for raw water (ppm) |
|---|---|---|
| $NO_3$-N | 90 | 90 |
| $NH_4$-N | 0 | 0 |
| P | 47 | 47 |
| K | 144 | 144 |
| Ca | 144 | 104 |
| Mg | 60 | 40 |
| S | 116 | 116 |
| Cl | 89 | 89 |
| Fe (EDTA) | 2 | 2 |
| Mn | 0.55 | 0.55 |
| Zn | 0.33 | 0.33 |
| Cu | 0.05 | 0.05 |
| B | 0.34 | 0.34 |
| Mo | 0.05 | 0.05 |

Let's Begin!

First add Cl, let's choose potassium chloride (47.6% Cl and 52.2% K)

- Target 89 ppm Cl. Use 89 mg/L / 0.476 = 187 mg/L KCl
- This also provides 187 mg x 0.522 = 98 mg/L K
- Account for 100 L stock tank, and 1:200 injector ratio, and convert mg to g
    - 187 mg/L x 100 L x 200 (injector ratio) / 1000 mg/g = 3,740 g KCl

Second calculate calcium nitrate (19% Ca and 15.5% N)

- Target 104 ppm Ca. Use: 104 mg/L / 0.19 = 547 mg/L calcium nitrate
- This also provides 547 mg x 0.155 = 85 mg/L N (to make it easy let's ignore the small amount of $NH_4$ from this fertilizer and just worry about the total N it provides).

- Account for 100 L stock tank, and 1:200 injector ratio, and convert mg to g
    - 547 mg/L x 100 L x 200 (injector ratio) / 1000 mg/g = 10,940 g (10.94 kg) calcium nitrate

Third no need to use MAP or DAP to complete the $NH_4$ demand as no $NH_4$ required.

Fourth calculate monopotassium phosphate to provide P (it is 22.7% P, 28.7% K)
- Target 47 ppm P. Use: 47 mg/L / 0.227 = 207 mg/L monopotassium phosphate
- This also provides 207 mg x 0.297 = 61.5 mg/L K
- Account for 100 L stock tank, and 1:200 injector ratio, and convert mg to g
    - 207 mg/L x 100 L x 200 (injector ratio) / 1000 mg/g = 4,140 g (4.14 kg) monopotassium phosphate

Fifth calculate magnesium sulfate to complete the Mg or S demand (it is 9.7% Mg, 13% S)
- We need less Mg than $SO_4$, so target 40 ppm Mg: 40 mg/L / 0.097 = 412 mg/L magnesium sulfate
- This also provides 412 mg x 0.13 = 54 mg/L S
- Account for 100 L stock tank, and 1:200 injector ratio, and convert mg to g
    - 412 mg/L x 100 L x 200 (injector ratio) / 1000 mg/g = 8,240 g (8.24 kg) magnesium sulfate

Sixth we can ignore this as we have reached our target Mg (the step was to add magnesium nitrate if more Mg is needed, or replace magnesium sulfate with magnesium nitrate if less sulfate is required)

Seventh calculate potassium sulfate to complete the S demand (it is 44.8% K, 18.3 % S)
- S target is 116 ppm (minus the 54 ppm added above), target is 62 ppm S: 62 mg/L / 0.183 = 339 mg/L potassium sulfate
- This also provides 339 mg x 0.448 = 152 mg/L K
- Account for 100 L stock tank, and 1:200 injector ratio, and convert mg to g
    - 339 mg/L x 100 L x 200 (injector ratio) / 1000 mg/g = 6,780 g (6.78 kg) potassium sulfate

Eighth, let's add up how much K we have so far: 61.5 ppm from step 4 and 152 ppm from step 7 = 213.5 ppm K – this is more than our 144 ppm target. So no added K is needed.

Then, let's add up how much N we have so far: 85 ppm from step 2, our target is 90 ppm, so we need 5 ppm N (potassium nitrate is 38.6% K, 13.7% N)
- N target is 5 ppm: 5 mg/L / 0.137 = 36.5 mg/L potassium nitrate
- This also provides 36.5 mg x 0.386 = 14 mg/L K
- Account for 100 L stock tank, and 1:200 injector ration, and convert mg to g
    - 36.5 mg/L x 100 L x 200 (injector ration) / 1000 mg/g = 730 g (0.73 kg) potassium nitrate

Now continue on with micronutrients (in the case of micronutrients no need to account for secondary nutrients added because they would be in very small quantities).

Iron (Fe) from FeEDTA (13% iron)
- Target 2 ppm, 2 mg/L / 0.13 = 15.38 mg/L
- Account for 100 L stock tank, and 1:200 injector ratio, and convert mg to g
    - 15.38 mg/L x 100 L x 200 (injector ratio) / 1000 mg/g = 307.6 g FeEDTA

Manganese (Mn) from manganese sulfate (32.5% Mn)
- Target 0.55 ppm, 0.55 mg/L / 0.325 = 1.69 mg/L
- Account for 100 L stock tank, and 1:200 injector ratio, and convert mg to g
    - 1.69 mg/L x 100 L x 200 (injector ratio) / 1000 mg/g = 33.8 g manganese sulfate

Zinc (Zn) from ZnEDTA (14.8% Zn)

- Target 0.33 ppm, 0.33 mg/L / 0.148 = 2.23 mg/L
- Account for 100 L stock tank, and 1:200 injector ratio, and convert mg to g
    - 2.23 mg/L x 100 L x 200 (injector ratio) / 1000 mg/g = 44.6 g ZnEDTA

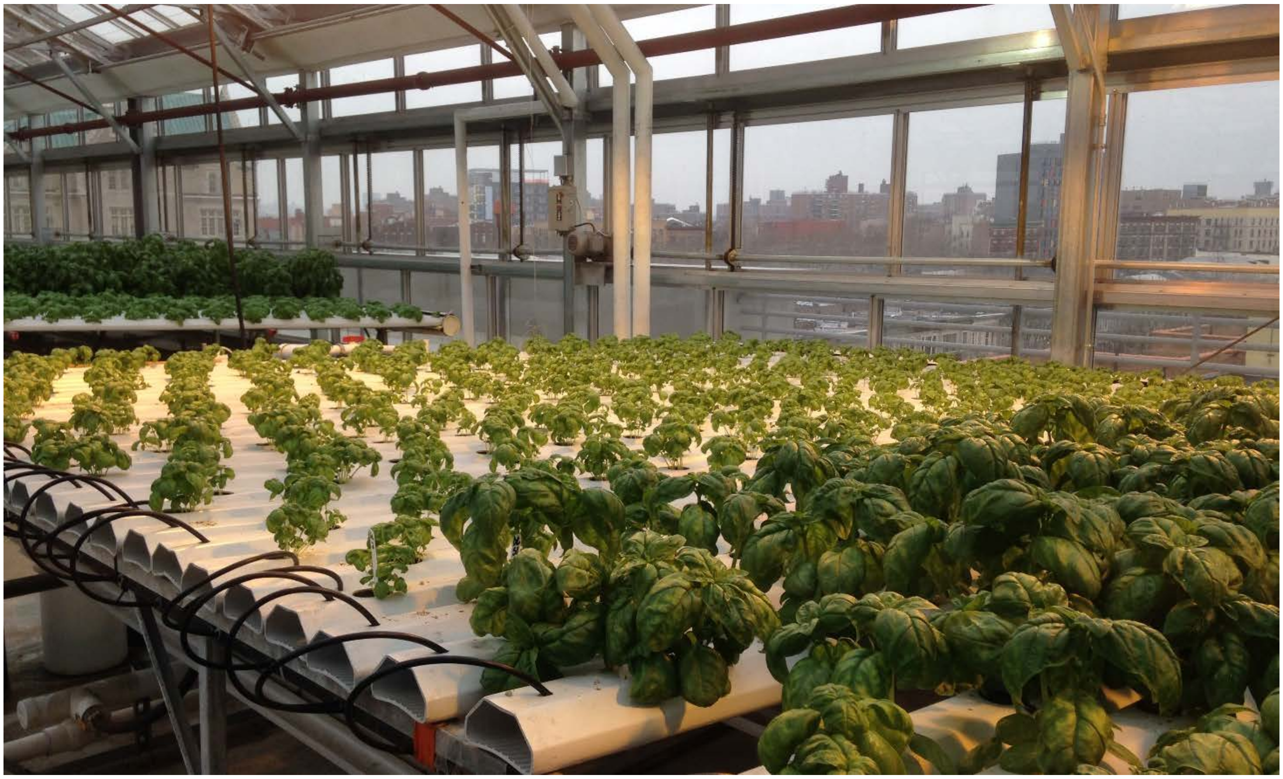
Boron (B) from Boric Acid (17.5% B)

- Target 0.34 ppm, 0.34 mg/L / 0.175 = 1.94 mg/L
- Account for 100 L stock tank, and 1:200 injector ratio, and convert mg to g
    - 1.94 mg/L x 100 L x 200 (injector ratio) / 1000 mg/g = 38.8 g Boric acid

Molydenum (Mo) from sodium molybdate (39.6% Mo)

- Target 0.05 ppm, 0.05 mg/L / 0.396 = 0.126 mg/L
- Account for 100 L stock tank, and 1:200 injector ratio, and convert mg to g
    - 0.126 mg/L x 100 L x 200 (injector ratio) / 1000 mg/g = 2.52 g sodium molybdate

Phew! If you made it to the end, congratulations are in order! I hope this article has provided a helpful framework for fertilizer calculations. When in doubt regarding fertilizer calculations/preparation be sure to check with your local cooperative extension educator or friendly fertilizer supplier.



American Floral Endowment
Funding Generations of Progress Through Research and Scholarships

P.L. LIGHT SYSTEMS
THE LIGHTING KNOWLEDGE COMPANY

eGRO Electronic Grower Resources Online

Project Sponsors

# e-GRO Alert

www.e-gro.org

## CONTRIBUTORS


**Dr. Nora Catlin**
Floriculture Specialist
Cornell Cooperative Extension
Suffolk County
nora.catlin@cornell.edu

**Dr. Chris Currey**
Assistant Professor of Floriculture
Iowa State University
ccurrey@iastate.edu

**Dr. Ryan Dickson**
Extension Specialist for Greenhouse Management & Technologies
University of New Hampshire
ryan.dickson@unh.edu

**Thomas Ford**
Commercial Horticulture Educator
Penn State Extension
tgf2@psu.edu

**Dan Gilrein**
Entomology Specialist
Cornell Cooperative Extension
Suffolk County
dog1@cornell.edu

**Dr. Joyce Latimer**
Floriculture Extension & Research
Virginia Tech
jlatime@vt.edu

**Heidi Lindberg**
Floriculture Extension Educator
Michigan State University
wolleage@anr.msu.edu

**Dr. Roberto Lopez**
Floriculture Extension & Research
Michigan State University
rglopez@msu.edu

**Dr. Neil Mattson**
Greenhouse Research & Extension
Cornell University
neil.mattson@cornell.edu

**Dr. W. Garrett Owen**
Floriculture Outreach Specialist
Michigan State University
wgowen@msu.edu

**Dr. Rosa E. Raudales**
Greenhouse Extension Specialist
University of Connecticut
rosa.raudales@uconn.edu

**Dr. Beth Scheckelhoff**
Extension Educator – Greenhouse Systems
The Ohio State University
scheckelhoff.11@osu.edu

**Lee Stivers**
Extension Educator – Horticulture
Penn State Extension
Washington County
ljs32@psu.edu

**Dr. Paul Thomas**
Floriculture Extension & Research
University of Georgia
pathomas@uga.edu

**Dr. Ariana Torres-Bravo**
Horticulture / Ag. Economics
Purdue University
torres2@purdue.edu

**Dr. Brian Whipker**
Floriculture Extension & Research
NC State University
bwhipker@ncsu.edu




## Cooperating Universities

Cornell University

Cornell Cooperative Extension Suffolk County

University of New Hampshire Cooperative Extension

PennState Cooperative Extension, College of Agricultural Sciences

Virginia Tech

Michigan State University

UCONN

Purdue University

The University of Georgia

The Ohio State University

NC State University

Iowa State University

## In cooperation with our local and state greenhouse organizations

Maumee Valley Growers – Choose the Very Best.

Metro Detroit Flower Growers Association

NC Flower Power

Western Michigan Greenhouse Association

Connecticut Greenhouse Growers Association

Indiana Flower Growers Association

lifga

New Hampshire Plant Growers – Quality Garden Centers & Growers

Virginia Flower Growers Association – Since 1954

Michigan Greenhouse Growers Council