FOLIAR TISSUE ANALYSIS STANDARDS FOR NITROGEN, PHOSPHORUS AND POTASSIUM IN *CALADIUM* x*HORTULANUM* BIRDSEY

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Abstract

Foliar levels of N, P and K were correlated to leaf and tuber weights of caladiums grown in sand and supplied with essential macro and micro elements and a wide range of available N, P or K. Optimal leaf or tuber weights were associated with foliar levels of 4.3 or 3.6% N, 0.55 or 0.52% P and 3.2 or 3.2% K, respectively. Regression analyses indicated sufficiency ranges for foliar nutrient levels (tuber or leaf fresh weights ± 10% of the optimum) were 3.6-4.9% N if plants were grown for foliage display (potted plants), and 3.1-4.1% N if plants were grown for tuber production. Response curves were similar for leaf and tuber weights for P and K, with sufficiency ranges of 0.37-0.68% P and 2.3-4.1% K. Visible deficiency symptoms were detected when foliar nutrient levels were less than 2.8% N, 0.18% P or 1.4% K. Visible toxicity symptoms were observed when foliar nutrient levels were greater than 4.8% N, 0.7% P, and 4.5% K.

1. Introduction

Plant tissue analysis has been successfully used as a diagnostic tool to provide an understanding of the nutritional status of many horticultural crops. Yet, information on standards for foliar tissue levels of macro and micro elements is lacking for many floricultural crops. Visual nutrient deficiency symptoms were described for N, P, K, Ca, Mg, Fe, Mn and B in caladiums (Harbaugh, 1986). Foliar nutrient content of plants with deficiency symptoms were given that could be used to confirm suspected deficiencies, but levels were not established relating foliar growth or yield (tuber size) to foliar tissue levels or ranges. The purpose of this research was to establish foliar tissue analysis standards for N, P and K in caladiums by correlating foliage and tuber growth to foliar nutrient levels.

2. Materials and methods

'Candidum' caladium tubers were cut into sections no larger than 2.5 cm square with one visible growing point. Sections were planted in 10 cm diameter pots with bottom drainage holes. Cheese cloth was placed in the bottom of each pot to prevent loss of the sand growing medium from drainage holes. Pots were placed on 1 mil plastic (10 x 10 cm) separated by 2.5 cm slits in the wood bench to prevent roots from obtaining nutrients from the bench or leachate from other treatments. The growing environment was a fan-and-pad cooled glasshouse with temperatures normally ranging from 20°C night to 30°C day. Shade

was provided by exterior paint and ranged from 50% winter to 80% summer (22-54 klx light within the glasshouse).

Preliminary studies were used to determine adequate levels and rates for test and nontest nutrients to provide for rapid growth of caladiums with this sand culture. A standard nutrient solution for N, P and K tests included the following (in g/l): 1.01 $MgSO_4 \cdot 7H_2O$, 0.05 $MnSO_4 \cdot H_2O$, 0.16 Sequestrene Fe 330, 0.07 $ZnSO_4 \cdot 7H_2O$, 0.03 H_3BO_3, 0.008 $CuSO_4 \cdot 5H_2O$. The following nutrient formulations and rates were used for each test as follows (in g/l): Nitrogen test: 0.769 NaH_2PO_4, 1.0 K_2SO_4, 1.03 $KHCO_3$, 0.97 $CaCl_2 \cdot 2H_2O$. Rates of N were 96, 192, 384, 768, 1152, 1536, and 3072 ppm from NH_4NO_3. Phosphorus test: 0.67 NH_4NO_3, 2.18 KNO_3, 1.77 $Ca(NO_3)_2 \cdot 4H_2O$. Rates of P were 4, 8, 16, 32, 64, 128, 256 and 512 ppm from NaH_2PO_4 + (HPO_3 + $NaPO_3$). Potassium test. 1.54 NH_4NO_3, 0.77 NaH_2PO_4 and 1.77 $Ca(NO_3)_2 \cdot 4H_2O$. Rates of K were 5, 10, 20, 40, 80, 160, 320, 640, 1280 and 2560 ppm from K_2SO_4 + KCl + $KHCO_3$. 10N NaOH was used to adjust the nutrient solutions to a pH of 6.8-7.1. Both the standard and test nutrient solutions were applied in 50 ml aliquots once a week. Once a week the pots were leached with 100 ml of distilled water to prevent imbalances in the medium solution from concentration of carrier or test nutrients, or from total soluble salts. Periodic samples were taken for pH and total soluble salts, and additional leaching or application of 0.3N CaOH was made to try and maintain leachate salts at less than 3000 ppm total soluble salts and pH within a range of 5.5-7.0. Plants were watered with distilled water as needed to saturate the sand with little or no leaching.

P and K tests were initiated 8 December and N on 11 February. P and K tests were terminated 24 May, and N 17 August, 1982. Data recorded included fresh weight of above ground leaves (representative of growth and quality of caladiums used as potted plants) and tuber fresh weight (representative of growth and yield of field grown caladiums grown for sale of tubers). Leaf blades of unfurled leaves were analyzed for N, P and K. Treatments were replicated 5 times in a completely randomized design and data were subjected to regression analyses to determine the relationship of foliar nutrient levels to leaf and tuber fresh weights. In addition, tissue analyses were run on Ca, Mg, Fe, Mn, Cu, B, Na and Cl to determine interactive effects of associated ions or test nutrients on uptake of nutrients and possible imbalances. N was determined by a modified Kjeldahl procedure (Perrin, 1953); P colorimetrically (Lowry and Lopez, 1946); B by the carmine-colorimetric method (Hatcher and Wilcox, 1950); Mg by thiazole yellow-colorimetric method (Young and Gill, 1951); Cl by the Mohr method (Hesse, 1971); Ca, K, and Na by flame spectrophotometry; and Fe, Mn, Zn and Cu by atomic absorption spectrophotometry.

3. Results

3.1. Nitrogen

Leaf and tuber fresh weights were quadratically related to foliar leaf nitrogen, significant at the 0.001 level. The estimated quadratic equations where Y=leaf or tuber fresh weight and X=% foliar N were: $Y = -297.5 + 176.8(X) - 20.7(X^2)$ and $Y = -372.7 + 251.4 - 34.6(X^2)$ with R^2 values of 0.66 and 0.46, respectively. Visible deficiency symptoms,

expressed as chlorosis on older leaf blades and leaf abscission (Harbaugh, 1986), were detected when foliar nutrient levels were less than 2.8% N. Visible symptoms from excess N were difficult to detect (foliar N greater than 4.8%). These plants had a stunted appearance (plant height = 35 cm at optimal N versus 29 cm with foliar N of 4.5-5.0%) and leaves became dark green with a decrease in the white color pattern. These differences were not great and would be difficult to detect unless one were very familiar with caladium growth characteristics, or other plants treated with less N were available for comparison.

Tissue levels of P (0.54-0.31%), K (4.4-3.0%) and Mg (0.19-0.13%) decreased with increasing N fertilization, while Ca (1.2-1.7%) Mn, (76-610 ppm), Zn (114-250 ppm), Fe (53-184 ppm) and Cu (9.4-19.4 ppm) increased with increasing N rates. B levels were similar (75 ± 5 ppm) among all treatments.

3.2. Phosphorus

Leaf and tuber fresh weights were quadratically related to foliar leaf phosphorus, significant at the 0.001 level. The estimated quadratic equations where Y=leaf or tuber fresh weight and Y=% foliar P were: $Y= -17 + 245.7(X) - 223.1(X^2)$ and $Y= -10.1 + 245.8(X) - 236.3(X^2)$ with R^2 values of 0.70 and 0.72, respectively. Visible deficiency symptoms, expressed as differences in plant size (height) or rate of growth (number of leaves) compared to plants in treatments with higher P fertilization rates (Harbaugh, 1986), were detected when foliar P leaves were below 0.18%. Plants with visible P toxicity (foliar P greater than 0.7%) were distinguishable due to their stunted appearance (24 versus 28 cm), without loss of the white color pattern.

Tissue levels of nutrients other than P remained relatively constant among treatments, except for a characteristic increase in tissue levels of plants treated with the lowest P rates where the plants were stunted from P deficiency. The tissue levels, excluding those for P rates of 4 or 8 ppm, were as follows: N=3.27 ± 0.23%; K=3.6 ± 0.2%; Ca=1.3 ± 0.25%; Mg= 0.22 ± .03%; Fe= 81 ± 21 ppm; Mn= 166 ± 48 ppm; Zn= 116 ± 25 ppm; Cu= 8.2 ± 1.2 ppm; and B= 131 ± 21 ppm. Tissue levels of Na (0.03-0.17%) increased with increasing P rates.

3.3. Potassium

Quadratic equations for the relationship of leaf and tuber fresh weights to foliar leaf K were: $Y= -15.4 + 33.8(X) - 5.22(X^2)$ and $Y= -7.38 + 36.0(X) - 5.55(X^2)$ where Y= leaf or tuber fresh weight, respectively, and X=% foliar K. The quadratic relationships were significant at the 0.001 level with R^2 values of 0.70 and 0.67, respectively. Visible deficiency symptoms, expressed as marginal and interveinal chlorosis (Harbaugh, 1986), were detected when foliar K levels were less than 1.4% K. Visible symptoms from excess K (foliar K greater than 4.5%) were expressed as blotchy areas of interveinal chlorosis which later included the veins.

Tissue levels of all other nutrients which were determined decreased with increasing K fertilization, except for Cl which increased with increasing fertilization and Zn which was relatively constant. The

range of foliar tissue levels from low fertilization to high, and excluding levels from stunted plants with severe deficiency symptoms, were: N= 3.29 to 3.15%; P= 0.47 to 0.43%; Ca= 1.6 to 1.1%; Mg= 0.29 to 0.12%; Fe= 89 to 65 ppm; Mn= 133 to 113 ppm; Zn= 135 to 129 ppm; Cu= 9.3 to 6.7 ppm; B= 143 to 99 ppm; and Cl= 1.12 to 1.80%.

4. Discussion

Fertilization rates of N, P or K resulted in growth and yield responses from deficiencies to toxicities in all three tests. Optimal foliar nutrient level associated with leaf or tuber fresh weights were derived from the quadratic equations developed for each test nutrient. Optimal foliar N correlating to maximum leaf fresh weight was 4.3%, while optimal foliar N relative to tuber weight was 3.2%. These results indicate that rates of N should be higher for caladiums grown as pot plants, where quality and value are enhanced with increases in foliage, than where caladiums are field grown for sale of tubers. On the other hand, optimal foliar P and K levels associated with either leaf or tuber fresh weights were similar, and thus fertilization practices for these elements would be similar for pot or field grown caladiums. Optimal foliar P levels were 0.55 and 0.52% for leaf and tuber fresh weights, respectively. Optimal foliar K was 3.2% for both leaf and tuber fresh weights.

Sufficiency ranges were calculated for foliar N, P or K levels from their respective response curves (Fig. 1). Since the meaning of "sufficiency range," or similar terms describing the relationship of tissue levels of nutrients to growth or yield of crops, varies considerably in the literature (Criley and Carlson, 1970 , Hershey and Paul, 1981, Munson and Nelson, 1973), the term "sufficiency range" as used in this paper is defined as: leaf or tuber fresh weight ± 10% of the optimal growth relative to the foliar nutrient concerned, a decrease in the nutrient below this range results in a rapid (usually linear) decrease in growth, and visual deficiency or toxicity symptoms are usually not distinguishable. The sufficiency range for N was 3.6-4.9% for foliage growth, and 3.1-4.1 for tuber growth. Again, since response curves for P and K were similar relative to both leaf and tuber weight, one sufficiency range for P (0.37-0.68% P) and K (2.3-4.1% K) would be applicable regardless of whether caladiums were grown as potted plants or for tuber production.

Interactive effects of test nutrients and associated ions on uptake of other nutrients varied with each test. In the N test, foliar levels of Mn and Zn were affected to the greatest extent. This was probably due to increased availability as pH decreased below 5.5 in the sand medium of treatments with high levels of NH_4NO_3, even though additional liming solution was applied. Although critical levels of Mn and Zn have not been established for most crops, tissue levels above 500 ppm Mn or 400 ppm Zn are generally considered to be in the toxicity range (Jones, 1972). Thus some plants treated with the greatest N rate may have had an induced Mn toxicity due to fertilization with NH_4NO_3. Interestingly, the typical chlorosis caused by NH_4^+ toxicity was not observed.

Since Na^+ was an associated ion in the P test, tissue levels were

analyzed to determine to what extent this may have affected growth. Very little literature exists on acceptable or toxic foliar levels of Na, but the range of Na was not great (0.03-0.17%) among treatments, and was well within levels found for a variety of crops (Lunt, 1966). Additionally, Na is characteristically a problem due to its effect on soil physical properties and as an antagonist to Ca and Mg uptake. Relatively small changes in foliar levels of Ca and Mg occurred.

In the K test, Cl^- was used in association with K fertilization and foliar Cl levels increased with increasing K rates (1.12-1.8% Cl). Critical toxicity ranges for salt sensitive crops are from 0.5-2.0% Cl and as high as 4.0% Cl for salt tolerant crops (Mengel and Kirkby, 1978). Foliar tissue levels from random samples of plants in the sufficiency range in the N test averaged 1.5% Cl, and would indicate levels in the K test would not significantly affect growth. Furthermore, the typical Cl toxicity symptoms of marginal chlorosis or necrosis and leaf abscission were not evident. Although tissue levels of other nutrients decreased with increasing K, only Mg levels were lower than normal ranges given for other ornamentals (Joiner et al., 1983). Indeed, the visible toxicity symptoms expressed with high K fertilization may have been an induced Mg deficiency since the interveinal chlorosis pattern was similar to that described for initial Mg deficiency in caladium (Harbaugh, 1986).

In summary, although any change in N, P or K rate must have an interactive effect on other elements or associated ions, the interactions within the sufficiency ranges of these tests were not great. Fertilization rates outside the sufficiency range, for both deficient and toxic levels, no doubt directly or indirectly affected growth and visible symptoms, and interpretation of tissue analyses to confirm suspected deficiency or toxicity symptoms should take these interactions into consideration. The area of greatest concern for most caladium producers is use of tissue analyses to correct or maintain adequate nutrition before loss of growth occurs. These results could be used for guidelines of foliar tissue analysis standards for N, P or K to meet these needs.

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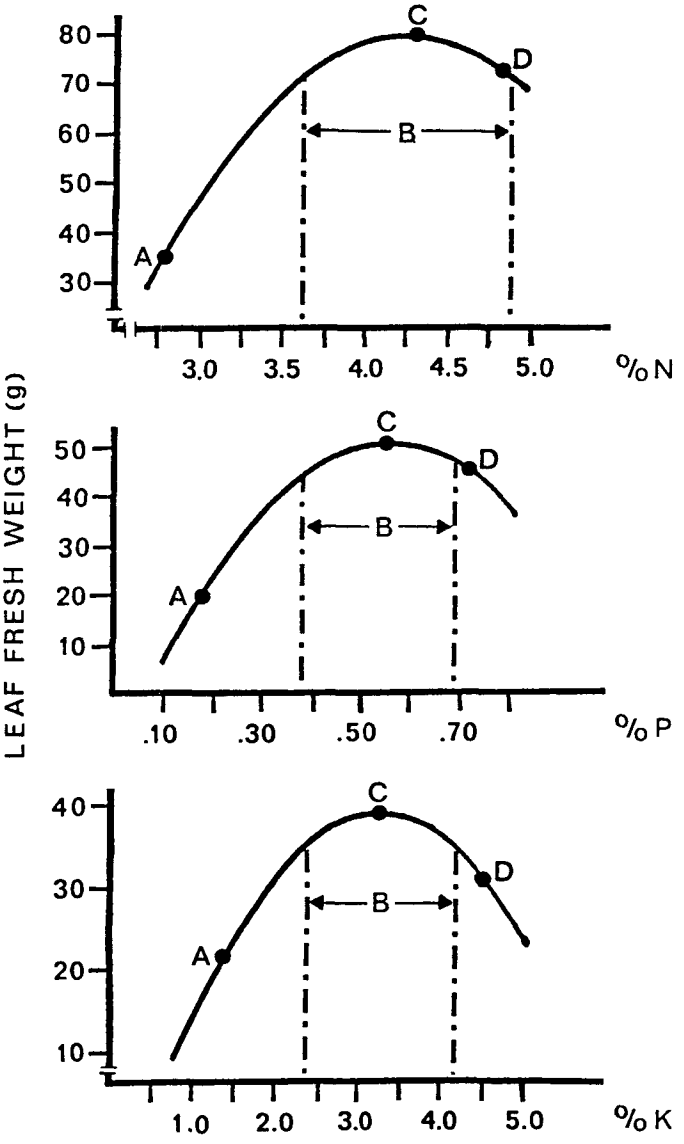

Figure 1. Estimated quadratic equation for the relationship of N, P or K to leaf fresh weight of caladium. A = Visible deficiency; B = Sufficiency range; C = Optimal; D = Visible toxicity.