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Nitrogen application rate, leaf position and age affect leaf nutrient status of five specialty cut flowers

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ABSTRACT

This study was conducted to determine the effect of nitrogen fertilizer levels on growth and yield of specialty cut flowers, 'Chief' celosia, 'Sensation' cosmos, 'Sunbright' and 'Sunrich Orange' sunflowers and 'Benary Giant Mix' zinnia, as well as record influence of leaf position and age on leaf nutrient concentrations. Plants grown in open field were supplied with five different N levels beginning five days after transplanting: no added N (control); one, two or three applications of N at 112 kg ha^{-1} at 40 day intervals; and a single application of 336 kg ha^{-1}. Plants fertilized with two or three applications of 112 kg ha^{-1} produced the most flowers in celosia and all fertilizer applications increased yield equally in zinnia, but had no effect on cosmos and both cultivars of sunflower. Nitrogen fertilization produced the longest flower stems for cosmos and both sunflower cultivars, but had no effect on celosia and zinnia stem length. Nitrogen fertilization rate did not significantly affect days to harvest of all species tested. For leaf nutrient analysis, the upper one-third of the plant proved to be a reliable tissue source in all species. Generally, young leaf samples collected early in the season had higher nutrient concentrations as compared with the same leaf position at mid or late season. Increasing N fertilization increased N content of foliage for all species. Our recommended tissue nutrient levels were generally lower than those previously recommended for greenhouse-grown bedding plant cultivars of the same species.

1. Introduction

Specialty cut flowers comprise a large number of ornamental species including annual and perennial herbaceous plants (Dole et al., 2009). As their production has become increasingly important, lack of exact nutritional recommendations has become apparent. Insufficient fertilization causes poor plant growth, short stems and lower yields and may reduce postharvest life (Starkey and Pedersen, 1997; Nielsen and Starkey, 1999; Mehran et al., 2008). Whereas, over fertilization may cause excessive nutrient runoff, environmental pollution and economic losses (Stagnari et al., 2007). Over fertilization is undesirable due to fertilizer runoff and leaching into groundwater (Biernbaum and Fonteno, 1989; Mickelbart, 2010). Nutrient concentrations also greatly affect crop growth and quality attributes such as stem length and thickness and flower color and longevity (Whitcomb et al., 1975; Marschner, 1995). Moreover, different cultivars vary in their nutritional demands and, as a result, they respond best to different nutrient concentrations (Marschner, 1995).

Among all plant nutrients, nitrogen is most important for plant biomass production and photosynthesis. It plays a vital role in both crop yield and quality (Gastal and Lemaire, 2002; Wang et al., 2002). Since plant N status is correlated with soil N supply and plant N uptake as well as demand (Balasubramanian et al., 1999), plant N analysis is a key technique for specifying quantity and time of N fertilization (Li et al., 2003).

However, it is quite difficult for growers to test a large number of plants. Sampling procedures need to be designed for collection of the tissue most representative of the plant nutrient status. Since leaf age and location on the plant affects greatly the nutrient concentration (Dole and Wilkins, 1991), research is needed to determine the optimum sample date (leaf age) and location on cut flower plants from where sampling should be collected for testing nutrient concentration. The objectives of this study were to optimize N application rate and timing for five field grown summer cut flowers and to determine leaf nutrient concentrations resulting from leaf age and position on the plant.

2. Materials and methods

Five field cut flower cultivars were grown in Raleigh, NC: 'Chief' celosia (*Celosia cristata* L.), 'Sensation' cosmos (*Cosmos bipinnatus* Cav.), 'Sunbright' and 'Sunrich Orange' sunflowers (*Helianthus*

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annuus L.), and 'Benary's Giant Mix' zinnia (*Zinnia elegans* L.). Celosia, cosmos and zinnia seeds were sown on 27 February, while both sunflower cultivars were sown on 12 March in 48 cell plug trays containing a commercial peat-based substrate (4P Fafard, Conrad Fafard, Inc. Agawam, MA) in a greenhouse. Seedlings were transplanted in thoroughly tilled 1.2 m × 1.2 m beds on 3 May spaced at 30 cm between plants and rows.

Five nutritional regimes were applied: (1) no added nitrogen, (2) one application on 8 May of 112 kg N ha^{-1}, (3) two applications on 8 May and 19 June of 112 kg N ha^{-1}, (4) three applications on 8 May, 19 June and 31 July of 112 kg N ha^{-1}, or (5) one application on 8 May of 336 kg N ha^{-1}. Ammonium nitrate fertilizer was broadcasted uniformly over beds. No phosphorus, potassium or any other nutrient was applied to the plants during the study as there was sufficient amount of those nutrients in the soil. Other cultural practices including irrigation, net support and weeding were similar for all treatments during the study period.

On 29 May (sunflowers), 15 June (celosia), 28 June (zinnia) and 3 August (comos) leaves were harvested from four positions on the stem: (1) lowermost leaf, (2) leaf 1/3 the way up from the lowermost leaf, (3) leaf 2/3 the way up from the lowermost leaf, and (4) most recently mature leaves. The most recently mature leaves were also harvested on 29 May and 15 June (celosia), on 29 May and 11 July (zinnia), and on 29 May (cosmos). The number of stems harvested, length of each stem, and date of harvest (days from sowing to harvest) was recorded for each species and fertilizer regime.

The leaves were first rinsed in deionized water, then washed in 0.2 N hydrochloric acid (HCl) for 30 s, and dried at 70 °C for 24 h. Dried tissue was ground in a stainless steel Wiley mill to pass 1 mm (20-mesh) screen. Tissue was then analyzed for macro- and micronutrients, with the exception of N, using a PerkinElmer 3300 inductively coupled argon plasma emission spectrophotometer (PerkinElmer, Shelton, Conn.), and N was analyzed using Carlo Erba NA 1500 series 1 O_2 combustion nitrogen analyzer (Carlo Erba, Lakewood, N.J.) at the N.C. Department of Agriculture Laboratory, Raleigh.

A completely randomized block design with factorial arrangements was used with four replicates of 16 plants each (arranged 4 × 4 plants). Data were analyzed using the GLM procedure in SAS (SAS 9.1, Cary, NC) and means separation using Duncan's Multiple Range test. Soil samples were collected from each nutrient regime (one per replicate), analyzed (Mehlich et al., 1976; Mehlich, 1984), and data averaged to determine initial pH and nitrogen (%) and nutrient content (mg kg^{-1}): pH 5.4, N 0.081, P 94.1, K 108.8, Ca 55.2, Mg 18.4, S 78.5, available Mn 90.1, Cu 61.2, available Zn 108.1, and Na 0.05.

3. Results

3.1. Celosia

Maximum number of harvested stems was obtained with two or three applications of 112 kg N ha^{-1}, but fertilization had no effect on stem length or production time (Table 1). Higher leaf N, Ca, Mg, and Mn were recorded in plants supplied with single application of 336 kg N ha^{-1} and P, S, Zn, Cu and B were higher in unfertilized (control) plant leaves (Table 2). For leaf positions, N and B were higher in upper 1/3rd of the plant, while K, Ca, Mg and Fe (especially when plants were fertilized) were higher in lower most foliage. Lower leaves were higher in P, S, and Zn when unfertilized, but when plants were fertilized, position had no effect on P or Zn, and upper leaves had higher S with 336 kg N ha^{-1}.

The highest N and Mn concentration occurred in plants receiving single 336 kg N ha^{-1} and the highest P, Cu and B in unfertilized plants. Calcium and Mg levels were lowest in unfertilized plants (Table 3). Higher N, K, Fe, and Mg were recorded in early season (29 May) harvests than late season samplings, midseason (15 June) harvests had the highest P, Ca, S, Mn, Zn, and Cu, and late season (11 July) the highest B.

3.2. Cosmos

One, two or three N applications at 112 kg ha^{-1} produced the longest stems, but fertilization had no effect on stem yield or production time (Table 1). Three applications of N supplied at 112 kg ha^{-1} produced higher leaf S, while P, Zn, Cu and B were higher in unfertilized plants (Table 4). Among leaf sampling positions, N (especially when unfertilized), P, S, Cu were higher in most recently matured leaves, while lower leaves had higher K, Fe, and B. Levels of Mg and Mn were lowest in the most recently mature leaves. When plants were unfertilized, Ca levels were higher in the lowest leaves.

Plants fertilized with single application of 336 kg N ha^{-1} had higher concentrations of N, K, Mg, S, Fe and Mn as compared with other treatments (Table 5). Unfertilized plants had the highest P. Early season harvest (29 May) produced higher N, except when plants were not fertilized. Phosphorus levels were highest early in the season, except when fertilized with one or two applications of 112 kg N ha^{-1}. Potassium, Ca, Mg, Fe, and Zn were highest with the early harvest. Manganese levels were highest in the early harvest when fertilized with 336 kg N ha^{-1}.

3.3. Sunflower

For both cultivars, one, two or three N applications at 112 kg ha^{-1} produced the longest stems (Table 1). Fertilization produced harvestable stems 6 days earlier for 'Sunbright' sunflower than no fertilization; whereas, interestingly, fertilization with 112 kg ha^{-1} delayed flower harvest of 'Sunrich Orange' sunflower by 2 days compared to 336 kg ha^{-1}. Fertilization had no effect on stem number as both cultivars grown typically do not produce axillary shoots that can be harvested.

In both sunflower cultivars, single application of 336 kg N ha^{-1} gave higher leaf N, Fe, Mn and Zn, while P, Ca, Mg, and B were higher with no fertilizer treatment (Table 6). The highest K levels occurred when plants were fertilized with 112 kg N ha^{-1}. For 'Sunbright', single application of 336 kg N ha^{-1} gave higher leaf Fe, while S was higher with no fertilizer treatment and 'Sunrich Orange' had higher Cu levels when unfertilized.

Moreover, for both cultivars the upper 1/3rd of plant foliage had higher N and P when plants were fertilized, while Ca, Mg, Fe, and B were higher and K lowest in lowermost leaves. Levels of S were higher in the lower foliage when not fertilized and highest in the upper foliage when fertilized with 336 kg N ha^{-1}. For 'Sunrich Orange' the upper 2/3rd had higher Zn and Cu, while lowest foliage had more Mn.

'Sunrich Orange' had higher N (3.65 vs. 2.76%; $P \leq 0.0001$) and P (0.34 vs. 0.31%, $P \leq 0.0004$) and lower Ca (2.46 vs. 3.13%, $P \leq 0.0001$), Mg (0.72 vs. 0.89%, $P \leq 0.0001$), Mn (112 vs. 175 mg kg^{-1}, $P \leq 0.0001$), Zn (51 vs. 76 mg kg^{-1}, $P \leq 0.0001$) and B (97 vs. 129 mg kg^{-1}, $P \leq 0.0001$) levels than 'Sunbright' (main effects not presented). There were no differences among the remaining elements, K, S, Fe, and Cu, between the two cultivars (main effects not presented).

3.4. Zinnia

Maximum number of harvested stems was obtained with all N fertilization treatments over control (Table 1). However, fertilization did not affect stem length or production time. Plants supplied with three applications of 112 kg N ha^{-1} had higher N, those with