MDARD Horticulture Fund Fiscal Year 2017 Final Report

Project Title: Physiological response of nursery crops to reduced phosphorus fertilization

Principal Investigator:
Name: Bert Cregg
E-mail: cregg@msu.edu
Department: Horticulture & Forestry
Mail Address: 1066 Bogue St., East Lansing, MI 48824

Team Members:
Shital Poudyal, Horticulture
R. Thomas Fernandez, Horticulture

Synopsis of Project:
In this project we evaluated the impact of varying phosphorus (P) additions on growth, physiology and morphology of three common nursery plants; oak leaf hydrangea, redtwig dogwood, and ninebark. This study is part our larger, on-going USDA SCRI-funded project "Clean WateR3: Reduce, Remediate, Recycle". The objective of the present study is to understand the response of nursery crops to phosphorus; with the ultimate goal of reducing phosphorus additions while maintaining crop productivity and quality. In the current study, plant biomass growth increased with increasing phosphorus additions up to 6 mg of P per L of liquid fertilizer. Shoot growth response was more responsive to P additions than root growth and shoot/root ratio increased with increased P. Photosynthetic quantum efficiency, a measure of the efficiency of light harvesting reactions of photosynthesis, was optimized at very low P levels (1 mg of P per L) for all three taxa. Analysis of the response of photosynthesis to internal leaf CO_2 (A/Ci curves) indicated a broader response to P addition, suggesting that overall photosynthetic response to P is driven by photosynthetic biochemistry rather than light harvesting reactions. Overall, growth was optimized at phosphorus levels that are lower than those in water soluble or controlled release fertilizers that are commonly used in the nursery trade. This suggests that nursery growers may be able to reduce P additions without reducing crop growth.

PROBLEM STATEMENT:
Agricultural non-point source (NPS) pollution is the leading cause of reduced water quality in rivers and lakes in the US and is also a major cause of impaired wetland and ground water quality. Hence, NPS pollution, including fertilizer runoff, is a major concern for the protection of surface water quality (US Environment Protection Agency, 2005; US Environmental Protection Agency, 2016). Fertilizer runoff, including nitrogen and phosphorus, has created a number of issues relating to water quality and environment. Eutrophication and algal blooms in fresh water are among some of these. One high-profile example of water quality issues related to NPS was the recent water crisis in Toledo, OH, which left a city of more than half a million people without potable water (Wines, 2014). Because of these issues and increasing problems associated with phosphorus runoff in the Great Lakes, the US and the Canadian governments are working together to manage phosphorus runoff in theses lakes. (Great Lakes Water Quality Agreement Nutrient Annex Subcommittee, 2015).

Container nursery production in an intensive agricultural system that uses large amounts of water and fertilizer per unit ground area compared to other plant-based agriculture, creating the potential for significant environmental impacts. In container nursery production, phosphorus is typically applied as a component of controlled release fertilizers or in water soluble fertilizers. In most nursery fertilizers, the rate of phosphorus is based on standard ratios but it is likely the actual phosphorus demand of crops varies. Over-application of phosphorus may cause environmental issues while under-application may result in reduced crop growth and quality, hence optimizing the application of phosphorus is crucial.

For container nurseries, irrigation is applied to meet the water lost from the container and to leach out accumulated soluble salts. A common standard for nursery irrigation to achieve a leaching fraction (proportion of daily irrigation that leaches through a container) of 10-20%, but often application of water exceeds this amount and resulting is substantial runoff (Warsaw et al., 2009; Kachenko, 2010). In a nursery with #1 containers placed 6 inches apart, up to 80% of applied water may be lost as runoff (Mathers et al., 2005). This runoff water will include nutrients and media particles that may ultimately reach surface water. Phosphorus leaching is increased when pine bark, sphagnum peat, vermiculite or sand is used as growing media and leaching is even higher when soluble granular fertilizer is used (Broschat, 1995). In soilless substrates, loss of 30% to 60% of applied phosphorus is common (Newman, 2014).

Phosphorus (P) is an essential plant nutrient and therefore P deficiencies reduce plant growth and development. Phosphorus is a major component of nucleic acids, phosphoproteins and enzymes and it also plays important roles in physiological processes that require energy. Deficiency of P causes reduction in leaf number and leaf area, resulting in increased root to shoot ratio, the process of carbon utilization (respiration) by plants is also slowed because of P deficiency ((IPNI (International Plant Nutrition Institute), 1999; Mengel et al., 2001). Phosphorus deficiency also can damage photochemical apparatus and reduce PSII efficiency (Xu et al., 2007). However, the effect of phosphorus on photosynthesis and respiration of plants is varied and largely dependent on the deficiency level. Some plants are sensitive to moderate P deficiency while others are not (Terry and Ulrich, 1973). Hence the objective of our experiment is to determine the growth, morphological and physiological response of nursery crops to various phosphorus application rates.

SPECIFIC OBJECTIVES AND HYPOTHESES:

In this research we examined three interrelated hypotheses:

1) The growth response of nursery crops to P is related to effects on physiological function and morphological development
2) The threshold for physiological and morphological responses to P varies among crop types
3) Understanding crop response to P can help growers to optimize P additions in order to maximize crop growth and quality while minimizing potential environmental impacts

METHODS

We conducted a greenhouse experiment to determine the responses of three common taxa of nursery plants, Queen of Hearts oakleaf hydrangea (*Hydrangea* quercifolia ‘Queen of Hearts’), Redtwig dogwood (*Cornus obliqua*) and Summer Wine® ninebark (*Physocarpus opulifolius* ‘Seward’) to different rate of P fertilization. Plants were grown in #3 (12 L) containers in a mix of 85:15 (v:v) pine bark and peat moss at 26º/20ºC (day/night temperatures) at the MSU Horticulture research greenhouse.

Treatments

All plants were watered regularly with a nutrient solution of 100 mg L^{-1} N and 60 mg L^{-1} K and 80 mg L^{-1} of micronutrients (Micromax). Plants received one of six rates of phosphorus (0, 1, 2, 4, 6, 8 mg L^{-1} of P) (Fig. 1). We irrigated plants every 2 to 3 days, targeting a standard 10-20% leaching fraction. Plants were placed in plastic saucers during irrigation and we collected and measured leachate from all plants following each irrigation.

Data collection

Shoot growth was measured periodically during the study and all plants were harvested at the end of the study to determine leaf, stem and root biomass and nutrient content. Photosynthetic gas exchange and chlorophyll fluorescence were measured three times on all plants over the course of the study using a Li-6400-XT portable photosynthesis system. Parameter estimates include quantum yield efficiency of photosystem II (ΦPSII), photochemical quenching (qp), maximum carboxylation rate of rubisco (Vcmax), maximum rate of electron transport (J), maximum rate of triose phosphate use (TPU), dark respiration (Rd), and mesophyll conductance (gm) Leaf area and specific leaf mass (g dry wt. / cm^2 leaf area) were measured on a subsample of leaves at the end of the study. Root/shoot ratio for each plant was calculated based on data from the destructive harvests.

RESULTS

Growth and morphology

Total plant biomass increased with phosphorus addition rate and then reached a plateau (Fig. 2). Maximum growth of Physocarpus and Cornus were reached at 6 mg P per L, whereas maximum growth of Hydrangea was reached at 4 mg P per L. Phosphorus deficiency symptoms were visible on plants of all three species at 0 and 1 mg P per L. Deficiency symptoms included stunted leaves and purplish coloration on Cornus and Hydrangea plants (Fig. 3). Root to shoot ratio decreased with increase P addition for all species (Figure 4) indicating that increasing phosphorus addition resulted in increased allocation of biomass to shoots, rather than roots.

Physiology

Photosynthetic quantum efficiency, a measure of efficiency of light capture in photosynthesis, was maximized at the lowest level of phosphorus addition (1 mg P per L) for all three taxa (Fig.5). This indicates that the phosphorus requirements for the light reactions of photosynthesis are relatively low. In contrast, analysis of photosynthetic response to internal CO2 (A/Ci curves) indicated that the biochemical reactions association with carboxylation and photosynthetic electron transport were maximized at P additions of approximately 6 mg P per L (Fig. 6)

SUMMARY

Plant growth and photosynthetic biochemistry of the landscape nursery plants used in this study were optimized at phosphorus addition rates that are considerably lower than rates found in many commercially available nursery fertilizers. Fertilizer grade is expressed as the percent nitrogen, phosphate and potash ($N\text{-}P_2O_5\text{-}K_2O$) contained in the fertilizer. A ratio of 3-1-2 of $N\text{-}P_2O_5\text{-}K_2O$ is commonly recommended for nursery crops. Commercially-available water soluble fertilizers often have $N{:}P_2O_5$ ratios of 3:1 or 2:1. Osmocote Plus, which is a widely used controlled release fertilizer in nursery production has $N{:}P_2O_5$ ratio of 1.7:1. In the current study the fertilizer addition rate that resulted in optimized growth and photosynthetic biochemistry was 100 mg N and 6 mg P per L. This equates to a 7.3:1 ratio of $N{:}P_2O_5$. This analysis suggests that growers may be able to reduce P additions by 50% or more without reducing crop growth. Some fertilizer manufacturers are now producing lower P fertilizers. For example, ICL produces a formulation of Osmocote, one of the most popular controlled-released fertilizer with a 17-3-6 analysis. This is a 5.7:1 N:P_2O_5 ratio, which is approaching the 7.3:1 ratio that optimized growth in this study. We encourage nursery growers to work with their fertilizer providers to trial lower P fertilizers on their crops.

Figure 1. Application of phosphorus fertilization treatments

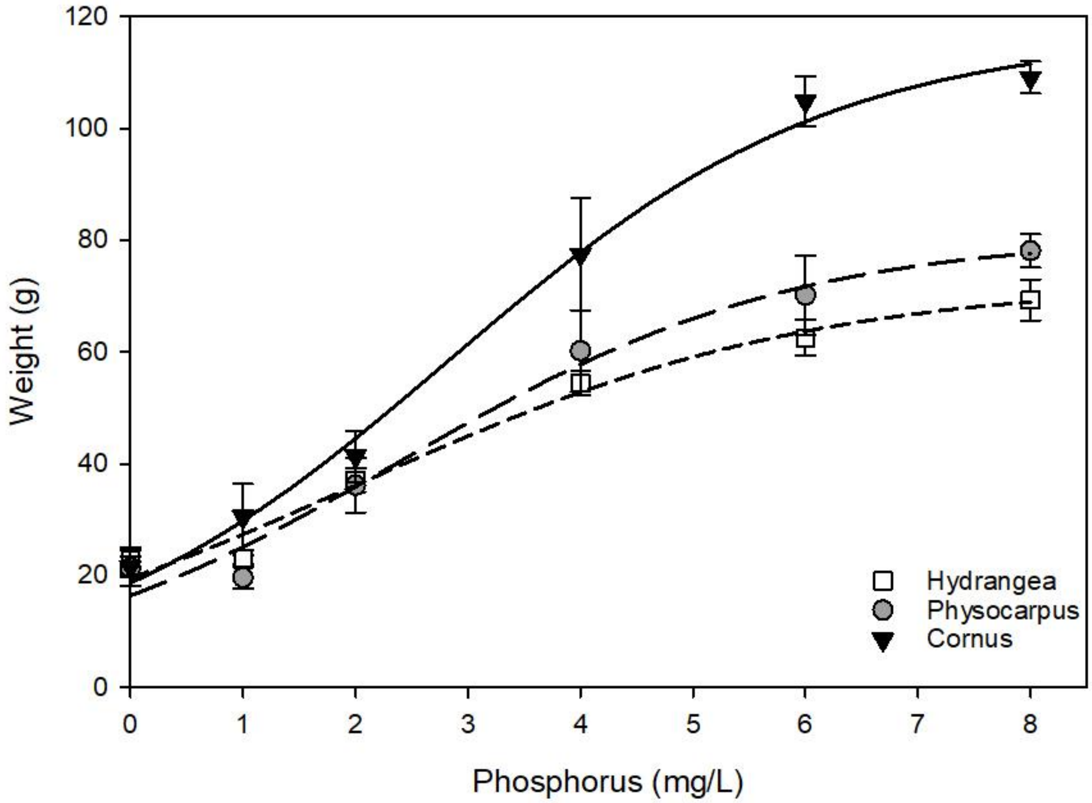

Figure 2. Total dry weight biomass accumulation of Queen of Hearts oakleaf hydrangea (*Hydrangea quercifolia* 'Queen of Hearts'), Summer wine ninebark (*Physocarpus opulifolius* 'Seward'), and redtwig dogwood (*Cornus obliqua*) in response to phosphorus addition rate.

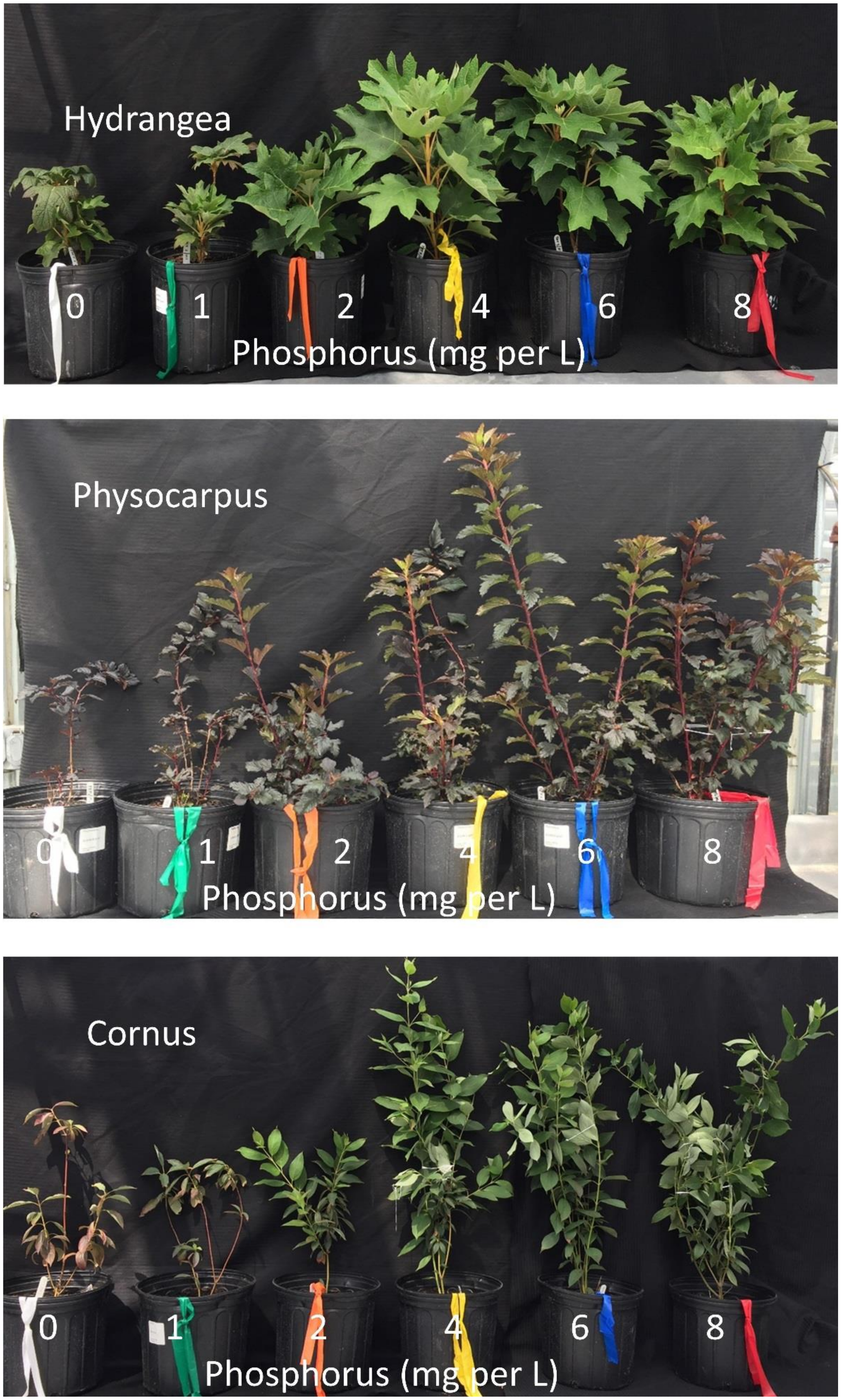

Figure 3. Queen of Hearts oakleaf hydrangea (*Hydrangea quercifolia* 'Queen of Hearts'), Summer wine ninebark (*Physocarpus opulifolius* 'Seward'), and redtwig dogwood (*Cornus obliqua*) fertilized with varying rates of phosphorus.

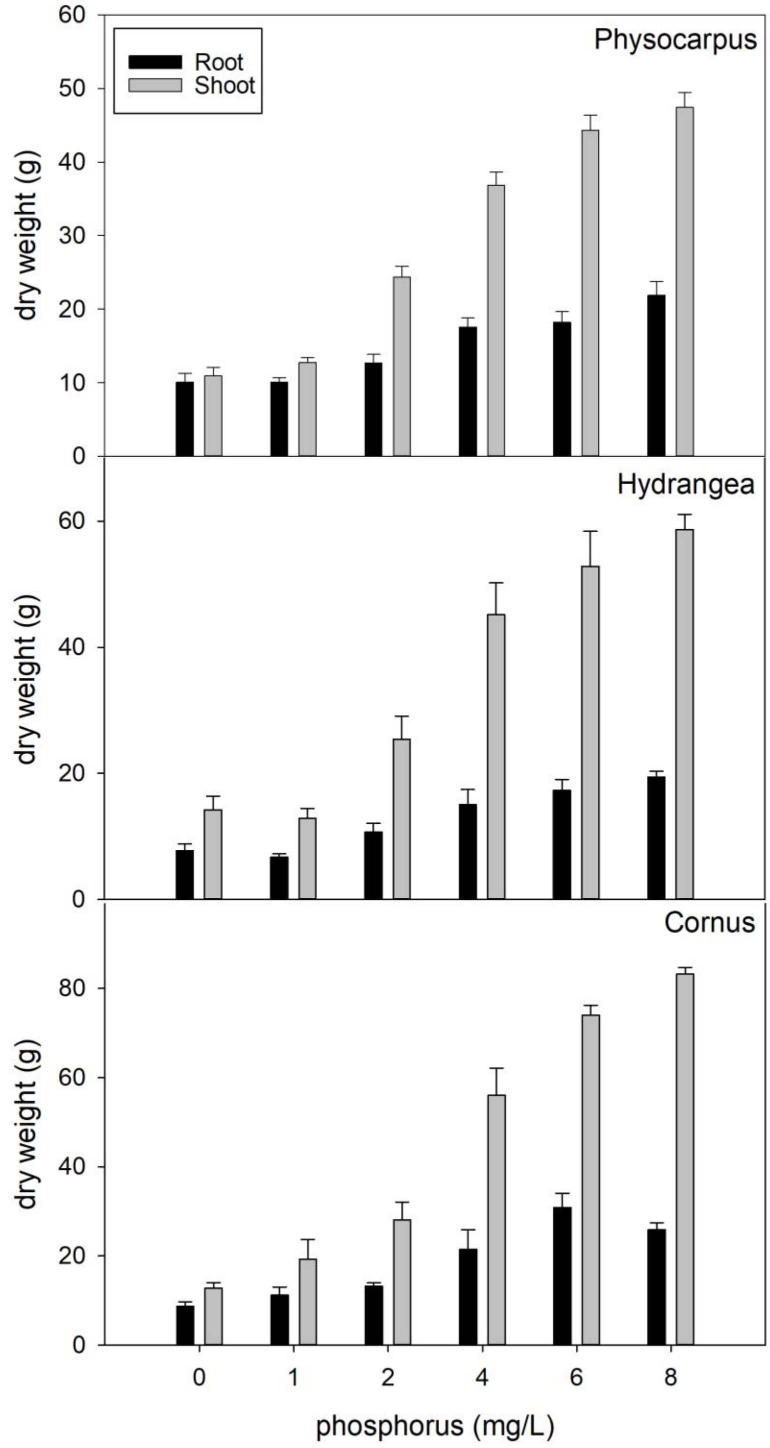

Figure 4. Shoot and root dry weight biomass accumulation of Queen of Hearts oakleaf hydrangea (*Hydrangea quercifolia* ‘Queen of Hearts’), Summer wine ninebark (*Physocarpus opulifolius* ‘Seward’), and redtwig dogwood (*Cornus obliqua*) in response to phosphorus addition rate.

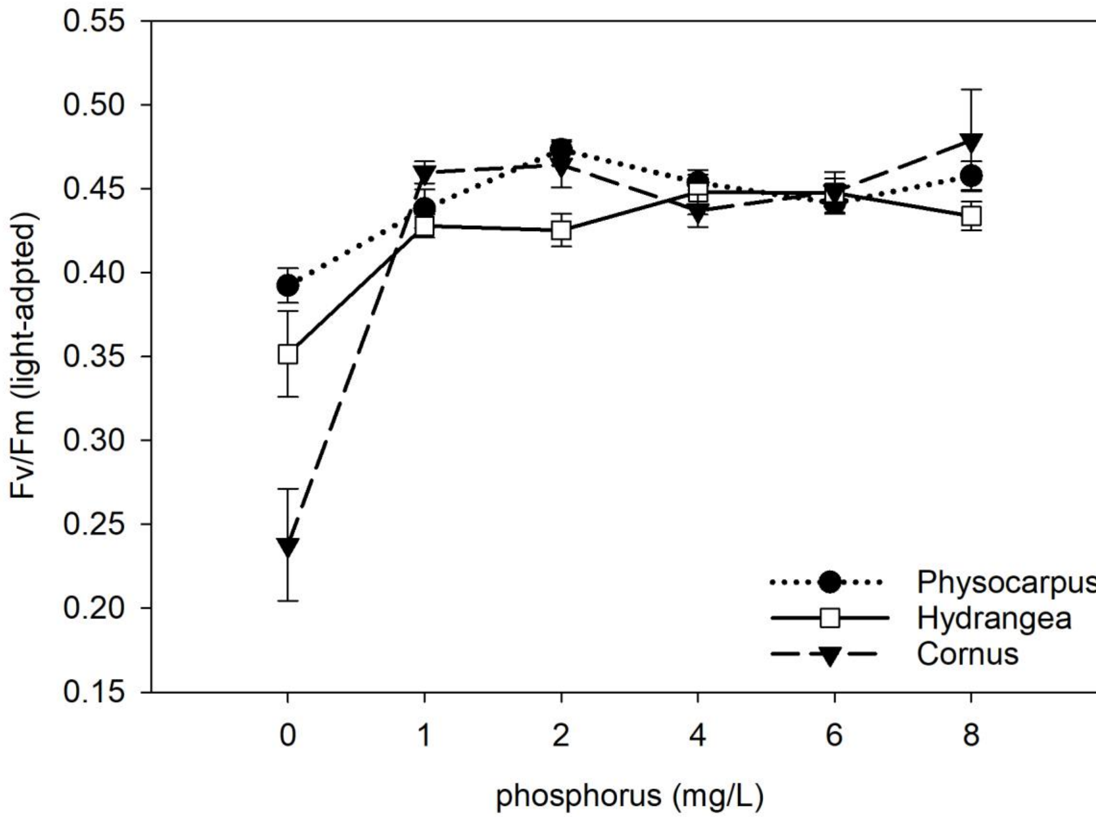

Figure 5. Photosystem II quantum efficiency Queen of Hearts oakleaf hydrangea (*Hydrangea quercifolia* 'Queen of Hearts'), Summer wine ninebark (*Physocarpus opulifolius* 'Seward'), and redtwig dogwood (*Cornus obliqua*) in response to phosphorus addition rate.

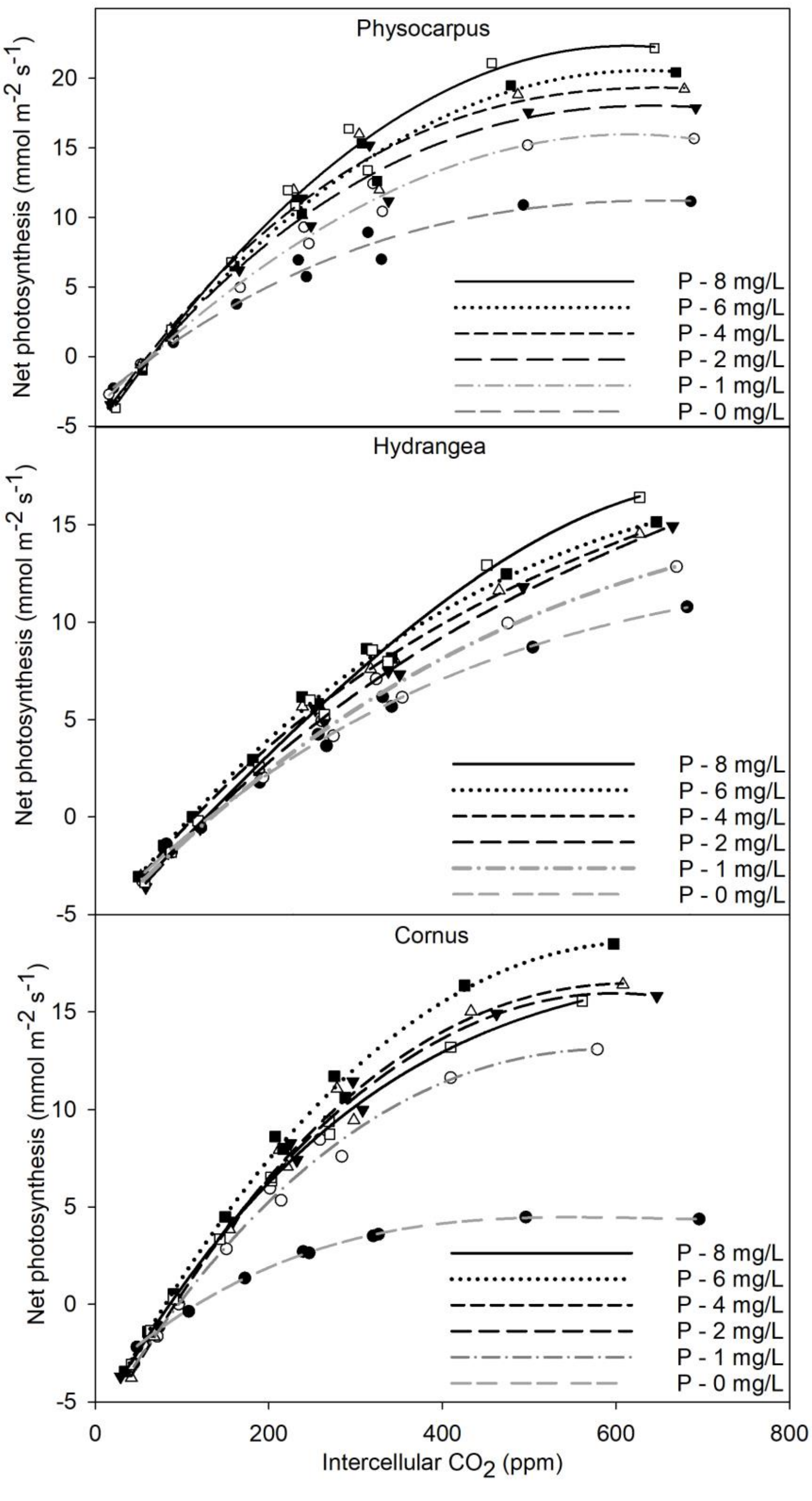

Figure 6. Response of net photosynthesis to intercellular CO2 concentration (A/ci curves) Summer wine ninebark (*Physocarpus opulifolius* 'Seward'), Queen of Hearts oakleaf hydrangea (*Hydrangea quercifolia* 'Queen of Hearts') and redtwig dogwood (*Cornus obliqua*) in response to phosphorus addition rate.

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