

# Reviews

## Effects of Nitrogen and the Various Forms of Nitrogen on Phalaenopsis Orchid—A Review

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**SUMMARY.** Growers realize the importance of nitrogen (N) on the vegetative growth of phalaenopsis orchids (hybrids of *Phalaenopsis* sp.), but often overlook its influence on reproductive growth. Low N may result in slow plant growth, pale-green leaves, abscission of lower leaves, and few flowers in phalaenopsis. Increasing N concentration up to 200 mg·L<sup>-1</sup> promotes leaf growth and increases flower count. High N concentration promotes lateral branching on the flowering stalk, thereby greatly increasing the total flower count and elevating the commercial value. It is important that N be continually applied during the forcing period for best flowering performance, particularly for those that had undergone international shipping. For the vegetative phalaenopsis plants that are induced to flower without being shipped internationally, the N that is already in the plant before spiking provides 43% and the N being absorbed by roots after cooling provides 57% of the total N in the inflorescence at time of visible bud. When insufficiently fertilized or no fertilization is applied during the forcing period, more of the existing N in a plant is mobilized for inflorescence development. Phalaenopsis roots can take up all three forms of N [i.e., nitrate (NO<sub>3</sub>-N), ammonium (NH<sub>4</sub>-N), and urea] directly. In two studies, phalaenopsis plants were supplied with the same amount of total N but with varying NO<sub>3</sub>-N from 100%, 75%, 50%, 25%, to 0% (a common N concentration was achieved by the substitution of the respective balance with NH<sub>4</sub>-N). Plants were smaller when receiving 75% or 100% NH<sub>4</sub>-N with a tendency of decreasing top leaf width and whole-plant leaf spread as NO<sub>3</sub>-N decreased from 100% to 0%. Spiking was delayed and spiking rate decreased when plants were grown in sphagnum moss, but not a bark mix, and received more than 50% of the N in NH<sub>4</sub>-N. As the ratio between NO<sub>3</sub>-N and NH<sub>4</sub>-N increased, flowers became increasingly larger. The negative effects of low ratios of NO<sub>3</sub>-N to NH<sub>4</sub>-N were more severe in the second flowering cycle. When supplied with 50% or more NH<sub>4</sub>-N, the absorption of cations by phalaenopsis roots declined, with reduced concentrations of calcium and magnesium in plants, while symptoms of ammonium toxicity appeared, including growth retardation, chlorotic leaves, and necrotic roots. In conclusion, adequate N and its continual supply during both vegetative and reproductive stages are recommended for the best growth and flowering of phalaenopsis. Since phalaenopsis plants prefer N in the NO<sub>3</sub>-N form, it is suggested that growers choose and apply a fertilizer with nitrate as the major N source.

Nitrogen is one of the most essential mineral elements that plants need to grow and reproduce well. Low N can result in slow plant growth, pale-green leaves, abscission of the lower

leaves, reduced flower count, and low productivity.

### Rate of N

Lee and Lin (1987) reported that phalaenopsis leaf size increased

when the minerals in Johnson's solution increased from one-fourth to full strength (plants grown in sand). Using several water-soluble fertilizer formulations (Peters; Everris NA, Dublin, OH), Wang (1994, 1996) found that, as the rate of each fertilizer increased from 0.25 to 1.0 g·L<sup>-1</sup> in the irrigation water, the vegetative growth, flower count, and flower size increased. When phalaenopsis is planted in sphagnum moss and using 15K-2.2P-12.5K (N = 78% nitrate + 8% ammonium + 14% urea), as N concentration increased from 0 to 200 mg·L<sup>-1</sup>, leaf span, leaf number, total leaf length, and flower count all increased (Wang, 2010) (Fig. 1). In this study, the increase in flower size as N rate increased could be due to the concomitant increase in potassium (K) concentration from 0 to 166 mg·L<sup>-1</sup>. In another study, K was found to result in progressively larger flower size as its rate increased from 50 to 400 mg·L<sup>-1</sup> (Wang, 2007). Increasing N concentration to 400 mg·L<sup>-1</sup>, in conjunction with other minerals, can be detrimental to phalaenopsis (Wang, 2003; Yao, 2007).

Nitrogen level and the length of its application may affect time of spiking in phalaenopsis. Kubota and Yoneda (1994) found that plants, which stopped receiving N at the beginning of September, spiked earlier than those receiving N until the end of September. Horio and Ichihashi (2004) and Ichihashi (2003) determined that N concentration at 280 mg·L<sup>-1</sup> caused a short delay in spiking. However, Wang (2003) found that N up to 400 mg·L<sup>-1</sup> did not delay spiking when used as a constant feed with other required minerals for over 1 year when grown in a bark/peat mix. In another study, it was found that spiking was delayed when phalaenopsis plants were grown in sphagnum moss and never received any fertilizer (Y.T. Wang, unpublished data) (Fig. 2). At 25 mg·L<sup>-1</sup> N, spiking and flowering were accelerated by 19 and 15 d, respectively, compared with those of nonfertilized plants. An increase in N rate up to 200 mg·L<sup>-1</sup> resulted in slower spiking (8 to 10 d when compared with N at 25 mg·L<sup>-1</sup>) and flowering (averaged 12 d when compared with N at 25 mg·L<sup>-1</sup>), with no statistical difference among

these higher rates, but still faster than plants that received no fertilizer.

van Noort and Dueck (2015) reported that N at 364 mg·L<sup>-1</sup> was detrimental to phalaenopsis by causing fewer double-spike plants than at 196 or 280 mg·L<sup>-1</sup> N. The high rate of N at 364 mg·L<sup>-1</sup> rendered the flowering stems to be more susceptible to infection by *Fusarium* (*Fusarium solani*).

N Rate on Flower Size

It was well documented that flower size of phalaenopsis orchid is unaffected by N levels (Huang et al., 2011a, 2011b; Lei, 2007; Peng, 2008; Susilo and Chang, 2014; Wang, 2003, 2010; Wang and Gregg, 1994; Y.T. Wang, unpublished data; Yu, 2012). Phalaenopsis plants simply produce fewer flowers as N rate decreases while maintaining the flower size. Ruamrungsri et al. (2007) found that 200 mg·L<sup>-1</sup> N resulted in longer inflorescence length and higher flower count than 100 mg·L<sup>-1</sup>.

During the reproductive phase, for vegetative plants that had undergone severe drying of the growing medium and been through 3–4 weeks of ocean container shipping in complete darkness at 18–20 °C, applying N up to 200 mg·L<sup>-1</sup> slightly increases flower count on the main spike. Increasing N also promotes lateral branching, which results in much higher total flower count (Y.T. Wang, unpublished data) (Fig. 3), as well as greener leaves (Huang et al., 2011a, 2011b; Wang et al., 2008; Y.T. Wang, unpublished data) (Fig. 4).

Use of N

The mature leaves and roots of phalaenopsis collectively serve as a N pool, whereas growing leaves and inflorescences have strong demands for N (Susilo et al., 2013).

Studies consistently showed that high N should be continually applied during the forcing period for best flowering performance (Huang et al., 2011b; Susilo et al., 2014; Susilo and Chang, 2014; Y.T. Wang, unpublished data). In an earlier study, ending fertilization when the flowering stem had reached 10 cm in length had no impact on flower count or size, despite a small loss of the lower leaves (Wang, 2000).

Using N<sup>15</sup> (N with an atomic weight of 15 and an isotope of the common N with an atomic weight of 14) as a tracer, it was determined that N already existing in the plant before spiking provided 43% and the N absorbed by roots following spiking accounted for 57% of the total N that is present in the inflorescence at the visible bud stage (Susilo et al., 2014). Of the 43% N in the inflorescence, N absorbed during the small, medium, and large plant stages contributed 7%, 11%, and 25% N, respectively.

When little or no fertilizer is applied during the reproductive stage (the forcing period), more existing N in phalaenopsis plants is mobilized and

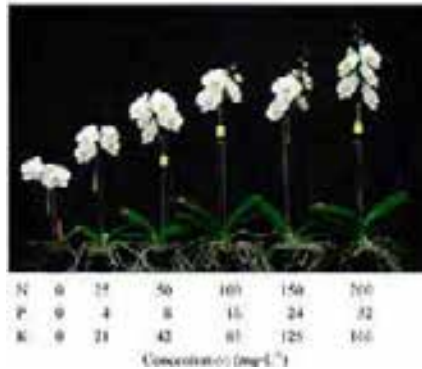


Fig. 1. Response of phalaenopsis orchid to various concentrations of nitrogen-phosphorus-potassium (N-P-K) fertilizer [15N-2.2P-12.5K, N = 78% nitrate + 8% ammonium + 14% urea (Peters Professional 15-5-15 Cal-Mag; Everris NA, Dublin, OH)] (Wang, 2010); 1 mg·L<sup>-1</sup> = 1 ppm.

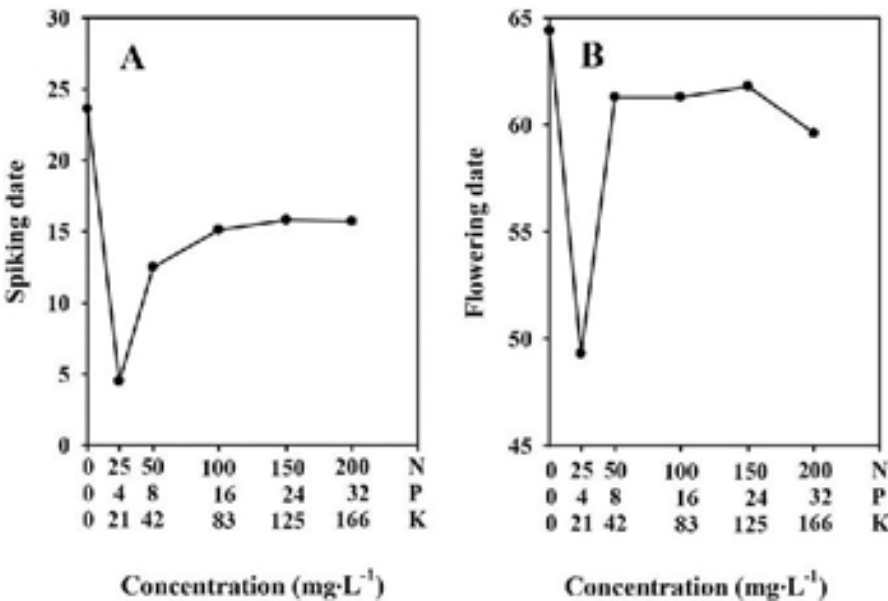


Fig. 2. Effects of various concentrations of nitrogen-phosphorus-potassium (N-P-K) fertilizer [15N-2.2P-12.5K, N = 78% nitrate + 8% ammonium + 14% urea-N (Peters Professional 15-5-15 Cal-Mag; Everris NA, Dublin, OH)] on spiking date [A (y axis = date in October)] and flowering time [B (y axis = number of days elapsed since 1 Jan. of the following year)] of a white-flowered phalaenopsis orchid (Y.T. Wang, unpublished data); 1 mg·L<sup>-1</sup> = 1 ppm.

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Units

| To convert U.S. to SI, multiply by | U.S. unit | SI unit            | To convert SI to U.S., multiply by |
|------------------------------------|-----------|--------------------|------------------------------------|
| 1                                  | mmho/cm   | dS·m <sup>-1</sup> | 1                                  |
| 0.001                              | ppm       | g·L <sup>-1</sup>  | 1000                               |
| 1                                  | ppm       | mg·L <sup>-1</sup> | 1                                  |
| (°F - 32) ÷ 1.8                    | °F        | °C                 | (°C × 1.8) + 32                    |

this is sufficient to meet most of the N demand for inflorescence development to make an acceptable commercial crop if plants had been fertilized well during the vegetative growing period (Susilo and Chang, 2014). However, the foliage may appear the less appealing pale green (Fig. 4) and one or more lower leaves may abscise.

Symptoms of N deficiency in phalaenopsis first occur in the lower leaves due to its easy mobility and translocation out of the older leaves under low or deficient conditions to support the new growth (Huang et al., 2011a, 2011b; Wang, 2010; Y.T. Wang, unpublished data). The symptoms can be yellowing and abscission of the basal leaves, which becomes progressively more severe with the opening of more flowers (Wang, 2010; Wang et al., 2006; Y.T. Wang, unpublished data).

### Forms and Uptake of N

Nitrogen comes in various forms, such as  $\text{NO}_3\text{-N}$ ,  $\text{NH}_4\text{-N}$ , and urea [ $\text{CO}(\text{NH}_2)_2$ ]. Most complete fertilizers carry two or all three forms of N in various proportions.  $\text{NH}_4\text{-N}$  and urea are treated collectively as the “ammoniacal N.”

Roots of phalaenopsis are the major organs responsible for the uptake of mineral nutrients in phalaenopsis. The amount of mineral nutrients that is absorbed through the foliage is limited and not enough to support good vegetative growth and flowering (Huang et al., 2011b; Susilo et al., 2013; Wang, 2010).

Phalaenopsis roots can take up all three forms of N directly. Burgeff (1936) showed that  $\text{NO}_3\text{-N}$  was best used by orchids (Orchidaceae) that attach to other plants or objects in light. Many tropical orchid species fall into this group.  $\text{NH}_4\text{-N}$  was necessary for growth in darkness or in light by the more heterotrophic (organisms that cannot fix carbon and use organic carbon for growth) and saprophytic (organisms that live on dead or decomposing matter) species. Using  $\text{N}^{15}$ , Trépanier et al. (2009) demonstrated that, for phalaenopsis plantlets in tissue-culture flasks, urea and  $\text{NH}_4\text{-N}$  are the two preferred forms of N absorbed, with 47% and 41%, respectively, of the total amount N taken up from the cultural medium.

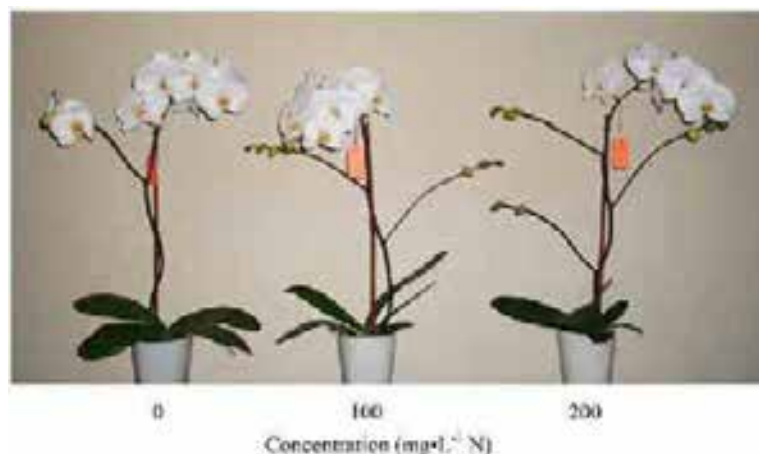


Fig. 3. Effects of increasing nitrogen (N) concentration from 0 to 200  $\text{mg}\cdot\text{L}^{-1}$  during the reproductive stage on lateral branching and total flower count of phalaenopsis orchid. Plants were grown in sphagnum moss and undergone shipping in an ocean container for 3 weeks in complete darkness at between 18 and 20 °C (64.4 and 68.0 °F) before being forced in a commercial greenhouse (Y.T. Wang, unpublished data); 1  $\text{mg}\cdot\text{L}^{-1}$  = 1 ppm.

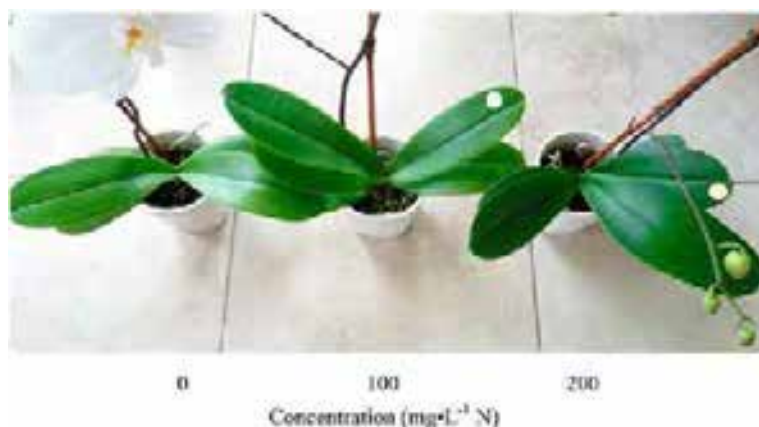


Fig. 4. Effects of increasing nitrogen (N) concentration from 0 to 200  $\text{mg}\cdot\text{L}^{-1}$  during the reproductive period on leaf color of phalaenopsis orchid. Plants were grown in sphagnum moss and undergone shipping in an ocean container for 3 weeks in complete darkness at between 18 and 20 °C (64.4 and 68.0 °F) before being forced in a commercial greenhouse (Y.T. Wang, unpublished data); 1  $\text{mg}\cdot\text{L}^{-1}$  = 1 ppm.

### Forms of N Affect Medium pH

When urea is applied to the growing medium, it is quickly converted to  $\text{NH}_4$  ion ( $\text{NH}_4^+$ ) and then to  $\text{NO}_3$  ion ( $\text{NO}_3^-$ ) by microorganisms, except at low temperatures. When  $\text{NH}_4^+$  is converted to  $\text{NO}_3^-$ , protons [hydrogen ions ( $\text{H}^+$ )] are released in the process, which lowers the pH of the growing medium (more acidic). When  $\text{NH}_4^+$  is absorbed by the roots, protons are released from the roots to balance the electrical charge in the root and this process causes the acidification of the

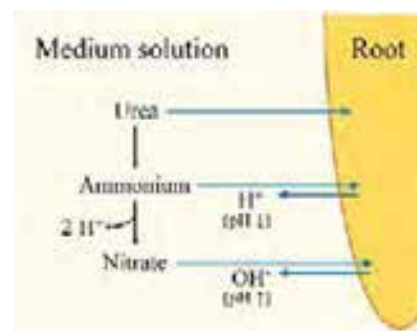


Fig. 5. Effects of various forms of nitrogen on the pH of growing media ( $\text{H}^+$  = hydrogen ion or proton,  $\text{OH}^-$  = hydroxyl ion).

surrounding growing medium (Fig. 5). Therefore,  $\text{NH}_4\text{-N}$  is a double-edged sword to cause the acidification of the growing medium.

When  $\text{NO}_3^-$  is absorbed, roots release hydroxyl ions ( $\text{OH}^-$ ), which neutralize the existing protons in the medium, resulting in increased pH [more basic (Fig. 5)]. Therefore, fertilizers that contain large proportions of N as ammoniacal-N are called acidic fertilizers, whereas those containing high percentages of  $\text{NO}_3\text{-N}$  are called basic fertilizers. Carefully selecting fertilizers can be a tool for managing the root-zone pH at a desirable level or to correct the pH of the growing medium. However, this statement does not hold entirely true in the case of growing the phalaenopsis. A study demonstrated that the phalaenopsis root is the main cause of pH drop in the sphagnum moss growing medium, not fertilizer alone (Yen et al., 2011) (Fig. 6). In addition, the pH of the moss in phalaenopsis containers is usually around 3 and it is difficult to bring the pH up in commercial production, even when a basic fertilizer is used for an extended period of time (Wang, 2010) (Fig. 7), or when the initial pH of the moss was adjusted by liming (Yen, 2010). Despite of the low medium pH around 3, phalaenopsis seems to grow well with no signs of mineral phytotoxicity. In contrast, snapdragon (*Antirrhinum majus*) and marigold (*Tagetes* sp.) plants exhibit severe symptoms of iron and manganese toxicity at a pH just below 6 (Brubaker, 2016). Pothos ivy (*Epi-premnum aureum*) also develops severe speckling on its lower, old leaves at low medium pHs as a result of mineral toxicity (Wang, 1991).

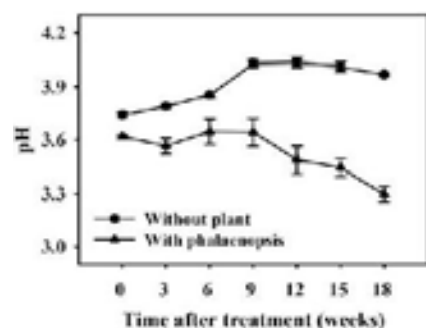


Fig. 6. Effect of phalaenopsis orchid Sogo Yukidian 'V3' on the pH of sphagnum moss medium (Yen et al., 2011).

## Nitrate vs. Ammonium N

Two studies were independently conducted to determine how the ratio of  $\text{NO}_3\text{-N}$  to  $\text{NH}_4\text{-N}$  would affect phalaenopsis. In the U.S. study (Wang, 2008), cloned plants of phalaenopsis Taisuco Kaaladian were grown in a mix consisting of 3 parts medium grade douglas fir (*Pseudotsuga menziesii*) bark and 1 part each of perlite and long-fiber peat (by volume) or in sphagnum moss. In the fertilizer solutions, the total N varied from 100%, 75%, 50%, 25%, to 0% as  $\text{NO}_3\text{-N}$  and

the balance was from  $\text{NH}_4\text{-N}$  ( $\text{NH}_4^+$  or ammonium only, no urea). Plants that were grown in sphagnum moss produced more leaves than those in the bark mix (4.5 vs. 3.4), regardless of the  $\text{NO}_3\text{-N}$  to  $\text{NH}_4\text{-N}$  ratio. The rate of leaf production did not differ across the various ratios of N sources in either medium.

Phalaenopsis plants in both media were smaller when receiving 25% or 0% of N as  $\text{NO}_3\text{-N}$  (Wang, 2008) (Fig. 8). There is a tendency of decreasing top leaf width and whole-plant

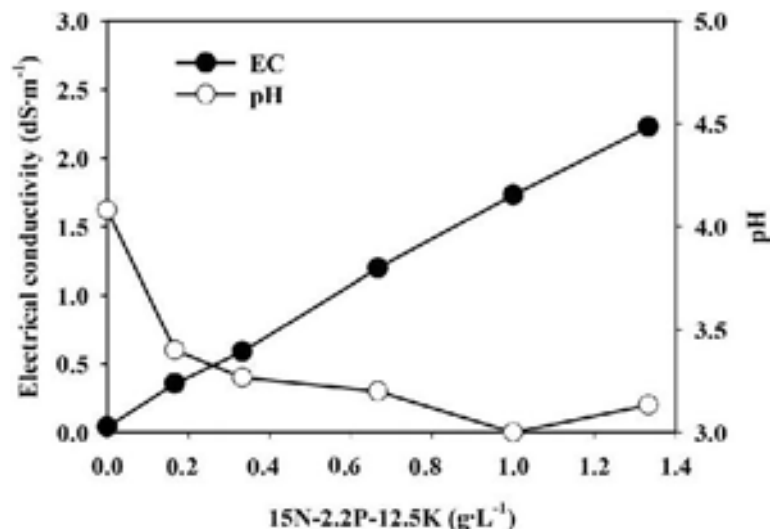


Fig. 7. Effect of nitrogen-phosphorus-potassium (N-P-K) fertilizer [15N-2.2P-12.5K fertilizer, N = 78% nitrate + 8% ammonium + 14% urea (Peters Professional 15-5-15 Cal-Mag; Everris NA, Dublin, OH)] on the electrical conductivity (EC) and the pH of sphagnum moss medium used for growing phalaenopsis orchid for over 18 months (Wang, 2010); 1 g·L⁻¹ = 1000 ppm, 1 dS·m⁻¹ = 1 mmho/cm.

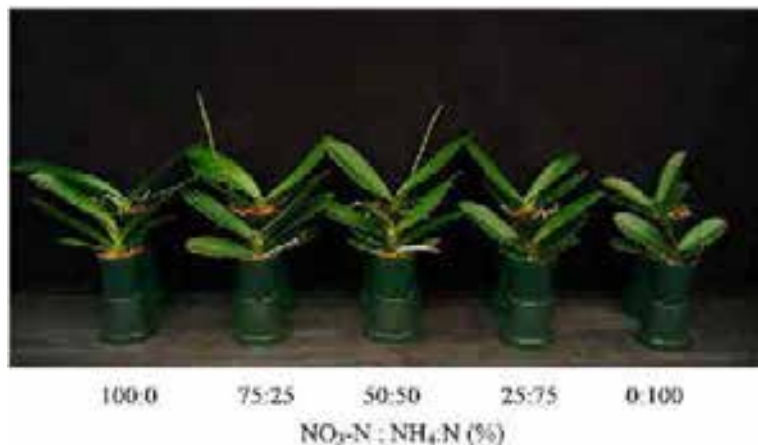


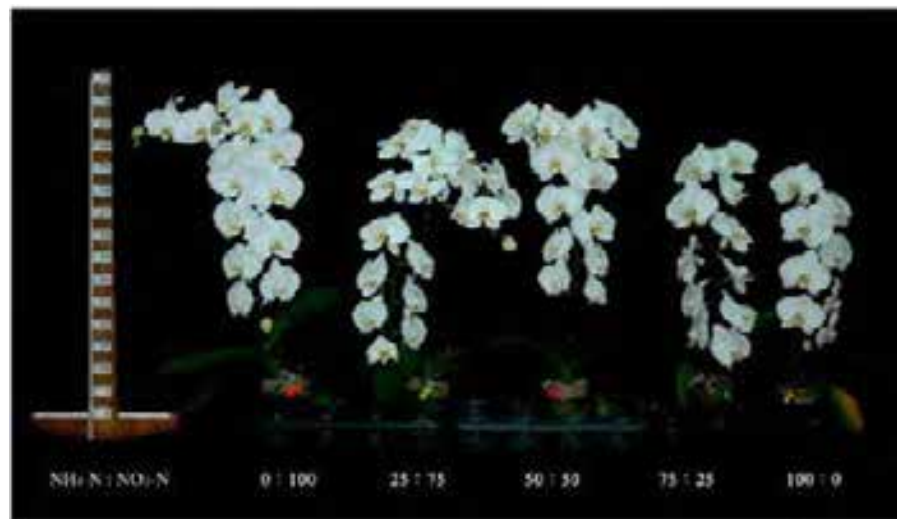
Fig. 8. A clone of phalaenopsis orchid Taisuco Kaaladian receiving 100%, 75%, 50%, 25%, and 0% nitrate nitrogen ( $\text{NO}_3\text{-N}$ ). The balance is ammonium N ( $\text{NH}_4\text{-N}$ ); no urea was used. Plants in the front row were planted in sphagnum moss; back row planted in a medium consisting of 60% medium-size douglas fir bark, 20% perlite, and 20% coarse sphagnum peat (Wang, 2008).



Table 1. Effects of nitrate ( $\text{NO}_3^-$ ) to ammonium ( $\text{NH}_4^+$ ) nitrogen ratio on spiking and flower count on phalaenopsis. Research was conducted independently in two countries and at different times. Plants used in the U.S. study were grown in sphagnum moss or a bark mix. Those used in Taiwan were planted in sphagnum only.

| NO <sub>3</sub> :NH <sub>4</sub> (%) | United States |                       | Taiwan      |               |
|--------------------------------------|---------------|-----------------------|-------------|---------------|
|                                      | Spiking (%)   |                       | Spiking (%) | Flowers (no.) |
|                                      | Sphagnum moss | Bark mix <sup>z</sup> |             |               |
| 100:0                                | 75            | 100                   | 91          | 19            |
| 75:25                                | 83            | 100                   | 95          | 19            |
| 50:50                                | 71            | 100                   | 86          | 16            |
| 25:75                                | 58            | 100                   | 67          | 12            |
| 0:100                                | 8             | 91                    | 10          | 9             |

<sup>z</sup>A mix consisting of 3 parts medium grade douglas fir bark, 1 part perlite, and 1 part long-fiber peat (by volume).



**Fig. 9.** Effect of ammonium nitrogen ( $\text{NH}_4\text{-N}$ ) to nitrate N ( $\text{NO}_3\text{-N}$ ) ratio (% of each) on leaf growth and flower quality in phalaenopsis orchid Sogo Yukidian 'V3' during the second flowering cycle (Y.C.A. Chang and Y.C. Peng, unpublished data).

leaf spread as  $\text{NO}_3\text{-N}$  decreased from 100% to 0%. Applying 100%  $\text{NH}_4\text{-N}$  to the bark medium or 75% and 100%  $\text{NH}_4\text{-N}$  to moss resulted in shorter top leaves than those in other treatments. *Phalaenopsis* plants in the bark mix spiked 10 to 14 d earlier than those planted in moss. Plants receiving 50% or more  $\text{NO}_3\text{-N}$  spiked earlier and had higher percentages of the plants that produced flowers (Wang, 2008) (Fig. 8). Nearly all of the plants in the bark mix produced flowers (91% for those receiving 100%  $\text{NH}_4\text{-N}$ ), whereas only 8% in moss receiving 100%  $\text{NH}_4\text{-N}$  spiked (Table 1). As the ratio between  $\text{NO}_3\text{-N}$  and  $\text{NH}_4\text{-N}$  increased, flowers became increasingly larger. In the bark mix, flowers on plants receiving 75%  $\text{NO}_3\text{-N}$  were 36% larger in area than those on plants receiving 100%  $\text{NH}_4\text{-N}$  (Wang, 2008).

A more detailed study (Peng et al., 2010) in Taiwan used phalaenopsis Sogo Yukidian 'V3' and was carried through two flowering cycles (20 months). Two experiments were conducted using young plants (20 cm leaf span) or mature plants (32 cm leaf span). The time to spiking and to flower opening of the mature plants was unaffected by  $\text{NH}_4\text{-N}$  to  $\text{NO}_3\text{-N}$  ratio in both flowering cycles. However, the spiking percentage, the flower count, and the diameter and length of the stalk in the second flowering cycle increased when plants received 50% or more  $\text{NO}_3\text{-N}$ . Only 10% of the phalaenopsis plants receiving 100%  $\text{NH}_4\text{-N}$  spiked in the second season (Table 1). Plant fresh weight, leaf number, and leaf area of both young and mature plants decreased with decreasing  $\text{NO}_3\text{-N}$  to  $\text{NH}_4\text{-N}$  ratio (Peng et al., 2010).

(Fig. 9). When supplied with 50% or more  $\text{NH}_4^+$ , the absorption of cations by phalaenopsis roots declined; and, hence, the concentration of calcium and magnesium in plants decreased, while symptoms of  $\text{NH}_4^+$  toxicity occurred, such as growth retardation, chlorotic leaves, and necrotic roots.

## Conclusions

Phalaenopsis plants grow and flower well when given 200–280 mg·L<sup>-1</sup> N during both the vegetative and reproductive periods. Phalaenopsis does not grow and flower well with 100% NH<sub>4</sub>-N, particularly when planted in sphagnum moss, and must be fertilized with no less than 50% and preferably 75% NO<sub>3</sub>-N in the total fertilizer N to achieve the highest percentage of spiking, high degree of lateral branching on the flower stalk, as well as increased flower count, flower size, leaf number, and plant fresh weight. High N must be applied during the reproductive period for best flowering.

For the commonly used 20N-8.8P-16.6K fertilizers, the  $\text{NO}_3\text{-N}$  varies from 11% to 28% of its total N (depending on the brand), whereas the 20N-4.4P-16.6K (e.g., Peters Professional 20-10-20) has 60%, the 15N-2.2P-12.5K (e.g., Peters Excel 15-5-15 Cal-Mag) has 79%, and the 15N-2.2P-20.8K (e.g., Peters Professional 15-5-25) has 71% of their N as  $\text{NO}_3\text{-N}$ . The 30N-4.4P-8.3K (e.g., Peters Professional 30-10-10) is not recommended for growing phalaenopsis in sphagnum moss due to its N coming mainly from urea (83%) and  $\text{NH}_4\text{-N}$  (7%), as well as its low K. A complete soluble fertilizer with at least 50% of its N in  $\text{NO}_3\text{-N}$  form is highly recommended, provided its K level is adequate.

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