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Use of nondestructive sensors to assess nitrogen status in potted poinsettia (*Euphorbia pulcherrima* L. (Willd. ex Klotzsch)) production

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ABSTRACT

Utilizing precision farming techniques in a greenhouse setting to manage plant site-specific nitrogen (N) needs can help to prevent N deficiency, increase final plant quality, reduce cost of excessive fertilizer, and prevent N runoff. Optical sensors are a fast and nondestructive approach to estimate plant chlorophyll content by measuring the reflectance or absorbance of the green leaves. The objective of this study was to test the reliability of normalized difference vegetative index (NDVI) values calculated by the GreenSeeker™ hand held sensor as an indirect indicator of poinsettia (*Euphorbia pulcherrima* L. (Willd. ex Klotzsch) N status, and compare the sensors performance to other optical sensors on the market. The second objective of the study was to investigate if plant quality is improved by correcting N fertilizer application during production based on the sensor readings. The experiment was conducted in fall 2013. Poinsettia 'Prestige Red' and 'Freedom Red' pots were supplemented with 0, 5, 10, 15, and 20 g of 15N-9P-12K controlled release fertilizer (CRF). Soil and plant analysis development (SPAD) chlorophyll meter, GreenSeeker™ NDVI sensor, and atLEAF meter readings were recorded for four consecutive weeks. Readings and visual qualities differences were monitored for significant separation between the different rates. At 40 days after planting (DAP), based on visual qualities differences, half of the deficient treatments were supplemented with extra fertilizer for treatment correction. All pots were completely randomized. All sensors values were compared to actual leaf N concentration to determine efficiency. Plants were assessed at the end of commercial production period by recording final height, final width, number of bracts, length of bract, dry weight, and salability. The GreenSeeker™ NDVI sensor correlated well with actual leaf N concentration during the vegetative phase of poinsettia production. As for the overall production period, SPAD and atLEAF meters showed an advantage with greater correlation to actual leaf N concentration. The GreenSeeker™ readings were less correlated with leaf N concentration at early stages of establishment due to plants small size and background noise, as well as at later stages of establishment due to anthesis. Poinsettia 'Freedom Red' responded better to treatment correction than 'Prestige Red'. The correction treatments showed greater results for plant growth in the treatment correction 5 (+5 g) compared to treatment correction 0 (+10 g), and as good as the 10 g treatment, indicating that the correction treatment could be used to correct deficiencies during production.

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1. Introduction

Euphorbia pulcherrima L. (Willd. ex Klotzsch), commonly known as poinsettia, is one of the most valuable potted crops in the US floriculture industry, due to plants popularity at Christmas (Dole and Wilkins, 2005). According to the USDA report for 2013, the total wholesale value of potted poinsettia was estimated at over $144 million. Although many operations are opting for the use of controlled release fertilizer (CRF) to reduce on labor cost, the majority of growers irrigate with 250 mg L^{-1} of N (250 kg N ha^{-1}) using a constant liquid fertilizer (CLF) (Ecke et al., 1990; Schuch et al., 1996). No matter the preferred fertilizing method, growers monitor soil nutrient content by measuring leachate EC and pH to monitor nutrient uptake (Ecke et al., 1990).

Nondestructive optical sensors use is being investigated for nutrient monitoring instead of traditional destructive and time consuming methods. Three of the commonly used optical sensors available on the market are the GreenSeeker™ handheld sensor (Trimble Navigation Ltd., CA), the soil plant analysis development

Abbreviations: N, nitrogen; NDVI, normalized difference vegetative index; SPAD, soil and plant analysis development; CRF, controlled release fertilizer; CLF, constant liquid feed; CRD, completely randomized design.

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(SPAD) meter (SPAD-502, Konica Minolta, Japan), and the atLEAF chlorophyll sensor (FT Green LLC, DE). Recent studies have shown a strong correlation between NDVI and leaf N concentration in field crops and trees, such as corn (*Zea mays* L.), wheat (*Triticum aestivum* L.), and pecan (*Carya illinoinensis* (Wang.) K. Koch) (Hardin et al., 2012; Raun et al., 2005). For greenhouse crops, NDVI has proven to correlate well with leaf N concentration for geranium (*Pelargonium* × *hortorum* L.H. Bailey) (Wang et al., 2012a,b). No previous research has been conducted on the use of GreenSeeker™ NDVI sensor to assess N status in poinsettias.

The SPAD meter is another handheld sensor commonly used to estimate the amount of chlorophyll present in a plant leaf through emitting light beams from two LEDs at two wavelength regions, red at 650 nm and NIR at 940 nm. The measured difference in absorbance is processed giving a value ranging between 0 and 99, and this value has been found to be proportional to the chlorophyll concentration in the leaf (Basyouni and Dunn, 2013; Uddling et al., 2007). Like the NDVI sensor, the SPAD meter has also shown to be correlated with leaf N content in multiple field crops, vegetables, and ornamentals like corn, wheat 'Dragon' and 'Laanteve', potato (*Solanum tuberosum* L., cv. Bintje), and silver birch (*Betula pendula* Roth) (Bullock and Anderson, 1998; Uddling et al., 2007). The SPAD meter had been reported to be used with poinsettias to track growth at different fertilizer rates (Schuch et al., 1996), to assess insects damage (Medina-Ortega, 2011), and to evaluate final plant quality (Fernández-Pavía et al., 2012).

The atLEAF chlorophyll meter (FT Green LLC, DE) was built to be a cheaper alternative to the SPAD chlorophyll meter (Basyouni and Dunn, 2013; Zhu et al., 2012). The device estimates leaf chlorophyll content by emitting two wavelengths: red at 660 nm and NIR at 940, then measures the absorbance of those wavelengths by the green color in the leaves. The atLEAF computes a unit-less value that is similar to the SPAD value (Basyouni and Dunn 2013). Zhu et al. (2012) showed that atLEAF readings were strongly correlated with the SPAD meter readings in five crop species: canola (*Brassica napus* L.), wheat, barley (*Hordeum vulgare* L.), potato, and corn. No previous use has been reported for the atLEAF chlorophyll meter to assess nutrient status in poinsettias. The objective of this experiment was to determine (1) the efficiency of the handheld GreenSeeker™ handheld NDVI sensor in estimating leaf chlorophyll and N concentration in potted poinsettia, (2) correlation of the GreenSeeker™ NDVI sensor with other sensors available on the market, (3) and efficiency of using the sensors values to identify and correct nutrient deficiencies.

2. Materials and methods

2.1. Plant material and experimental setup

Rooted cuttings of *E. pulcherrima* 'Prestige Red' and 'Freedom Red' were obtained from Ecke Ranch Inc. (Encinitas, CA). Cuttings were transplanted into standard 15.24 cm diameter and 1.35 L volume pots filled with about ~0.35 kg of Metro-Mix 902 media (Sun Gro Horticulture, Bellevue, WA). Each pot was planted with a single cutting. Pots were irrigated with tap water through drip emitters and were grown in the Department of Horticulture and Landscape Architecture Research Greenhouses at Stillwater, OK. Under natural photoperiods, temperature was set at 22 °C/17 °C day/night with a photosynthetic photon flux density (PPFD) range of 148–1136 μmol m^{-2} s^{-1} at 1200HR.

2.2. Growth conditions

On 15 August 2013, 400 rooted cuttings (three–five leaves) were received in 13 cells trays, and were put under mist until being transplanted into pots 6 day later. A sample of the potting media and tap water were analyzed, and both showed an initial total N content of <0.5 g kg^{-1} DM. On 5 September 2013, five different rates (0, 5, 10, 15, and 20 g) (0, 80, 160, 240, and 320 kg N ha^{-1}) of 15N-9P-12K CRF (Osmocote® Plus, The Scotts Co., Marysville, OH) were added to the surface of the pots. Rates were selected based on the previous year's observation of plant responses to provide treatments that ranged from deficient to excessive levels of N. Pots were drip irrigated with tap water at a rate that allowed media saturation and ~25% leaching. Plants were pinched at a seven internodes height on 11 September 2013. The experiment consisting of five treatments replicated 40 times with single pot replications, with a total of 200 pots per cultivar. Treatments and cultivars were assigned to pots in a CRD.

2.3. NDVI, SPAD, atLEAF, and N concentration determination

After 34 days of establishment, on 24 September 2013, individual plants were assigned and scanned from 10 pots per treatment, using the GreenSeeker™ handheld NDVI sensor, SPAD chlorophyll meter, and an atLEAF chlorophyll meter. Readings were taken for the assigned pots once a week for four consecutive weeks. During measurements, the NDVI sensor was held 61 cm above the plant canopy, giving an oval field of view with an area of 0.41 m^2. The SPAD readings were taken as an average of three different leaf readings located in the middle to upper level of the plant, and in the middle of the leaf excluding the midrib. Three atLEAF readings were taken from three different leaves located in the middle to upper level of the plant, and in the middle of the leaf excluding the midrib. To assure that sensor readings and the foliar N concentration represent the same individual plant, 10 pots were randomly assigned and numbered for each treatment. Those pots were sensed weekly in the same order with leaves from two plants being sent to the lab for leaf N concentration analysis. Readings of the first three sensing date were ran in a statistical program designed to detect significant difference between the five different fertilizer rates (data not shown). Leaf samples were analyzed for total N content (g kg^{-1} DM) by the Soil, Water and Forage Analytical Laboratory (SWFAL) at Oklahoma State University, using a LECO TruSpec Carbon and Nitrogen Analyzer (LECO Corporation, St. Joseph, MI). Leachate was collected from five pots selected randomly per cultivar per N rate on a weekly basis to monitor pH and EC using the Pour-Thru method (Whipker et al., 2001) (data not shown).

2.4. Treatment correction growth conditions

On 30 September, 2013, at 40 DAP, using the pots from the first experiment, the 0 g pots were supplemented with either 0 or 10 g, and the 5 g pots were supplemented with 0 or 5 g fertilizer applied on the surface of each pot. Pots were drip irrigated with tap water at a rate that allowed media saturation and ~25% leaching. The experiment consisting of seven treatments (0,0 (+10 g), 5,5 (+5 g), 10, 15, and 20 g, respectively) replicated 15 times with single pot replications, with a total of 105 pots per cultivar. Fertilizer supplements were added to pots in a CRD.

2.5. Post treatment correction NDVI, SPAD, and atLEAF values

After fertilizer correction, individual plants were scanned from 10 pots per treatment for NDVI, SPAD, and atLEAF readings using the same three sensors and placement mentioned above. On 19 November 2013, plant quality was assessed by recording height (from the media to the highest point), width (average of two perpendicular measurements), colored bract number (only bracts that were fully colored were counted), bract length (taken from the longest colored bract), and salability (quality was assessed visually