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Eustoma Quality is Adversely Affected by Low pH of Root Medium

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Abstract. **Foliar chlorosis or bleaching, interveinal chlorosis, leaf edge and tip necrosis, a poor root system, and stunted growth of *Eustoma grandiflorum* (Raf) Shinn seedlings were associated with a medium pH of 5.0 or 5.5 but not when the values ranged from 6.4 to 7.5. The range in medium pH resulting in the best growth of seedings and flowering plants was 6.3 to 6.7. Responses to medium pH were similar, regardless of fertilizer solution pH or cultivar. *Eustoma* seedling and shoot fresh weights for pH 5.0 and 5.5 were only 23% to 66% of corresponding values for plants grown at pH 6.4. Leaf tissue Zn was extremely high (1050 mg·kg^{-1} dry leaf tissue) at a medium pH of 5.0, but other macro- and micronutrients in leaves were not at abnormal levels.**

Eustoma grandiflorum (lisianthus) hybrids have continued to gain acceptance as new cut flowers, bedding plants, and potted flowering plants since their introduction into the floriculture trade in the early 1980s (Halevy and Kofranek, 1984). As with most new crops with limited cultural information, commercial producers have struggled with different aspects of the production and management of this crop. We have observed many instances when seedling production was variable, with small, poor-quality seedlings frequently being produced. In extreme cases, seedlings had foliar chlorosis, leaf edge or tip necrosis, and a stunted or poorly developed root system. Initial investigations indicated low medium pH (in the range of 5.0 to 5.8), now commonly recommended for peat-based media (Joiner et al., 1983; Peterson, 1982), typically was associated with these symptoms. Although no published data on the effects of medium pH on *Eustoma* could be found, Roh and Lawson (1984) indicated a pH near neutral or 6.5 was satisfactory for *Eustoma. The* research reported here was conducted to determine the influence of medium pH on seedling production and subsequent growth to flowering.

The medium in two tests consisted of 4 sphagnum peat : 2 horticultural vermiculite : 1 quartz sand : 1 perlite (by volume) amended with 3 kg single superphosphate (ON-9P-OK-22Ca)/m^3. To obtain a range in pH, the medium was amended with the following hydrated : calcitic lime ratios (kg·m^{-3}): 0.3:0.15, 0.9:0.45, 2.7:1.4, 5.4:2.7, and 8.0:4.0. Media were moistened and stored for 1 week before tests were initiated. After an additional week of daily irrigation for seedling establishment, pH values of saturated-paste medium extracts for each hydrated/calcitic lime regime were 5.0, 5.4, 6.4, 7.1, and 7.5, respectively.

pH of medium and fertilizer solution (Expt. 1). This experiment was a 5 (medium pH) × 5 (fertilizer solution pH) factorial. The fertilizer solution pH was adjusted with 1 M $Ca(OH)_2$ to 5.0, 5.6, 6.2, 6.8, or 7.5. Calcium chloride was used to provide equal amounts of Ca in each solution. The fertilizer solution contained 500N-200P–600K–175Ca (mg·liter^{-1}) from $NH_4H_2PO_4$, KNO_3, and NH_4NO_3 (62% NO_3-N).

Six-week-old *Eustoma* ‘Saga Purple’ seedlings were transplanted into 3.5 × 3.5 × 6-cm pyramidal cell transplant flats (35 ml medium/cell) on 5 Mar. Fertilizer solutions were applied weekly at 6 ml/cell. Seedling width, shoot fresh weight, and medium pH were recorded 10 Apr. At this time, additional seedlings were transplanted into 0.5-liter (10 cm) pots with the same medium and fertilizer treatments from which they were grown for seedling evaluations. Fertilizer solutions were applied weekly at 100 ml/pot. Plant height, shoot fresh weight, number of flowers and buds, and medium pH were recorded 4 June. Leaf tissue samples were also taken at this time for elemental composition analyses. Foliar N, excluding NO_3-N, was determined by a micro-Kjeldahl procedure (Perrin, 1953); B by the azomethine-H colorimetric method (Gaines and Mitchell, 1979); and P, K, Ca, Mg, Fe, Mn, and Cu by inductively coupled argon plasma spectrophotometry. There were two plants per experimental unit and three replications of each treatment combination in the seedling stage and seven replications of single-plant experimental units in the flowering plant stage.

Medium pH, microelements, and cultivar (Expt. 2). This experiment was a 5 (medium pH) × 2 (± microelements) × 3 (cultivar) factorial to determine if cultivars would respond similarly to medium pH and if symptoms associated with low medium pH would increase with micronutrients in the fertilizer solution. Color variants have distinct growth habits, and cultivars were selected from several seed companies in an attempt to represent a broad genetic diversity of available seed.

Seven-week-old *Eustoma* ‘Saga Pink’ (Takii and Co., Kyoto, Japan), ‘White’ (Sluis and Groot, Enkhuizen, Holland), and ‘Yodel Mixture’ (blue, white, and pink blend; Sakata Seed Co., Yokohama, Japan) seedlings were potted into the five media and conditions of Expt. 1 for seedling evaluation. The fertilizer solutions were 300N-200P-600K (mg·liter^{-1}) with or without the following micronutrients: 25Fe-10Mn–5Cu-5Zn-1.6Mo (mg·liter^{-1}) from Fe-DTPA chelate, $MnSO_4H_2O$, $CuSO_4 \cdot 5H_2O$, $ZnSO_4 \cdot 7H_2O$, and $Na_2MoO_4 \cdot 2H_2O$. There were three plants per experimental unit and three replications of each treatment.

The growing environment for both experiments was a fan-and-pad-cooled glasshouse, where the air ranged from 18C night to 33C day. Shade was provided by exterior paint, and the midday photosynthetic photon flux ranged from 600 to 800 µmol·m^{-2}·s^{-1}.

Experiment 1. Interactive effects between medium pH and fertilizer solution pH were not significant for any measured growth response for either stage of growth. Fertilizer solution pH had little effect on growth responses, but medium pH had a significant effect on all growth responses for both developmental stages (Table 1). Thus, data

Table 1. Growth responses of *Eustoma* ‘Saga Purple’ seedlings (age 6 to 11 weeks) and flowering plants (age 11 to 20 weeks) to medium pH.[z]

	Seedling stage			Flowering stage			
Initial medium pH	Width (cm)	Fresh wt (g)	End pH	Ht (cm)	Fresh wt (g)	No. flowers and buds	End pH
5.0	3.3	0.14	4.9	16	7.6	0	5.4
5.4	3.8	0.30	5.4	46	31.0	52	5.2
6.4	7.3	0.60	6.4	63	68.8	69	6.5
7.1	6.6	0.46	6.9	63	52.5	75	7.2
7.5	4.9	0.27	7.1	54	38.0	63	7.4
Quadratic[y]	0.01	0.01		0.01	0.01	0.01	
Estimated[x] optimal pH	6.4	6.4		6.6	6.5	6.7	

[z]The medium pH × fertilizer solution pH interaction was not significant, and the main-effect values presented represent the mean of 30 observations for the seedling stage (three replications of two-plant experimental units averaged over five fertilizer solution pHs) and 35 for the flowering stage (seven replications of single-plant experimental units averaged over five fertilizer solution pHs).
[y]Quadratic term significant at $P = 0.01$.
[x]Estimated maximum pH derived from quadratic equations from regression analyses.

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Table 2. Foliar nutrient content[z] of *Eustoma* 'Saga Purple' grown for 14 weeks in media with pH ranging from 5.0 to 7.5.

Medium pH	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	Elemental composition (dry-wt basis)									
	(g·kg⁻¹)					(mg·kg⁻¹)				
5.0	36	4.0	49	5.5	4.6	144	64	1050	12	23
5.5	29	2.8	41	4.0	4.6	87	49	94	6	19
6.4	26	1.2	36	3.9	4.3	85	42	32	3	14
7.1	27	1.2	34	4.4	5.2	87	50	25	2	14
7.5	27	1.5	34	4.1	5.4	107	64	28	8	17
Linear	**	**	**	NS	*	NS	NS	**	NS	**
Quadratic	**	**	NS	NS	**	*	**	**	**	**

[z]Values represent the mean of all leaves above the fourth leaf pair of 35 plants, except from medium pH of 5.0, where samples were combined for N and B determinations due to the small size of the plants.
NS,*,**Nonsignificant or significant at $P = 0.05$ or 0.01, respectively.

Table 3. Growth responses of three *Eustoma* cultivar seedlings to medium pH and micronutrients in the fertilizer solution.[z]

Medium pH	Width (cm) −	Width (cm) +	Wt (g) −	Wt (g) +
	Micronutrients			
5.0	4.0	6.3	0.3	0.6
5.4	4.5	7.0	0.4	0.7
6.4	7.7	7.7	1.1	0.9
7.1	7.3	7.3	0.9	0.9
7.5	6.3	6.3	0.6	0.6
Quadratic[y]	0.01	0.01	0.01	0.01
Estimated[x] optimal pH	6.7	6.3	6.5	6.3

[z]Values represent the mean of 27 observations (cultivars Saga Pink, White, and Yodel Mixed with three replications of three-plant experimental units). + Micronutrients = 25Fe–10Mn–5Cu–5Zn–1.6Mo (mg·liter⁻¹ of fertilizer solution).
[y]Quadratic term significant at $P = 0.01$.
[x]Estimated optimal pH levels derived from quadratic equations from regression analyses.

presented are main-effect means for effects of medium pH on seedling and plant growth averaged over fertilizer solution pH treatments.

Regression analyses indicated quadratic relationships for the effect of medium pH on all measured growth responses (Table 1). Seedlings and flowering plants grown with a medium pH of 5.0 or 5.4 were only half the weight and width of seedlings grown at pH 6.4. Symptoms of foliar chlorosis, a poor root system, and stunted plants were similar to symptoms associated with problems observed in commercial production of *Eustoma* seedlings. Maximum growth responses estimated from quadratic equations were within a range of medium pH from 6.4 to 6.7, encompassing all growth characteristics.

In general, foliar nutrient levels were inversely related to optimum pH levels for growth (Table 2). This response is typical when plants are stunted for various reasons but continue to take up nutrients. Only foliar levels of Zn (1050 $mg \cdot kg^{-1}$ dry leaf tissue) were at levels that might be toxic (Joiner et al., 1983). Experience with geranium is similar in that micronutrient levels, especially Mn and Fe, were enhanced by low medium pH (Biernbaum et al., 1988). *Eustoma* apparently can accumulate high concentrations of Zn at a low pH, levels that might cause the chlorosis and necrosis often observed. However, further research is necessary to determine if Zn toxicity caused the plants to grow poorly or if other nutrient imbalances or additional factors associated with low medium pH inhibited growth, resulting in luxuriant absorption of Zn.

Since Ca was introduced with lime sources for pH adjustment, medium Ca levels increased with increasing medium pH. However, 0.66 kg Ca/m^3 of medium from single superphosphate, 175 mg Ca/liter in fertilizer solutions, and 30 mg Ca/liter in irrigation water probably would have supplied adequate levels of Ca for growth in all media even though *Eustoma* requires relatively high levels of Ca (Fret et al., 1988). Foliar levels of Ca were higher at low than at high media pHs (Table 2), indicating that availability was more important than absolute amount present in the media.

Experiment 2. Similar trends were evident for effect of medium pH and micronutrients on growth of all cultivars. There was an interaction of micronutrient fertilization with medium pH, so regression analyses for the influence of medium pH on seedling growth were made for each fertilization method from data combined for all cultivars (Table 3). Quadratic relationships were indicated for the effect of medium pH on seedling width and fresh weight for both fertilization methods. Estimated optimum pH for seedling growth ranged from 6.3 to 6.7.

If Zn toxicity due to high volubility at low medium pH was the cause of stunting of *Eustoma* seedlings, one might expect the addition of Zn along with other micronutrients in the fertilizer solution to aggravate seedling growth problems. However, differences in seedling width and fresh weight due to low medium pH were greater when seedlings were grown without than when grown with micronutrients (Table 3). Results from both experiments indicate the need for additional research on the requirements and balance of micronutrients for seedling growth, although the practical solution to the problem at this time appears to be to produce seedlings in media with a pH near 6.4 (Biernbaum et al., 1988).

In summary, medium pH had a dramatic effect on seedling growth for all cultivars tested. The range of medium pH for maximum growth estimated for both experiments, including all. measured responses, was from 6.3 to 6.7. Perhaps more importantly, however, was that at lower pH levels, which are commonly used in floriculture for peat-based media, *Eustoma* seedling and plant fresh weights were only 23% to 66% of the fresh weight of seedlings grown at a medium pH of 6.4.

Literature Cited

Biernbaum, J., W. Carlson, C. Shoemaker, and R. Heins. 1988. Low pH causes iron and manganese toxicity. Greenhouse Grower 6(3):92-93, 96-97.

Frett, J. J., J.W. Kelly, B.K. Harbaugh, and M. Rob. 1988. Optimizing nitrogen and calcium nutrition of lisianthus. Commun. Soil Sci. & Plant Anal. 19(1):13-24.

Gaines, T.P. and G.A. Mitchell. 1979. Boron determination in plant tissue by the azomethine H method. Commun. Soil Sci. & Plant Anal. 10(8):1099-1108.

Halevy, A.H. and A.M. Kofranek. 1984. Evaluation of lisianthus as a new flower crop. HortScience 19(6):845-847.

Joiner, J. N., R.T. Poole, and C.A. Conover. 1983. Nutrition and fertilization of ornamental greenhouse crops, p. 317-403. In: J. Janick (ed.). Hort. Rev. vol. 5. AVI, Westport, Conn.

Perrin, C.H. 1953. Rapid modified procedure for determination of Kjeldahl nitrogen. Anal. Chem. 25(6):968-969.

Peterson, J.C. 1981. Modify your pH perspective. Florists' Rev. 169(4386):34-35, 92-93.

Rob, M. and R. Lawson. 1984. The lure of lisianthus. Greenhouse Manager 2:103, 104, 108, 110, 112-114, 116-121.