MANGANESE NUTRITION AND PHOTOSYNTHESIS OF 'PAWNEE' PECAN

Joshua Sherman and Richard J. Heerema
Graduate Student, New Mexico State University, Las Cruces, NM
Extension Pecan Specialist, New Mexico State University, Las Cruces, NM

ABSTRACT

Southwestern pecan (*Carya illinoinensis*) orchard soils are alkaline and calcareous which negatively affects manganese (Mn) availability for root uptake. Mn is essential for photosynthesis because of its roles in the photosystem II complex and chlorophyll biosynthesis. Levels of leaf Mn for optimum photosynthesis (P_n) in pecan is not known. Our objective was to characterize the relationship of widely different leaf tissue Mn concentrations on P_n. The experiment was conducted from 2011 through 2012 in immature, non-bearing 'Pawnee' pecan. Manganese was foliar-applied to whole trees at different spray tank concentrations to create differential leaf tissue Mn concentrations amongst trees. Leaf P_n was measured one week following each Mn application. A relationship in pecan between P_n and Mn was confirmed with optimum P_n rates at leaf tissue Mn concentrations of 150 $\mu g \cdot g^{-1}$ Mn.

OBJECTIVES

The NMSU Cooperative Extension Service recommendations for New Mexico pecans are 100-300 $\mu g \cdot g^{-1}$ Mn in July-sampled leaflet tissue (Heerema, 2013). Pecan trees exhibit leaf chlorosis symptoms with leaf Mn concentrations below 18 $\mu g \cdot g^{-1}$ (Smith et al., 2001), but little is known about the effects of Mn deficiency on P_n. Our objective was to characterize relationships of leaf Mn nutrition and P_n.

METHODS

This experiment was conducted at the Linwood Research Orchards at the NMSU Leyendecker Plant Science Research Center in Las Cruces, NM in 2011 and 2012. The trees were 'Pawnee' cultivar and were planted in 2010.

Four treatments were assigned to individual trees (6 replications per treatment). Treatments consisted of foliar spray applications of varying concentrations of Mn (Metalosate®, Albion Plant Nutrition, Clearfield, UT) as follows:

- High – 1.3 mg $Mn \cdot ml^{-1}$ applied 3 times in 2011 and 5 times in 2012.
- Medium – 0.68 mg $Mn \cdot ml^{-1}$ applied 2 times in 2011 and 4 times in 2012.
- Low – 0.34 mg $Mn \cdot ml^{-1}$ applied 1 time in 2011 and 3 times in 2012.
- Control – 0.00 mg $Mn \cdot ml^{-1}$ (H_2O only) applied 3 times in 2011 and 5 times in 2012.

P_n of fully sun-exposed leaves was measured using the LI-6400XT portable P_n system equipped with the 6400-02B Red/Blue Light Source (LI-COR Biosciences, Lincoln, NE) between 0800 and 1300 h about one week after each Mn application. Light levels in the chamber were controlled using the track ambient *PAR* function (so that the same irradiance was being applied as the ambient irradiance the leaflet was receiving just prior to measurement). Carbon

dioxide (CO_2) concentration (reference CO_2) was held constant in the chamber at 390 $\mu l \cdot l^{-1}$, near ambient atmospheric CO_2 levels.

When Mn applications were completed each season, leaf samples were collected from 12 non-fruiting shoots per experimental tree (July 25, 2011 and August 25, 2012) for tissue nutrient analyses. Samples were washed with phosphorous free detergent and 0.1M hydrochloric acid, rinsed twice with deionized water, and dried for 48 hours at 60° C. Leaflet tissues were analyzed for macro- and micro-nutrients by Inductively Coupled Plasma Spectrometer.

Gas exchange data (P_n, g_s, and c_i) data were analyzed by year (as a randomized complete block design, blocked by measurement time) with repeated measures using SAS proc mixed software version 9.3 (SAS Institute, Cary, NC, 2010). Leaf analyses were analyzed separately by year with ANOVA using SAS proc mixed with each macro- or micronutrient as the main effect and Mn treatment as a repeated factor, classified by Mn treatment and cultivar. Treatment effect was fitted to variance components covariance structure for variable Mn to account for increasing variance.

For all statistical analyses sensitivity of findings to extreme data points was examined using the outlier strategy with outliers identified as those observations with studentized residual magnitude > 2.5 (Ramsey & Schafer, 2002). Statistical significance was defined as $P \leq 0.05$.

RESULTS AND DISCUSSION

Average leaf Mn concentrations were significantly different amongst all treatments in both years, increasing from less than 55 $\mu g \cdot g^{-1}$ for the untreated control to more than 300 $\mu g \cdot g^{-1}$ for the high treatment (Fig. 1). The Control and Low treatments supplied levels below the recommended range (100 $\mu g \cdot g^{-1}$; Fig. 1), but there were no visible symptoms of Mn deficiency evident in these trees. The average leaf Mn concentration of High treatment trees exceeded recommended levels (Fig. 1), but did not have visible toxicity symptoms. The Medium Mn treatment in both years supplied sufficient Mn (mean range of 147 – 177 $\mu g \cdot g^{-1}$) to the pecan trees to bring leaf Mn levels into the recommended range (Fig. 1). With the exception of potassium (slightly deficient in 2011 for all treatments) and zinc (slightly deficient in 2012 for all treatments), other essential nutrients were within normal ranges for pecan according to recommendations by the New Mexico.

Analyzed across date the Medium Mn treatment had significantly higher P_n and stomatal conductance (g_s) than the other treatments in both years (Figs. 2 and 3). There was a 5.8% increase in P_n between the Medium Mn treatment and the Control in 2011 and an 8.7% increase in 2012 (Fig. 2). In 2011 and 2012, P_n for the Low and High treatments were not significantly different from the Control (Fig. 2). Intercellular CO_2 (c_i) effects of Mn nutrition, however, were less consistent than P_n or g_s (Fig. 4). In 2012 c_i was significantly higher in the Medium Mn treatment than the Control, but not in 2011 (Fig. 4). In both years, the Medium Mn treatment had significantly higher c_i than the Low and High treatments (but c_i in the Low and High treatments were not different from each other; Fig. 4).

Increased g_s in the Medium Mn treatment seems to explain the higher Pn rates in those trees. Stomatal conductance is affected by numerous environmental and physiological factors. These factors were outlined by Farquhar and Sharkey (1982) as light intensity and quality, CO_2, leaf water status, mesophyll metabolites (i.e. ABA), root metabolites (i.e. cytokinins), salinity, and humidity. However, the mechanism by which Mn nutrition is affecting the g_s in pecan is unclear. Since the c_i was actually higher for the Medium Mn treatment, our data gave no evidence of increased carboxylation capacity in the leaves of the trees receiving that treatment.

SUMMARY

These data showed optimal photosynthetic performance for immature non-bearing pecan trees with leaf tissue Mn concentration around 150 $\mu g \cdot g^{-1}$. We predict a similar response for mature, nut-bearing pecan trees and, as a result, the possibility of improvement on flowering, fruit set, nut yield and nut quality. Since average leaf Mn concentration in commercial New Mexico pecan orchards receiving no Mn fertilizer sprays is 85 $\mu g \cdot g^{-1}$ (Pond et al., 2006), our data indicate that Mn may be a limiting factor on P_n in New Mexico pecans and tree performance may benefit from annual foliar Mn application.

REFERENCES

Farquhar, G.D. and Sharkey, T.D. (1982). Stomatal conductance and photosynthesis. Annual Review of Plant Physiology 33(1):317-345.

Heerema, R.S. (2013). Diagnosing nutrient disorders of New Mexico pecan trees. Retrieved from http://aces.nmsu.edu/pubs/_h/H658.pdf.

Pond, A.P., Walworth, J.L., Gibson, R.D., Call, R.E., and Núñez, H. (2006). Leaf nutrient levels for pecans. HortScience 41(5):1339-1341.

Ramsey, F.L. and Schafer, D.W. (2002). Statistical sleuth: A course in methods of data analysis. (2nd ed.). Pacific Grove: Duxbury Press.

Smith, M.W., Cheary, B.S., Samuel, T., and Noble, R. (2001). Manganese deficiency in pecan. HortScience 36(6):1075-1076.

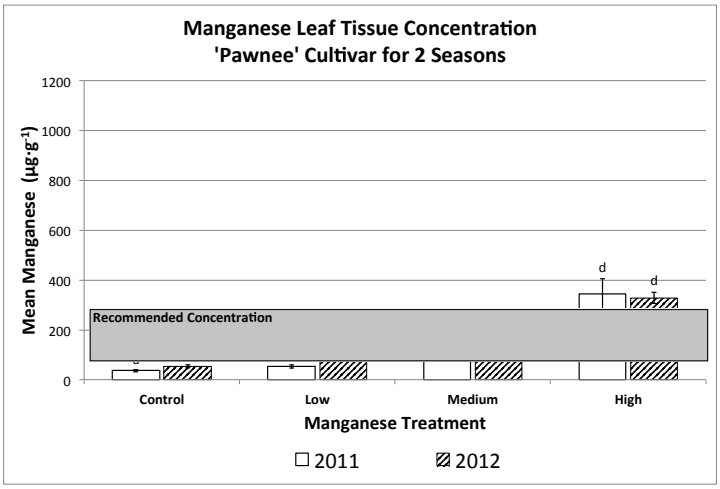

Figure 1. Leaf Mn concentrations of 2011 and 2012 showing treatment application effect of the Control, Low, Medium, and High treatments. Data are Least Squares Means and bars correspond to the model-based standard error. New Mexico Cooperative Extension recommendation of leaf Mn concentration is shown in gray shaded region. Leaf Mn concentration means with different lower case letter indicate significant difference ($P \leq 0.05$).

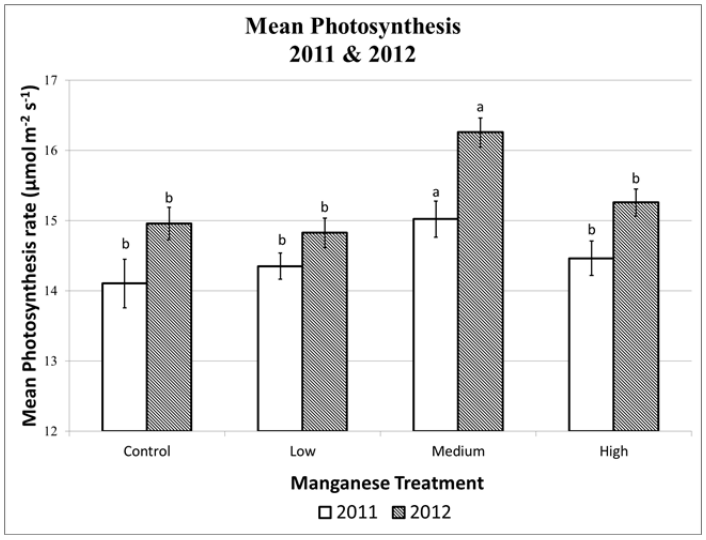

Figure 2. Mean leaflet photosynthesis on 'Pawnee' across the season in 2011 and 2012. A total of three measurement dates in 2011 and five dates in 2012. Foliar applied Mn treatments ranged from 0.0 – 1.3 mg Mn·ml-1. Data are Least Squares Means and bars correspond to the model-based standard error. Photosynthesis means for particular year with different lower case letter indicate significant difference ($P \leq 0.05$).

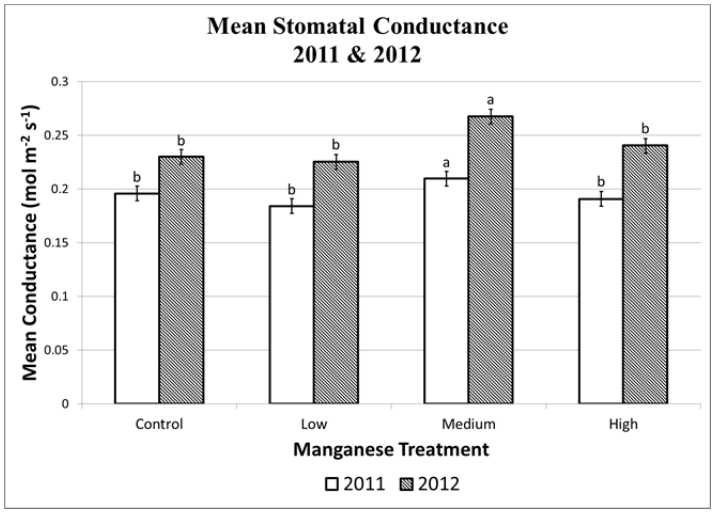

Figure 3. Mean leaflet stomatal conductance on 'Pawnee' across the season in 2011 and 2012. A total of three measurement dates in 2011 and five dates in 2012. Foliar applied Mn treatments ranged from 0.0 – 1.3 mg Mn·ml-1. Data are Least Squares Means and bars correspond to the model-based standard error. Photosynthesis means for particular year with different lower case letter indicate significant difference ($P \leq 0.05$).

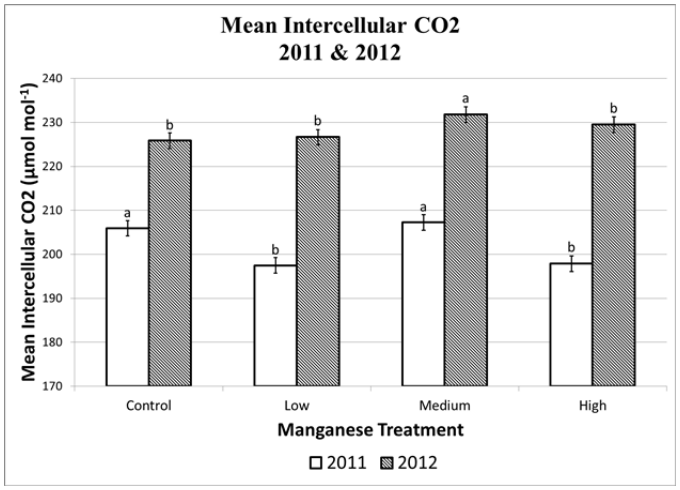

Figure 4. Mean leaflet intercellular CO2 on 'Pawnee' across the season in 2011 and 2012. A total of three measurement dates in 2011 and five dates in 2012. Foliar applied Mn treatments ranged from 0.0 – 1.3 mg Mn·ml-1. Data are Least Squares Means and bars correspond to the model-based standard error. Intercellular CO2 means for particular year with different lower case letter indicate significant difference ($P \leq 0.05$).

PROCEEDINGS

OF THE

WESTERN NUTRIENT

MANAGEMENT CONFERENCE

Volume 11

MARCH 5-6, 2015
RENO, NEVADA

Program Chair
David Tarkalson
USDA - ARS
3793 N 3600 E
Kimberly, ID 83341
(208) 423-6503
David.tarkalson@ars.usda.gov

Coordinator
Phyllis Pates
International Plant Nutrition Institute
2301 Research Park Way, Suite 126
Brookings, SD 57006
(605) 692-6280
ppates@ipni.net