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Effects of six fertilizers on vegetative growth and flowering of phalaenopsis orchids

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Abstract

One of six water-soluble fertilizers, 10N-13.1P-16.6K, 15N-4.4P-24.9K, 15N-8.7P-20.8K, 20N-2.2P15.8K, 20N-4.4P-16.6K, and 20N-8.7P-16.6K (10-30-20, 15-10-30, 15-20-25, 20-5-19, 20-10-20, and 20-20-20 in N-P_2O_5-K_2O, respectively), was applied to young seedlings of Phalaenopsis Tam Butterfly at concentrations of 200 or 100 mg N l^{-1}. After seven months, leaf span, leaf size, total leaf area, and shoot and root fresh weight were not different among various fertilizers within either concentration. However, plants had a wider leaf spread, produced more and larger leaves, and had greater total leaf areas in response to the higher fertilizer concentration, regardless of which fertilizer was used. The different fertilizers had a small but significant effect on leaf number. The 10N-13.1P-16.6K fertilizer caused a lower medium pH than the others. Medium fertigated with the 10N-13.1P-16.6K or 15N-8.7P-20.8K fertilizer always had higher EC than that receiving the 20N-8.7P-16.6K fertilizer. In a second experiment, the same fertilizers at the 200 mg N l^{-1} concentration were used on mature plants in late August, with either municipal water (EC = 1.4 dS m^{-1}) or water from a reverse osmosis system (RO, EC = 0.03 dS m^{-1}). Regardless of which fertilizer was used, flowering date, flower size and number, as well as plant width were unaffected. The 10N-13.1P-16.6K fertilizer resulted in 12% more leaves than 20N-8.7P-16.6K by May the following year. Plants fertigated with RO water had slightly larger flowers and longer leaves.

Keywords: Phalaenopsis, pot plants, nutrition

Abbreviations: PPF = photosynthetic photon flux; RO = reverse osmosis; EC = electrical conductivity.

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1. Introduction

For years, orchids were a relatively small group of plants in the floricultural trade, both in volume and in gross value. But, production of the Phalaenopsis orchids has increased drastically in recent years due to advanced production techniques and increasing interest among consumers (Griesbach, 1995; Wang and Lee, 1994a, 1994b). It was estimated that more than 6 million plants of various sizes may be sold annually on the U.S. market alone. Europe and Japan each consumes several million plants annually (Griesbach, 1995; Sinoda, 1994).

There has been very little information in the scientific literature to assist growers in improving the production of Phalaenopsis. Previously, it was reported that increasing the N concentration from 50 to 200 mg l^{-1} promoted flowering and leaf production in a white-flowered hybrid Phalaenopsis (Wang and Gregg, 1994). However, only one fertilizer was used in that study and the effect of different N-P-K fertilizers on the performance of this orchid remained unknown. Poole and Seeley (1978) also demonstrated that Phalaenopsis in hydroponic culture needed relatively high fertilizer concentrations for improved growth.

The objective of this study was to determine the effect of six N-P-K fertilizers on vegetative growth and flowering of a hybrid Phalaenopsis orchid. The pH and electrical conductivity of the medium leachate were also monitored.

2. Materials and methods

Plant material. Seeds of Phalaenopsis Tam Butterfly were sown on 6 September 1992 on an aseptic culture medium. Seedlings were removed from culture boxes in July 1993 and transferred to 73-cell trays filled with New Zealand sphagnum moss and irrigated with water containing 1 g l^{-1} Peters 20N-8.7P-16.6K soluble fertilizer (Scotts, Inc., Marysville, Ohio). The plants were potted into 0.6-liter containers in mid-November with a medium consisting of 70% fine grade fir bark and 30% peat moss amended with 0.25 g Micromax (Scotts, Inc.), 3.0 g powdered dolomitic limestone, and 0.93 g AquaGro wetting agent (Aquatrols of America, Pensauken, N.J.) per liter of medium.

Vegetative growth. Three-hundred uniform plants with a leaf spread measuring 8 to 10 cm were selected on 3 January 1994 and placed on benches in a greenhouse with a photosynthetic photon flux (PPF) ranging between 240 (February) and 285 (May) μmol m^{-2} s^{-1}. Greenhouse air temperature ranged between 15°C and 28°C in spring and between 22°C and 31°C in summer. The top leaf on each plant was labeled so that new leaf growth could be determined.

Six water-soluble fertilizers (Scotts, Inc.) having diverse percentages of N, P, and K, as well as different N sources and acidity (Table 1) were used at 100 or 200 mg N l^{-1}. Four of the fertilizers contained urea and the other two did not. Local municipal water with an electrical conductivity (EC) ≈ 1.4 dS m^{-1} was used to formulate the fertilizer solutions. Plants were fertigated when the medium surface appeared dry and pots became light in weight until March, after which water without fertilizer was used at every third irrigation to avoid salt accumulation in the medium. Leachate samples for

Table 1
N, P, K levels in solutions of six fertilizers at 100 mg l^{-1} concentration.

Fertilizer (% N-P-K)	Nutrient concentration (mg l^{-1})						Potential acidity (kg $CaCO_3t^{-1}$)
	N				P	K	
	Total	Source					
		NO_3^-	NH_4^+	Urea			
10-13.1-16.6	100	56.4	43.6	0	131	166	223
15-4.4-24.9	100	60.7	20.8	18.5	29	166	38
15-8.7-20.8	100	46.6	26.7	26.7	58	138	199
20-2.2-15.8	100	30.0	60.6	9.4	11	76	190
20-4.4-16.6	100	60.0	40.0	0	22	83	211
20-8.7-16.6	100	8.1	19.8	52.1	44	83	300

measuring the initial pH and EC were collected from 25 pots on 14 December 1993 by the pour through technique (Yeager et al., 1983) and additional samples were collected from five pots of each treatment after the second fertigation at irregular intervals until July 1994.

Plants were harvested on 31 July. Leaf spread, number and total area of the new leaves, area of the largest leaf, and fresh weight of shoot and roots were recorded for each plant. A single plant represented an experimental unit and treatments were replicated 25 times in a randomized complete block design.

Flowering. Additional plants of the same hybrid as above with four or five mature leaves and a leaf spread of ≈ 30 cm, grown in 0.6-liter pots and receiving fertigation with Peters 20N-8.7P-16.6K fertilizer, were transferred into 1.75-liter pots in mid-August 1994. The container medium consisted of equal volumes of No. 3 perlite, Metro Mix 700 (Scotts, Inc.), and horticultural grade charcoal, amended with 0.5 g l^{-1} Micromax. The top leaf of each plant was labeled. Plants were placed on a greenhouse bench receiving 325 (September) to 280 (November) μmol m^{-2} s^{-1} PPF. The same six fertilizers as above were used at 200 mg N l^{-1} only with the municipal water or water from a reverse osmosis purification unit (EC ≈ 0.03 dS m^{-1}). All plants were given water containing 0.6 g l^{-1} $Ca(NO_3)_2 \cdot 4H_2O$ at every fourth irrigation. Leachate samples were collected soon after planting and at two-month intervals thereafter for the determination of pH and EC. Dates of flower spike emergence (spiking), and the first flower becoming flat open (anthesis), flower number and size, number of new leaves (10 May 1995), and plant width were recorded for each plant. The experiment had a randomized complete block design with 20 single plant replications.

Analysis of variance was performed on all data. Duncan's multiple range test was used for mean separation.

3. Results and discussion

Because of the diverse N, P, and K analyses among the fertilizers, the concentrations of P and K varied a great deal at each of the N concentrations. For instance, when both

Table 2
The effect fertilizer concentration on the vegetative growth of *Phalaenopsis* Tam Butterfly seedlings

N rate ($mg\ l^{-1}$)	Leaf span (cm)	New leaves			Fresh weight (g)	
		Number	Largest leaf (cm^2)	Total area (cm^2)		
100	28.5	4.8	89	275	52	22 *
200	32.8 ***	5.5 ***	103 ***	355 ***	73 ***	19

Mean separation within columns by F test. * and ***, significant at $\alpha = 0.05$ and 0.001, respectively.

were used at 100 mg N l^{-1}, the 10N-13.1P-16.6K provided 131 and 166 mg l^{-1} of P and K, while the 20N2.2P-15.8K provided only 11 and 79 mg l^{-1} of P and K, respectively (Table 1). Therefore, it was expected that plant growth might be affected by the various levels of P and K, too.

Vegetative growth. There was no significant interaction between fertilizer type and concentration. Therefore, plants responded similarly to all fertilizers at a given fertilizer concentration. The only difference among plants as a function of fertilizer type was that plants fertilized with 10N-13.1P-16.6K or 15N-8.7P-20.8K had a greater mean leaf number than plants given the 20N-4.4P-16.6K or 20N-8.7P-16.6K (data not shown). However, there was no difference in total leaf area among fertilizer treatments at either concentration.

Plants responded to the higher N rate by producing wider and heavier plants with larger leaves (Table 2), which agrees with previous work (Lee and Lin, 1987; Wang and Gregg, 1994). Plant growth at 100 mg N l^{-1} during the seven-month period was exceptional by commercial standards. One leaf was produced, on average, every 40 days. At the time of harvest, all plants were considered mature and capable of flowering if placed under inductive conditions (Lee, 1991; Lee and Lin, 1984, 1987). Heavy fertilization was reported to result in more leaf production and greater flower count in Phalaenopsis (Wang and Gregg, 1994; Wilcock, 1973) and three other species of orchids grown in stone chips (Wilcock, 1973).

The final medium pH increased slightly or remained unchanged during the course of this experiment as compared to the initial pH (data not shown). The 10N-13.1P-16.6 K fertilizer resulted in a lower final pH (6.0) than the others (6.3–6.7), despite its potential acidity (193 kg $CaCO_3$ t^{-}ul) being similar to that of the 20N-4.4P-16.6K but lower than the 20N-8.7P-16.6K (273 kg $CaCO_3$ t^{-1}). The difference in pH was not related to the types of N present in the fertilizers (Table 1). Higher fertilizer concentration resulted in a lower medium pH, regardless of which fertilizer was used (Table 3). However, the pH difference was probably not meaningful under commercial production conditions. Helton (1969) reported that three epiphytic orchids, including Phalaenopsis, grew best in a medium with a pH ranging between 4.5 and 5.5, possibly due to increased levels of soluble micronutrients. In a previous study (Wang and Gregg, 1994), leaf production and flowering were excellent when plants were grown in media with composted pine bark, having a final pH of 4.4. Micromax added to the medium used in the current experiment may have supplied an adequate level of micronutrients even at a pH above 6. The

Table 3
The effects of fertilizer concentration on leachate pH and electrical conductivity (EC). The medium consisted of 70% fine fir bark and 30% peat moss (by volume prior to mixing)

N rate ($mg\ l^{-1}$)	Time				
	14 March	12 April	23 May	7 June	8 July
pH					
100	6.44 ***	6.68 ***	7.70 ***	6.38 ***	6.69 ***
200	6.09	6.26	6.33	5.99	6.30
EC ($dS\ m^{-1}$)					
100	2.47	2.02	1.79	1.59	1.64
200	3.56 ***	2.79 ***	2.59 ***	2.44 ***	2.42 ***

Mean separation within columns and factors by F test. * and ***, significant at $\alpha = 0.05$ and 0.001, respectively.

soluble fertilizers and the minerals in the municipal water (Wang, 1989) may have supplied the necessary micronutrients.

The fertilizers with 20% N resulted in lower leachate EC (1.8–1.9 $dS \cdot m^{-1}$) than the 10N-13.1P-16.6K fertilizer which had the highest EC (2.4 $dS \cdot m^{-1}$, data not shown). As expected, the higher fertilizer concentration caused the leachate to have consistently higher EC than that from the lower concentration (Table 3).

Flowering. Fertilizer had no effect on most of the parameters recorded, except that the 10N-13.1P-16.6K fertilizer resulted in plants having more leaves (12%) than those receiving the 20N-8.7P-16.6K by May 1995 (data not shown). Water source did not affect spiking date (averaged 14 October 1994), flowering date (averaged 29 January 1995), inflorescence number (1.5 per plant), total flower number (21 per plant), and number of new leaves (4). Wu et al. (1994) reported that a balanced fertilizer at 200 mg $N\ l^{-1}$ resulted in more growth than 70 mg $N\ l^{-1}$, but caused a slight delay in flowering which was not observed in this and another study (Wang and Gregg, 1994). Although plants given the RO water had slightly larger flowers and longer leaves, the differences were not visually apparent.

Medium pH dropped by 1.0 to 1.2 units over the 8-month period, regardless of which fertilizer or water was used (data not shown). The 10N-13.1P-16.6K fertilizer resulted in lower pH than all others (5.8–6.1), having a final pH of 5.5. As anticipated, the EC of the leachate varied with fertilizer, with water source, and with time of year. In general, the 10N-13.1P-16.6K fertilizer resulted in higher leachate EC than 20N-4.4P-16.6K or 20N-8.7P-16.6K. Pots receiving the municipal water had slightly higher pH but much elevated EC (3.7 $dS \cdot m^{-1}$) than those given RO water (2.2 $ds \cdot m^{-1}$). Careful selection of a low-salt fertilizer, and/or use of RO water can significantly reduce EC of the leachate. Although there was no effects of these variations in pH and EC on productivity of Phalaenopsis plants under our experimental conditions, one would need to test these parameters to ensure that they fall within reasonable values for his production regime and chosen fertilizer.

The media used in the present experiments contained peat moss that apparently retained more moisture and possibly more nutrients than bark alone. In similar media, 30N-4.4P-8.3K (30N-10P_2O_5-10K_2O) and 18N-7.8P-15.5K (18N-18P_2O_5-18K_2O) fertil-

Table 4
The effects of water source on *Phalaenopsis* growth and flowering. The municipal water had an EC = 1.4 dS m^{-1} and the reverse osmosis (RO) water had an EC = 0.03 dS m^{-1}

Water source	Bloom date	Flower diameter (cm)	Inflorescence number	Total flowers per plant	New leaf number	Plant width (cm)
RO	27 Jan.	9.7 *	1.76	20.7	4.1	58.3 *
Municipal	31 Jan.	9.4	1.77	20.8	4.0	55.4

Mean separation within columns by F test. * significant at $\alpha = 0.05$.

izers have been recommended and used (Gordon, 1988; Sheehan, 1991; White, 1986). It was suggested that Phalaenopsis does not require much fertilizer due to its slow growth, probably under less than optimal conditions (Batchelor, 1983). In a medium containing 25% peat moss, Poole and Seeley (1977) found that the 8N-7.0P-10.3K Osmocote (8N-16P_2O_5-12K_2O, 8–9 months release time) at 4 g per 10-cm pot resulted in better seedling growth than 200 mg N l^{-1} from a 16N-1.7P-10.3K (16N-4P_2O_5-12K_2O) water soluble fertilizer when applied at every third irrigation. However, all plants were relatively small after 14 months in production. The growth difference might have been the consistent supply of nutrients from the slow release fertilizer, whereas the soluble fertilizer was not applied frequently enough for best growth. This and previous studies show that high fertilizer concentrations accelerated growth of the Phalaenopsis orchid (Gomi et al., 1980; Lee and Lin, 1987; Wang and Gregg, 1994).

Gordon (1990) recommended that a fertilizer high in P be used prior to and during the development of the inflorescence for best flowering. Since all plants used in the second experiment were fertigated with 1.0 g l^{-1} 20N-8.7P-16.6K until mid-August, changing to the 10N-13.1P-16.6K fertilizer would meet the above recommendation for better flowering. However, the six fertilizers used in this study affected neither flower number nor size (Table 4). It is possible that the peat-containing medium retained an adequate level of all nutrients for good flowering, regardless of which fertilizer was used, whereas P level may need to be increased for plants grown in bark to get similar results. In one study, doubling, tripling, or quadrupling the N-P-K levels from 39-8-20 mg l^{-1} did not affect the concentration of P in Phalaenopsis shoots or roots (Gomi et al., 1980). Current data suggest that, when grown in media containing peat moss, switching

Table 5
The influence of water source on medium leachate pH and electrical conductivity (EC) over an 8-month period

Water source	pH		EC (dS m^{-1})	
	August 1994	April 1995	August 1994	April 1995
RO	7.02	5.81	1.80	2.19
Municipal	7.03	5.95 *	2.48 ***	3.70 ***

Mean separation within columns by F test. * and ***, significantly different at $\alpha = 0.05$ and 0.001, respectively.

to a high P fertilizer may not further improve flowering in plants previously receiving a balanced fertilizer.

The results of this study suggest that when media having good moisture and nutrient retention capacity are used for growing Phalaenopsis orchid, it is not critical which balanced fertilizer is used. Since the length of the juvenile period of this orchid is directly associated with the speed of leaf production and leaf area expansion (Lee, 1991), it may be beneficial to use a high concentration of fertilizer (200 mg N l^{-1}) on young plants for rapid growth (Table 2). Once plants have reached maturity, one may want to reduce the fertilizer concentration to avoid having excessively large plants (Wang and Gregg, 1994) which occupy more bench area and increase production costs.

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