Combined Proceedings IPPS 69:411-418. 2019.

Extra Phosphorus for Flowering and Other Myths

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Keywords: Nursery production, Landscape Management, Fertilizer, Flowering, Controlled Release, Best Management Practices

INTRODUCTION

Do you use a high-phosphorus fertilizer such as 10-10-10 or 14-14-14 to promote roots or flowers? If so, you are following an outdated recipe for nursery production and landscape management. Hopefully, this article will convince you to avoid that practice. In the process, you might save on fertilizer costs, protect natural water resources, and avoid an environmental damage lawsuit!

Phosphorus: A key plant element

Phosphorus is an essential plant nutrient with an interesting mythical origin. This 13th element in the periodic table was discovered by the alchemist Hennig Brand in Germany in 1669 in his quest for the Philosopher's Stone which would turn other metals into gold.

Hennig experimented with thousands of liters of human urine, figuring that it had a promising golden color. He discovered an interesting residue which would not turn lead into gold but did burn and glow in the presence of oxygen (hence its modern use in match heads). The element was named phosphorus, meaning "bearer of light". Appropriately, given the raw material from which it was first derived, its chemical symbol is P.

Phosphorus is one of 12 essential fertilizer nutrients (Figure 1). The ability of P to add and drop electrons leads to a major role in plant metabolism as the plant's battery, allowing energy from photosynthesis (the sun) to be used for many processes in the plant. Like other essential plant elements and environmental conditions, lack of P can limit plant growth and flowering. However, it is not specifically a root- or flower-promoting nutrient.

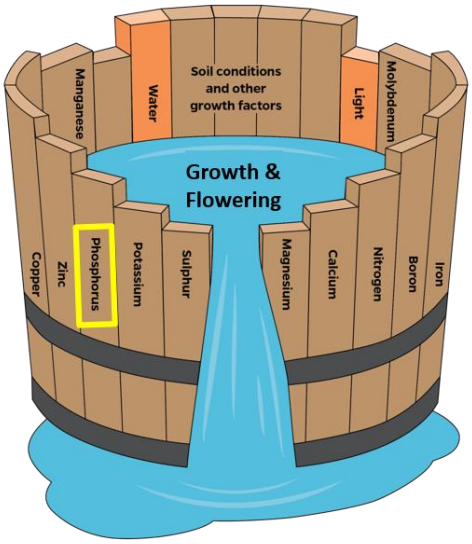

Figure 1. Phosphorus is one of the essential requirements for plant growth.

Phosphorus is the "P" in NPK fertilizers (along with nitrogen, N, and potassium, K). The traditional way to write fertilizer phosphate is P_2O_5, and K_2O is commonly called potash. Depending on your location and supplier, blended fertilizers are often expressed in two ways. Fertilizer labels can list N–P_2O_5–K_2O (which we will use in this article), or as elemental NPK. This can cause challenges when interpreting fertilizer recommendations:

- Nitrogen (N) is always described on a fertilizer label as elemental N.
- Elemental phosphorus (P) = P_2O_5 × 0.4364; P_2O_5 = elemental P × 2.2915.
- Elemental potassium (K) = K_2O (potash) × 0.8301; K_2O (potash) = elemental K × 1.2047.

A common symptom of P deficiency is purple or red leaves (Figure 2).

Verbena

Kale

Figure 2. Purpling of leaves from phosphorus deficiency in verbena and kale.

However, avoid diagnosing P deficiency based on physical appearance alone. As shown in Figure 3, purpling can result from several other causes, such as cold temperature, nitrogen deficiency, excess light level, and pesticide phytotoxicity.

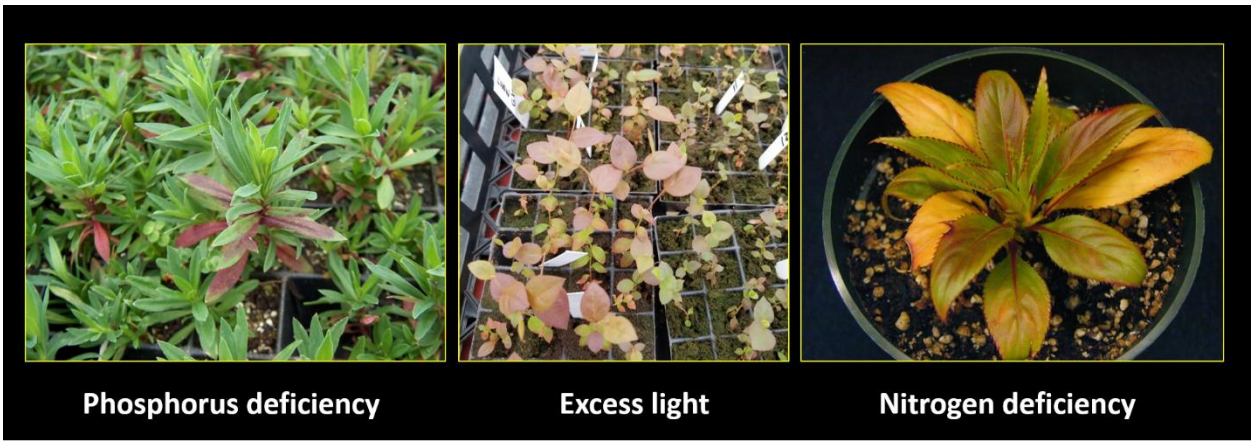

Figure 3. Red or purple coloration can be caused by several factors, not just P deficiency.

Some species show other P deficiency symptoms, such as tip burn in azalea or decreased growth (Figure 4). To confirm a P deficiency, it is therefore necessary to send soil and leaf tissue samples to an analytical laboratory.

You can ensure adequate P in container crops by providing a moderate fertilizer level and substrate-pH. Phosphorus deficiency may result from lack of fertilizer. When growing in container substrates, P will remain available if the substrate pH is less than 6.5. Insoluble calcium phosphate can form at high pH (above 6.5) in both field soil or container substrates. Phosphorus can also be tied up in acidic field soils, because high levels of iron and aluminum in mineral soils reduce P solubility at low pH.

Figure 4. Evergreen azaleas show tip burn (top) and hydrangea 'Limelight' has decreased growth (bottom) in response to phosphorus deficiency. Research by Virginia Tech University.

Excess P fertilizer can have negative environmental impacts. Because the soluble, plant-available form of P (phosphate, PO_4^{3-}) has a negative charge in the substrate solution, it can easily drain from the substrate (just like nitrate, NO_3^-) and subsequently leach into groundwater or runoff to nearby streams and lakes. Around 40 to 70% of P fertilizer typically leaches from nursery containers. This is a wasted expense, which is important because and the cost of P fertilizer is rising quickly and profit margins are often tight for horticulture businesses.

Phosphorus and N contamination are the main algae-promoting nutrients in natural waterways, and a very low concentration (0.1 ppm P) can be enough to trigger eutrophication. Mining P from calcium phosphate in the ground can also cause a significant waste issue, which has been experienced in phosphate mines in Florida, US. As the "green industry", we want to both stay out of the spotlight and be good stewards of the environment.

Figure 5. Phosphorus is easily leached from container substrates and causes eutrophication of water resources.

Do high P fertilizers promote flowering?

Blooming annuals: Many fertilizers sold to consumers as flowering fertilizers contain high levels of P. For example, the N-P_2O_5-K_2O ratio of one retail "Bloom Plus" product is 10-54-10. However, how much P from a water-soluble fertilizer (WSF) do plants need to flower? Henry and Whipker (2015) from North Carolina State University showed that 5 to 10 parts per million (ppm) of P provided with each irrigation using a WSF is adequate for most flowering and foliage annuals. Additional P did not increase blooms or growth. Another research team from North Carolina State University (Kraus et al., 2011) reported similar findings for herbaceous perennials, citing that growth and flowering of *Rudbeckia* and hibiscus fertilized with 3 ppm P were similar to those given 50 ppm P. In fact, 100 ppm P (with 100 ppm N) severely decreased growth of 'Luna Blush' hibiscus. This is just another reason why it's better "to aim low" when selecting your P fertilizer levels.

Table 1 will help you calculate how much P is in a WSF. The concentration of blended WSF is usually described in terms of ppm of N. Typical constant WSF concentration for annuals is based on 100 ppm N or up to 200 ppm N for heavy-feeding crops such as petunias. With different N-P_2O_5-K_2O ratios, this means the ppm of P increases if the overall fertilizer concentration is

increased, or if we choose a fertilizer with a high P_2O_5 content relative to N. If we used the Bloom Plus fertilizer, even at a low N level (100 ppm N), we would be applying 236 ppm P (which is 20 times the amount that a plant would need for flowering). Instead we could apply a fertilizer such as 15-5-15 at 100 ppm N, and not waste all that P fertilizer.

Table 1. The concentration of elemental P in a water-soluble fertilizer with different N-P_2O_5-K_2O ratios when applied at two nitrogen concentrations (ppm N). Levels in bold italics are close to recommended 6 to 13 ppm of P for maximum flowering (for example, 100 ppm N from 15-5-15 provides 11 ppm P).

	ppm of elemental phosphorus (P)	
Fertilizer N-P_2O_5-K_2O	**At 100 ppm N**	**At 200 ppm N**
10-54-10	236	472
20-20-20	43	86
20-10-20	***22***	43
15-5-15	***11***	***22***
13-2-13	4	***9***
15-0-15	0	0

Flowering shrubs: Perhaps you grow flowering shrubs and therefore think your plants are different and need higher P. In fact, research has found that only 5 to 10 ppm P on a constant feed basis (similar levels to annual plants) is needed for maximum growth and flowering. Best management practices (BMPs) adopted around the US for nursery growers to provide healthy growth (and to avoid environmental law suits) is to only use 5 to 15 ppm P when applying constant WSF.

Table 2. Research showing the minimum ppm P in constant water-soluble fertilizer required to maintain maximal growth in flowering shrubs.

Study	**Plant Taxa**	**ppm P**
Graca and Hamilton, 1981	*Cotoneaster divaricatus*	5
Yeager and Wright, 1982; Wright and Niemiera, 1985	*Ilex crenata* 'Helleri'	5
Havis and Baker, 1985	*Rhododendron* 'Victor'	2.5
Havis and Baker, 1985	*Cotoneaster adpressus* var. *praecox*	10
Shreckhise, Owen & Niemiera, 2018	*Hydrangea paniculata* 'Limelight'	5
Shreckhise, Owen & Niemiera, 2018	*Ilex crenata* 'Helleri'	1
Shreckhise, Owen & Niemiera, 2018	Azalea hybrid 'Karen'	3

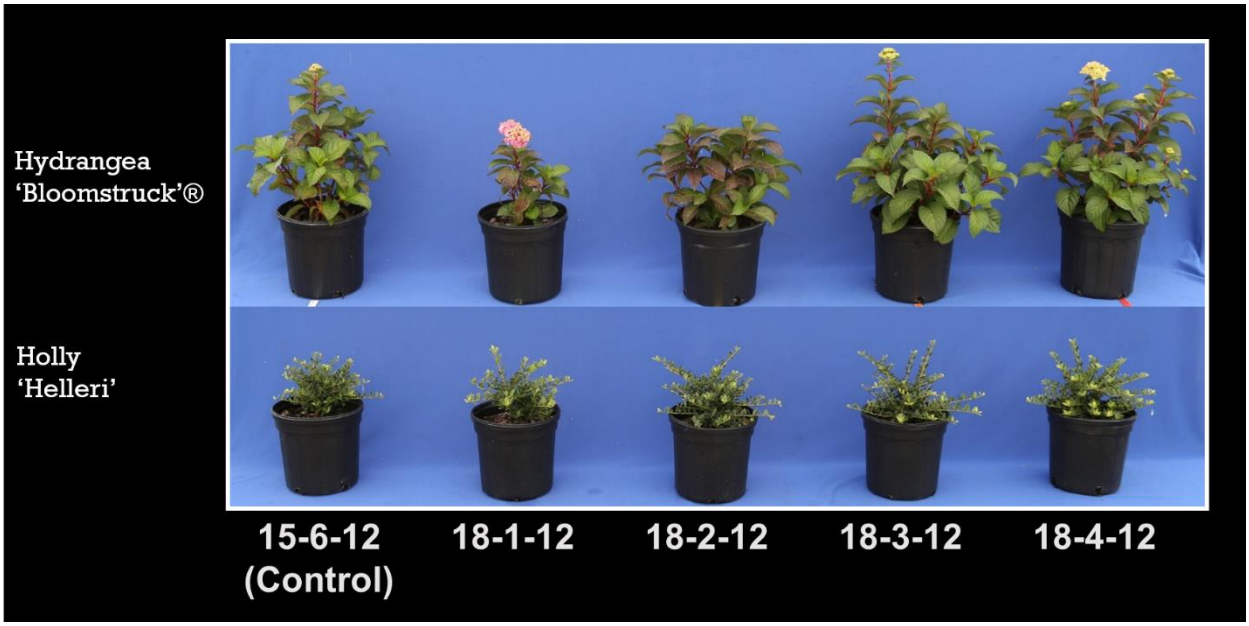

Figure 6. Growth and flowering response of hydrangea and holly to several CRF products. Research by Virginia Tech University.

Controlled release fertilizer: You may use controlled release fertilizer (CRF) and it is hard to relate these WSF concentrations to your nursery. Research at Virginia Tech found that 0.3 to 0.6 grams P per 1-gallon (3.8L) pot provided maximum growth of holly and hydrangea. To achieve that level of P depends on how much fertilizer you apply to a container and the N–P_2O_5–K_2O ratio. For example, plants grown with 18-3-12 or 18-4-12 CRF applied at the medium recommended label rate had as much growth and flowering as a 15-6-12 CRF that contained up to twice the P level (Figure 6).

Table 3 shows examples of the P contribution from three common CRF products. A high-P fertilizer (14-14-14) greatly over-applies P if it is top-dressed at a high rate of 24 grams of fertilizer per container.

Table 3. The grams of elemental P from controlled release fertilizers with different N-P_2O_5-K_2O ratios when top-dressed at two weights of total fertilizer per container. Levels in bold italics are close to recommended 0.3 to 0.6 grams of P for maximum growth (for example, 12 grams of fertilizer per 3.8L container from 15-9-12 provides 0.5 grams P).

	Grams of elemental phosphorus (P) per 1 gallon (3.8 liter) nursery container	
Fertilizer N-P_2O_5-K_2O ratio	**Top-dress 12 grams fertilizer per container**	**Top-dress 24 grams fertilizer per container**
14-14-14	***0.7***	1.5
15-9-12	***0.5***	0.9
13-3-13	0.2	***0.3***

Landscapes: Are you still not convinced? Perhaps your business is in landscape maintenance. Many landscapes where manures, composts, and general fertilizers have been applied in the past are already high in P. You might be able to save money without decreasing plant performance by not applying any P fertilizer. Best management practices for P fertilization in landscapes is to take a soil test first (this is actually a requirement in some areas of the US). If the soil analysis shows high P, no fertilizer is needed (or even permitted in some areas). For example, Florida has porous sandy soils, high rainfall, a high-water table, and a subtropical climate, and is therefore very sensitive to algal blooms. Landscapers in Florida are required to have BMP training and follow several guidelines, such as:

- No more than 0.25 kg P_2O_5/100 m^2 per year may be applied to urban turf without a soil test. A one-time application of up to 0.50 kg P_2O_5/100 m^2 is permitted for establishment of new turf.
- Annual landscape rates for established Florida garden beds (kg per 100 m^2 per year) are up to 1.0 kg N, 0.5 kg P_2O_5 = 0.2 kg P, and 1 kg K_2O = 0.8 kg K, using slow-release fertilizer or compost in order to reduce rapid leaching.

Recommended rates vary depending on the plant, soil, and location, but we recommend reviewing BMP documents provided by university extension services. Free fact sheets are available from University of Florida IFAS Extension (see https://ffl.ifas.ufl.edu). Note that when interpreting US units, 1 lb/1000 ft^2 = 0.5 kg/100 m^2.

Do high P fertilizers promote rooting?

Here is the kind of misinformation that permeates the internet: "[I]f you want a fertilizer that supports root growth, ensure the second and third numbers are larger than the first. For example, a 3-20-20 fertilizer that contains 3 percent nitrogen, 20 percent phosphorus and 20 percent potassium encourages roots to grow strong and healthy."

It **is** true that high levels of nitrogen encourage excess shoot growth. Therefore, do not over-apply nitrogen. However, does high P increase rooting? No.

The billions of commercial transplants grown each year provide evidence for avoiding high P. Seedling plug growers often purposely create a slight P deficiency by limiting phosphorus fertilizer supply in order to produce transplants with compact shoot growth, strong roots, and dark green leaves. That is why a low P fertilizer (13-2-13 N-P_2O_5-K_2O) is widely used in seedling plug production in the US. Increasing P does not increase root/shoot ratio, and these growers limit both P and N (especially the use of ammonium-N, favoring instead nitrate-N) to avoid leggy shoot growth.

As an essential element, P is of course required by plants to grow. That is true of growing both roots and shoots. However, P is not a root-promoting nutrient. Research at Virginia Tech found that increasing ppm P when fertilizing hydrangea and holly had a big effect on increasing shoot growth, but had less effect on increasing root growth. In other words, as P was increased from 0.5 to 6 ppm P, there was less allocation by the plant to growth of roots relative to the growth of shoots (the "root-to-shoot ratio" decreased). Phosphorus does not specifically target root growth.

In Conclusion

Phosphorus has mythical origins. Unfortunately, our industry also hangs on to a persistent myth about the need for high P fertilizer. This negatively affects both our wallet and our environment. Why is it so hard to change our beliefs, and for the nursery and landscape industry to reduce P application? We can put

it down to the psychology of bloody-mindedness:

- We would rather deny new, uncomfortable information than reshape our worldview
- When doubts do creep in, we dig in our heels
- There is a grief process to change: denial - anger - bargaining - depression - acceptance
- We love myths!

Don't just take our word for it, but look at the research that this article is based on and take the following steps:

- Run a soil test in the landscape to see if any P fertilizer is needed. Remember that N, not P, is the most common production and landscape deficiency.
- Use a tissue analysis to diagnose a P deficiency (not just red or purple leaves).
- Use slow release forms, including CRF or compost in the landscape.
- Provide nutrients in the ratio that plants can use: A 4-1-4 N-P_2O_5-K_2O is always adequate for vegetative and flowering growth.
- See for yourself by running trials.

Using best management practices can help improve plant quality, reduce production cost, and is our responsibility as stewards of the environment.

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Acknowledgements:

We thank USDA-ARS Floriculture and Nursery Research Initiative #58-3607-8-725, National Institute of Food and Agriculture, USDA "Clean WateR3 - Reduce, Remediate, Recycle", #2014-51181-22372, Horticultural Research Institute, Virginia Agricultural Council, Virginia Nursery and Landscape Association, and industry partners of the Floriculture Research Alliance at the University of Florida (floriculturealliance.org) for supporting this research.