AGRONOMY SCIENCE AND BIOTECHNOLOGY

REVIEW ARTICLE

Mineral nutrition in orchids

Rodrigo Thibes Hoshino[1,*], Helio de Souza Junior[2,*], Débora Perdigão Tejo[1], Sergio Pedro Junior[1], Alexandra Scherer[3] and Ricardo Tadeu de Faria[1]

[1]State University of Londrina, Agronomy Department, Rod. Celso Garcia Cid, PR-445, Km 380 - Campus Universitário, Londrina, PR, Brazil, CEP 86057-970. [2]Federal University of Viçosa, Department of Genetics and Improvement, Avenida Peter Henry Rolfs, s/n, Viçosa, MG, Brazil, CEP 36570-000. [3]Universidade Norte do Paraná (UNOPAR), Setor de Agronomia, Avenida Paris, 675, Jardim Piza, Londrina, PR, Brazil, CEP 86041-140. *Co-corresponding authors, E-mails: rodrigohoshino@gmail.com; helioszjr@gmail.com

Citation: Hoshino, R. T., Souza-Junior, H., Tejo, D. P., Pedro Junior, S., Sherer, A., & Faria, R. T. (2023). Mineral nutrition in orchids. *Agronomy Science and Biotechnology*, 9, 1-11 https://doi.org/10.33158/ASB.r178.v9.2023

Received: December 2nd, 2022.
Accepted: January 11, 2023.
Published: February 7, 2023.

English by: Sergio Pedro Junior

ABSTRACT

The Orchidaceae family stands out when it comes to the commercialization of pot flowers, this is due to their flowers being widely attractive and have variability of colors, size and shapes according to the species; this results in plants with high relevance to the economy in the floriculture sector. The goal of this study was to elucidate questions about the effect of micronutrients on initial growth, the influence of electrical conductivity and frequency of fertilizer application, and the efficiency of organic fertilization with castor bean cake, on the growth and nutrition of *Brassia verrucosa* Lindley orchid. Studies with mineral fertilization involving nitrogen (N), phosphorus (P) and potassium (K) *in Cattleya* and *Phalaenopsis* seedlings allowed to obserevar that the N increment increased the number of flowers *in Cattleya*, while P and K did not affect this variable. The salinity of irrigation water also has an effect on growth and flowering. The electrical conductivity, the sources of fertilizers, their interaction with the substrate, the balance between the nutrients, the quantities and frequencies to be used, in addition to the different phenological requirements and characteristics intrinsic to the species, are important aspects to be considered in fertirigation.

Keywords: Flower of vase, ornamental plant, fertility, macronutrients, organic fertilizer, perennial plants.

INTRODUCTION

The production and commercialization of flowers is a segment of floriculture that generates income and development in the regions where it develops, because it enables small production units, due to the high added value of its products. The segment generates jobs in the field, where it has high labor demand in the productive sectors, and also in cities, along the production chain, transportation, retail and production of insums, being an alternative in the diversification of rural properties (Bertoncelli et al., 2018).

It is estimated that the market for flowers and ornamental plants has around 3,000 cultivars available. In addition, sales in supermarkets of these products have become popular among consumers, keeping the domestic market warm, despite the reduction in exports (Kiss, 2013). In 2013, the results of Brazilian exports of flowers and ornamental plants decreased 8.43% compared to the previous year, closing the year at an overall value of US$ 23.81 million, reflecting the economic and financial context of the main world importing markets, which reduced demand for floriculture products (Junqueira & Peetz, 2017).

In Brazil, 98% of the production of floriculture is destined to the domestic market for domestic consumption, which guarantees the support of the sector's floriculture businesses. In the period 2008-2011, there was an increase of 8% to 10% in the supply of goods and increases between 12% and 15% in revenues, with a global financial movement of R$ 4.8 billion in 2012, with per capita consumption in the order of R$ 25.00/year. Although these values fall far short in international terms, these indices indicate a heated and expanding sector (Junqueira & Peetz, 2017). Others works in basic and applied horticulture area have been done in Brazil (Timm et al., 2020; Giard, Lucotte, Moingt & Gaspar 2022; Leão et al., 2019; Rosado et al., 2021; Takane et al., 2020).

The Brazilian flower shop has about 8,000 producers with average-sized properties of 2.5 hectares. In these production units 81.3% of the labor is contracted, which generates around 8 direct jobs per hectare, resulting for the country more than 102,000 jobs, related only to production (Brazilian Institute of Floriculture [IBRAFLOR], 2013a). In Paraná there are 249 producers, which represents the equivalent of 11% of the number of producers in São Paulo, the largest producer, and only 3.1% of the total producers in the country, although it has the fifth largest market value with R$ 294 million, of just over R$ 5 billion total, with more than 1240 retail points in the state. (Brazilian Institute of Floriculture [IBRAFLOR], 2013b)

The production and sale of orchids as potted flowers is an important segment of the sector, with Brazil being an importer of seedlings. Orchid seedlings imported by Brazil from the Netherlands, Thailand and Japan in 2012 totaled US$ 8.87 million, representing 25.61% of the total imported by the country, up 31.47% over the same period a year earlier. Orchids are considered materials for the final commercial production of plants for consumption, especially in the ascending markets *of Phalaenopsis*, *Cymbidium* and *Vandas*, among others (Junqueira & Peetz, 2017).

Among the flowers marketed in pot, the orchidaceae family receives prominence for its high ornamental potential, which guarantees them a greater economic value. However, despite orchid is considered a rustic plant, the process of domestication and improvement of the crop has increased the demand for appropriate production techniques and management, which should consider both the specificities between the genera and the different stages of growth and development of the crop.

Due to the slow growth of plants in this family, which results in a long production cycle, fertilization becomes a fundamental management to be considered in commercial production, which in addition to ensuring quality and standardization, also reduces the time required for seedlings and flowers to reach commercial standards. However, its realization is still empirical, with few scientific papers related to the subject, and the recommendations are in charge of the experience of producers and orchidophiles.

In this context, the use of mineral fertilization can be highlighted, which is usually applied via fertigation, which has advantages such as: having its formulation, concentration and frequency, easily altered according to the requirements of cultivation. Another possibility would be the use of organic products from the use of waste that due to its gradual release of nutrients could be an ecological and easy alternative, both for producers and consumers of potted flowers.

The beneficial effect of the use of ultra soluble Formulas based on NPK is known, however the formulas mostly provide nitrogen, phosphorus and potassium, neglecting the effects of calcium, magnesium, sulfur and micronutrients. Furthermore, studies indicate that the efficiency of fertigation varies according to the different formulations, nutrient sources, salinity of the solutions, as well as the interaction of the same with the type of substrate used, and that a standardized recommendation should be tied to a specific type of substrate, species and stage of development of the plant under study.

The use of organic fertilizers uses the same questions, regarding the quantities, frequencies and methods of application, however, the results are subject to greater variations, due to the different nutritional compositions that vary with the type of residue and the manufacturing method. Although the empirical efficiency of some organic fertilizers is recognized, there is still no information to scientifically describe its effects on plant growth and nutrition.

Thus, the aim of this study was to elucidate questions about the effect of micronutrients on initial growth, the influence of electrical conductivity and frequency of fertilizer application, and the efficiency of organic fertilization with castor bean cake on the growth and nutrition of *Brassia verrucosa* Lindley orchid.

THE ORCHIDACEAE FAMILY

Orchids, as the plants of this family are called, are mostly epiphytes (73% of the total), have aerial roots and live on trees or on rocks in tropical regions, but can also be terrestrial, usually found in temperate regions. The orchidaceae family is the most numerous among angiosperms, being represented by more than 850 genera and about 35,000 species (Miller & Warren, 1996).

This number corresponds to 8% of all species of plants with seeds (Govaërts, 2006) and the index tends to increase, since only in 2008 the International Plant Names Index (IPNI), one of the most important taxonomic databases, recorded about 400 new orchid species. These plants are found in virtually every region of the planet, from the vicinity of the Arctic pole to the Antarctic pole. Brazil has one of the largest orchid diversities in the American continent and the world, with about 2,420 species distributed in 235 genera, of which 1620 are endemic (Barros, Vinhos, Rodrigues, Barberena & Fraga, 2010).

In general, orchids share unique characteristics. They are perennial, terrhous, rugorous or epiphyte, rhizomatous or stem-led herbaceous plants, often with pseudobulbs. They have alternate leaves that are rarely opposed or verticilated, simple, whole, elliptical, oval or linear, more or less juicy or coriaceous. They may present isolated flowers or inflorescences in panicles, racemes or ears. The flowers are hermaphrodite, rarely unisexual and zygomorphic.

The orchid flower is formed by three sepals and three highly developed petals. The sepals act as a protective organ of the floral bud. After the flowers bloom, the sepals become colored like the petals that intersperse. One of the petals differs from the other ones in shape and color and is called labelo, this structure has the function of attracting pollinating insects that guarantee the reproduction of the species (Watanabe, 2002).

The genus *Brassia* belongs to the tribe Oncidiinae, is native to Mexico, Central America and northern South America. The species of the brassia genero and its hybrids have as most remarkable characteristic the presence of long sepals, from which comes the common name of spider orchid. The genus is epiphytic of CAM metabolism, and occurs in humid forests from the altitude of the sea to 1500 m. *The species Brassia verrucosa* presents oblong pseudobulbs, with two leaves at the apex, lateral inflorescence with 6 to 10 flowers, the flowers have light green petals with coffee stains on the base, the labelis whitened with red spots and green verrugosities, characteristic that distinguishes it from other species (Silvera, Santiago, Cushman, Winter, & Lu, 2009; Watanabe, 2002).

GENERAL ASPECTS OF MINERAL FERTILIZATION IN ORCHIDS

Nutrients play an essential and specific function in plant metabolism, performing structural function (part of the structure of any organic compound vital to the plant), enzyme constituent (part of a specific structure) and activating enzymatic reactions, not being part of the structure, but being able to both activate and inhibit enzymatic systems, affecting the speed of many reactions in plant metabolism (Marschner, 2005).

According to the criteria of essentiality, mineral nutrients are equally important for plant production, however, there is a classification, based on the proportion in which they are required and accumulate in the dry matter of plants, and can be classified as macronutrients (N, P, K, Ca, Mg and S) and micronutrients (B, Cl, Cu, Fe, Mn, Mo, Ni and Zn) (Marschner, 2005; Malavolta, 2006).

In nature, there is a gradual and continuous flow of nutrients, and they are present in the environment from: animal droppings, plant and animal remains, rainwater, in addition to the microbial contribution via biological fixation of N_2. In a protected environment, as in commercial crops, most natural sources of nutrients are compromised, where the high density of plants and the scarcity of nutrients make fertilization indispensable for the growth and development of orchids (Naik, Barman, & Medhi, 2009).

Studies related to the nutrition and fertilization of orchids are scarce and restricted to a few species, which ends up generating limited scientific information. Most of the fertilizers on the market were not developed considering the specificity of orchids, since their fertilization has been done empirically given the lack of appropriate information. The recommendations are in charge of the experience of orchid growers and fertilizer manufacturers.

It is known that orchid species have different nutritional needs, varying with the stages of development. However, most producers use conventional fertilizers, developed to meet food production crops such as grains, fibers, proteins, etc. In the case of orchids it is still worth the general rule that one should commend with higher amounts of nitrogen and potassium (Takane, Yanagisawa, & Pivetta, 2010).

MINERAL NUTRITION IN ORCHIDS

Sheehan, Fisher and Clara (1960) studying the influence of nitrogen (N), phosphorus (P) and potassium (K) *in Cattleya* and *Phalaenopsis seedlings* found that the n increment increased the number of flowers *in Cattleya*, while P and K did not affect this variable. For *Phalaenopsis seedlings*, the increase in N doses resulted in an increase in leaf area, with no effect of the other two nutrients. The same author verified interactions between N levels and substrate types. N responses were more evident in white pine bark (softer wood) than in red pine and cedar barks.

Poole and Seeley (1977) studying the nutrition of *the genera Cymbidium, Phalaenopsis* and *Cattleya*, recommend that for daily fertigations nutrient solutions should contain 100 mg $^{L-1}$ N, 50-100 mg $^{L-1}$ K and 25 mg $^{L-1}$ Mg, for the first two genera, however *for Cattleya*, 50 mg $^{L-1}$ of N, K and Mg, are indicated. The authors report that *Cymbidium plants that* received 50 mg $^{L-1}$ of N presented symptoms of deficiency for this nutrient. K has little effect on orchid growth. However, for Mg the increase from 50 mg $^{L-1}$ to 100 mg $^{L-1}$ reduced the growth of all genera.

For *Vanilla* grown on substrate, nitrogen deficiency is visible in just three weeks, while for phosphorus and potassium deficiencies appear only after three months. *Cattleya* seedlings when grown in sand with the addition of iron-free nutrient solution only showed symptoms of deficiency after seven months of growth. It has also been observed *that Dendrobium phalaenopsis* is severely affected by deficiency N, P, K, Ca and Mg in nutrient solution, where leaves fall before symptoms of deficiency appear (Poole & Sheehan, 1982). The same authors studying, the requirements of *Cattleya, Phalaenopsis and Cymbidium* report that the best N:P:K relationships for these genera are: 10:04:08 *for Cattleya and Cymbidium*; 10:08:15 for the genus *Phalaenopsis*.

According to Higaki and Imamura (1987), the height of *Vanda plants* increases linearly as a function of N, even in the absence of P, this same trend occurs for flower production, although the application of both P and K also benefit the total production of flowers. Moreover, according to the same authors, the application of K is beneficial for the growth of the stem diameter.

Studies carried out by Wang (1994), with the use of different concentrations of the formula NPK 20-20-20 (Peters®), *in Phalaenopsis*, indicate that for an early flowering, a high number of flowers and a better growth of plants, soluble fertilizer should be used at the concentration of 1 g $^{L-1}$ in each irrigation. Wang (1994), evaluating constant fertilization (in each irrigation) and intermittent fertilization (interspersed with 2 watering) *in Dendrobium,* observed that constant fertilization had little effect on the height and number of leaves, although it anticipated the emergency and development of the second pseudobulb, increasing its diameter, which subsequently resulted in an increase in the number of flowers.

Working with six NPK formulations (10-30-20, 15-20-30, 15-20-25, 20-5-19, 20-10-20 and 20-20-20) *in Phalaenopsis*, applied at concentrations of 100 or 200 mg $^{L-1}$ of N in fertigations, Wang (1996) found no statistical difference between them. This author considered that the concentration greater than 200 mg $^{L-1}$ of N (corresponding to 1.0 g $^{L-1}$ of 20-20-20) should be used in the initial phase of plant growth and, when adults, a lower concentration should be used to avoid the exaggerated growth of leaves, which occupy a larger area of the benches, and imply a higher cost of production.

For *Cymbidium sinense*, the NPK ratio in tissues is 6:1:9. Fertilization between 1 and 10 mmol of N increases leaf growth and the number of flowers, but high N concentrations reduce these variables. The same authors report that the preferential form of N absorbed *by Cymbidium sinense* is in the NO 3-N form, however the combination between NH 4-N and NO 3-N, when supplied at the appropriate concentrations, is more indicated for leaf and root growth (PAN). YE, HEW; According to the same authors, the application of 5 mmol of KCl is recommended, which results in the increase of soluble sugars, starch, cellulose and proteins. For P, it is the shoots that have the highest demand, followed by pseudobulb and leaves, in flowering the accumulation occurs in floral buds, this nutrient can be absorbed by roots of one or two years, being more intense in the younger roots.

The salinity of irrigation water also has an effect on growth and flowering in *Phalaenopsis*. According to Wang (1998), the most negative effect of increasing salinity is root injury. With increasing salinity more roots died, and became hollow. However, the effect of salinity varies according to the substrate used, and leaf contents of nutrients are differently affected. In a mixture of pine bark and moss, the increase in salinity led to a reduction of the leaf contents of P, Fe and Cu and increase of K, Ca, Mg and Zn. In pine bark, only the levels of Ca were increased with the increase of salinity, due to the high levels of this nutrient in the irrigation water.

Swampa (2000) found that the use of NPK in formulation 30-10-10 at the concentration of 2 g $^{L-1}$ + 200 mg $^{L-1}$ BA (cytokinin) applied twice a week promoted, higher height, number of shoots, number of leaves, leaf area, number of roots, and biomass, during the growth period, *in Dendrobium* 'sonia'. However, the use of NPK 10-20-10 (2 g $^{L-1}$) + BA 100 mg $^{L-1}$ results in a greater number of tassels with a higher number of florets per tassum.

A continuous but adequate application of N seems to be more important than a reduction in the use of N with increased P to optimize flowering in *Phalaenopsis*. According to Wang (2000), the treatments that received high doses of P had no effect on the date of emergence of the flowers, anthesis or flower size, and the plants treated with the highest doses of P presented less flowers in relation to the control, which received standard fertilization (NPK 20-20-20). The same authors also verified that longevity was reduced by 12 days when the end of fertilization was anticipated. The suspension of fertilization for prolonged periods resulted in redderation of the leaves and loss of the lower leaves, as well as limited the emission of new leaves.

Despite the importance of fertilization in orchids, in adult plants the development of deficiency symptoms is slow, and this characteristic is attributed to the ability to mobilize nutrients from old leaves and other storage organs such as pseudobulbs to meet the new growth demands. This phenomenon of efficiency in nutrient recycling can be observed in most tropical orchids, being attributed to the epiphyte origin of these orchids, a condition in which the supply of nutrients is scarce (Khee, Ng, & Sin, 2000).

In the study conducted by Wang and Konow (2002) the interaction between different soluble formulations (NPK: 10-30-20, 20-05-19, 20-20-20, liquid fertilizer: 02-01-02, standardized to provide 200 mg $^{L-1}$ of N) and substrate composition was verified. In pine bark the formula NPK 20-05-19, resulted in higher quality plants, however in the mixture of pine and moss (7:3, v:v), the formulas NPK 20-05-19 and 20-20-20, resulted in increments of 40-50% in shoot weight, and 40% in the leaf area, than other fertilizers, the authors attribute the positive results to urea present in these formulations. According to the authors, substrates and fertilizers had little effect on nutrient concentration, except phosphorus, which was 100% higher in pine bark.

In a trial with *Dendrobium nobile* fertigated plants with different concentrations of the nutrient solution of Sarruge, Bernardi et al. (2004) verified that the treatment with 75% of the concentration of the solution, applied weekly, provided good vegetative development of the plants, being indicated for the optimization of production on a commercial scale. However the increase of up to 150% of the concentration did not impair vegetative development, where plant height and pseudobulb diameter had a linear increase as a function of nutrient solution concentration.

In this study with K doses on different substrates, Wang (2007) found that below 50 mg $^{L-1}$ *Phalaenopsis plants showed* symptoms of deficiencie after flowering, such as leaf yellowing, irregular purple spots and necrotics. Symptoms intensified during the emission of the floral stem, however the use of 100 mg $^{L-1}$ of K eliminated any symptoms of deficiency. As for the substrate, all plants in pine bark and perlite bloomed, however no plant grown in sphagen bloomed, when they did not receive K. In both substrates the increase in K concentration increased the number of flowers, length and diameter of the stems. The same author recommends that 300 mg $^{L-1}$ of K, combined with 200 mg $^{L-1}$ of N and P, regardless of the substrate used, are indicated.

In *Dendrobium* Bichsel, Starman and Wang (2008) evaluating the suspension of fertilization in flowering observed that the length of pseudobulbs and the number of flowers increase when N is applied. However at doses of 200 and 400 mg $^{L-1}$, delay in fertilization suspension before flowering causes anthesis retardation, however continuous application of 100 mg $^{L-1}$ of N does not affect any flowering characteristic. P doses resulted in higher plants with an equal or greater number of nodes when compared to the control. For the K small doses result in increased height, having beneficial effect on the number of flowers and flowers per knot. The authors recommend 100 mg $^{L-1}$ of N, 25 mg $^{L-1}$ of P and 100 mg $^{L-1}$ of K, for the vegetative and reproductive stage in *Dendrobium*.

However, for Yen and Starman (2008), the delay in the suspension of fertilization before flowering improves growth and flowering. Suspending fertilization late results in taller plants with more nodes and leaves remaining, as well as a greater number of flowers by us and less abortion of them. In *Dendrobium nobile* the results suggest that the development of flowers is more benefited with nutrients that have been accumulated in mature pseudobulbs. However, early suspension causes a faster floral differentiation.

In addition to the time of application, the form in which the element is available is important, for n according to Trépanier, Lamy and Dansereau (2009), urea and ammonium are the n forms preferably absorbed *in Phalaenopsis*. The nutritional requirements of orchids are similar to those of other plants, except that they take longer to present symptoms of deficiency. The effectiveness of the application of a nutrient is dependent on the presence of others, and evidence indicates that the combination between organic and mineral fertilization favor the growth of orchids (Naik et al., 2009).

Rodrigues, Novais, Alvarez, Dias and Villani (2010b) studying limestone doses *in Epidendrum*, report that the doses of 4 and 5 g dm-3 resulted in deficient plants of N, S and B and the increase in limestone doses linearly reduced Zn, but in the treatment that did not receive limestone, deficient plants of Ca. To avoid problems of unbalanced fertilization Rodrigues, Novais, Alvarez, Dias and Villani (2010a) were observed. Suggest that for better production of dry mass of plants, the combination of mineral and organic fertilization is used, as this provides superior results to the use of fertilizers alone.

The levels of nutrients to be offered may vary according to the production objective. According to Zong-Min, Ning, Shu-Yun and Hong (2012), N enrichment results in increased leaf area and leaf length during vegetative state, however, it has little effect on the size of flowers *in Paphiopedilum*. In seed production, the use of intermediate levels of N provides an increase in capsule weight and seed germination rate, in addition to improving seedling development. However, for clonal reproduction, a low concentration induces the production of shoots with more leaves and greater leaf area.

For flowering, the application of 200 mg $^{L-1}$ of K increased the emission of flowers in *Cymbidium* when the plants were submitted to nocturnal interruption with low light intensity. With the application of N, the diameter of the flowers as well as the length and diameter of the inflorescences increased, and it is recommended to maintain this fertilization after the emergence of the inflorescences (An, Kim, & Kim, 2012).

The electrical conductivity, the sources of fertilizers, their interaction with the substrate, the balance between the nutrients, the quantities and frequencies to be used, in addition to the different phenological requirements and characteristics intrinsic to the species, are important aspects to be considered in fertirigation.

Naik et al. (2013) observed that fertigation with NPK 20-20-20 maintaining conductivity at 1.5 mS $^{cm-1}$, results in improvements in vegetative characteristics such as plant mass, leaf length, number, length and circumference of *Cymbidium pseudobulbs*. However, fertigation with NPK 12-30-10 was superior for flowering, and conductivity of 1.0 mS $^{cm-1}$ provided greater stem length and number of flowers per stem, conductivity of 2 mS $^{cm-1}$, inhibited flowering.

In *Laelia*, the highest averages for leaf dry mass were obtained when the plants were irrigated in solutions with electrical conductivity of 2.11 mS $^{cm-1}$ (Jiménez-Peña et al., 2013), however these results are conditioned to the type of substrate used. According to the same authors, the highest values of dry mass of leaves were observed in substrates containing high proportions of coal and moss, which were independent of the conductivity used, but the higher dry mass of pseudobulbs and roots were observed in the conductivity of 1.42 mS $^{cm-1}$, mainly in mixtures with coal or 100% of moss. The same authors report that increased conductivity results in greater absorption of N and K, and reduction in P, Ca and Mg levels.

Another important aspect in the fertilization of orchids is to provide the nutrients in the appropriate amounts according to the different demands of the same by the plant. Susilo, Peng, Lee, Chen and Chang (2013), studying the partitioning of N, observed in *Phalaenopsis* that during vegetative growth, newly formed tissues such as new leaves are large drains of this element and tend to decrease with increasing leaf age, which begin to exercise storage function as a source of nutrient for the reproductive stage, where stems and flowers become the largest drains.

FINAL COMMENTS

In view of the above in this study it is permissible to understand that mineral nutrition is extremely important in the production of plants of species belonging to the orchidaceae family. In addition, it is essential to analyze the ways in which such nutrients will be provided with how the species is working and at what stage of its phenological cycle it is, since the effects may be positive or harmful according to the different combinations between such variables.

REFERENCES

An, H. R., Kim, Y. J., & Kim, K. S. (2012). Flower Initiation and Development in Cymbidium by Night Interruption with Potassium and Nitrogen. *Horticulture, Environment, and Biotechnology*, 53(3), 204–211. https://doi.org/10.1007/s13580-012-0023-5

Barros, F., Vinhos, F., Rodrigues, V. T., Barberena, F. F. V. A., Fraga, C. N. (2010). Orchidaceae. in R. C. Forzza, et al (Org.). *Catálogo de plantas e Fungos do Brasil.* Rio de Janeiro, RJ: Jardim Botânico do Rio de Janeiro. v.2, p.1344- 1426.

Bernardi, A. C., Faria, R. T., Fiuza, J., Portela, R., Unemoto, L. K., & Assis, A. M. (2004). fertirrigadas com diferentes concentrações da solução nutritiva de sarruge vegetative development of Dendrobium nobile Lindl . plants fertirrigated with diferents concentrations of sarruge nutritive solution. *Semina: Agrarian Sciences*, 25(1), 13–20.

Bertoncelli, D. J., Alves, G. A. C., Freiria, G. H., Furlan, F. F., Ibanhes Neto, H. F., & Faria, R. T. (2018). Iron concentrations in the in vitro cultivation of native Brazilian orchid Schomburgkia crispa. *Agronomy Science and Biotechnology*, 4(2), 93-100. https://doi.org/10.33158/asb.2018v4i2p93

Bichsel, R. G., Starman, T. W., & Wang, Y. (2008). Nitrogen , Phosphorus , and Potassium Requirements for Optimizing Growth and Flowering of the Nobile Dendrobium as a Potted Orchid. *HortScience*, 43(2), 328–332.

Giard, F., Lucotte, M., Moingt, M., & Gaspar, A. (2022). Glyphosate and aminomethyphosphonic (AMPA) contents in Brazilian field crops soils. *Agronomy Science and Biotechnology*, 8, 1–18. https://doi.org/10.33158/asb.r155.v8.2022

Govaërts, R. (2006). *World checklist of selected plant families. Orchidaceae.* Kew: Board of Trustees of the *Royal Botanic Gardens*. https://powo.science.kew.org/

Higaki, T., & Imamura, J. S. (1987). NPK requirements of vanda miss Joaquim orchid plants. *Resarch Extension Series*, 87, 1-5.

IBRAFLOR - Brazilian Institute of Floriculture. (2013a). *General industry data. Press Release*. Campinas, SP: IBRAFLOR. http://www.ibraflor.com.br

IBRAFLOR - Brazilian Institute of Floriculture. (2013b). *Internal Market Industry numbers*. Campinas, SP:IBRAFLOR. http://www.ibraflor.com.br

Junqueira, A. H., & Peetz, M. S. (2017). Brazilian consumption of flowers and ornamental plants: habits, practices and trends. *Ornamental Horticulture*, 1, 178–184. https://doi.org/http://dx.doi.org/10.14295/oh.v23i2.1070

Kiss, J. (2013). Sales of flowers and plants can go from R$ 5 billion. V*alor Econômico Newspaper*. http://www.hortica.com.br

Khee, C., Ng, Y., & Sin, C. (2000). Orchid pseudobulbs ± ` false ’ bulbs with a genuine importance in orchid growth and survival ! *Scientia Horticulturae*, *83*(3), 165–172.

Leão, P., Neves, L., Colombo, R., Shahab, M., Oliveira, J., Luz, F., & Roberto, S. (2019). Temperature and storage periods on the maintenance of chemical composition of medicinal plants. *Agronomy Science and Biotechnology*, 5(1), 40-51. https://doi.org/10.33158/asb.2019v5i1p40

Malavolta, E. (2006). *Manual de nutrição mineral de plantas.* São Paulo, SP: *Agronômica Ceres*.

Marschner, H. (2005). Mineral nutrition of higher plants. (2nd ed.). London: *Academic*.

Miller, D., & Warren, R. (1996). *Orchids from the top of the mountain range: from the atlantic rain forest of southeastern Brazil.* Rio de Janeiro, Brazil: Salamandra Consultoria Editorial.

Naik, S. K., Barman, D., & Medhi, R. P. (2013). Evaluation of electrical conductivity of the fertiliser solution on growth and flowering of a Cymbidium hybrid. *South African Journal of Plant and Soil*, 30(1), 33–39. https://doi.org/10.1080/02571862.2013.771753

Poole, H. A., & Seeley, J. G. (1978). Nitrogen , Potassium and Magnesium Nutrition of Three Orchid Genera. *American Society for Horticultural Science*, 103(4), 485–488.

Rodrigues, D. T., Novais, R. F., Alvarez, V. H., Dias, J. M. M., & Villani, E. M. A. (2010a). Orchid growth and nutrition in response to mineral and organic fertilizers. *Revista Brasileira de Ciências Do Solo*, 34(5), 1609–1616.

Rodrigues, D. T., Novais, R. F., Alvarez, V. H., Dias, J. M. M., & Villani, E. M. A. (2010b). Response of Epidendrum Ibaguense (Orchidaceae) to the application of lime rates to the pot. *Revista Brasileira de Ciência Do Solo*, 34(1), 793–800.

Rosado, R. D. S., Oliveira, A. M. C., Santos, I. G., Carneiro, P. C. S., Cruz, C. D., & Cecon, P. R. (2021). Parental selection based on molecular information under a population genetics approach. *Agronomy Science and Biotechnology*, 7, 1–9. https://doi.org/10.33158/asb.r131.v7.2021

Sheehan, T. J., Fisher, A., & Clara, X. P. (1960). Effects of nutrition and potting media on growth and flowering of certain epiphytic orchids. *Horticultural Science*, 30, 352–354.

Silvera, K., Santiago, L. S., Cushman, J. C., Winter, K., & Lu, C. A. M. (2009). Crassulacean Acid Metabolism and Epiphytism Linked to Adaptive Radiations in the Orchidaceae 1 [OA]. *Plant Physiology*, 149, 1838–1847. https://doi.org/10.1104/pp.108.132555

Susilo, H., Peng, Y., Lee, S., Chen, Y., & Chang, Y. A. (2013). The Uptake and Partitioning of Nitrogen in Phalaenopsis Sogo Yukidian ' V3 ' as Shown by 15 N as a Tracer. *Journal of the American Society for Horticultural Science*, 138(3), 229–237.

Takane, R., Silva, F. C., Pereira, S. J., Takemura, M. C., Angélica, T., & Faria, T. R. (2020). Doses of bokashi in the growth of two basil cultivars. *Agronomy Science and Biotechnology*, 6, 1–9. https://doi.org/10.33158/asb.r113.v6.2020

Timm, C. R. F., Schuch, M. W., Pinto Tomaz, Z. F., Casarin, J. V., Ramm, A., & Raasch, C. G. (2021). Rooting dynamics of Prunus minicuttings. *Agronomy Science and Biotechnology*, 6, 1–7. https://doi.org/10.33158/asb.r115.v6.2020

Trépanier, M., Lamy, M., & Dansereau, B. (2009). Phalaenopsis can absorb urea directly through their roots. *Plant and Soil*, 319, 95–100. https://doi.org/10.1007/s11104-008-9852-5

Wang, Y. (1994). Medium and fertilizer affect the performance of Phalaenopsis orchids during two flowering cycles. *Scientia Horticulturae*, 29, 269–271.

Wang, Y. (1996). Effects of six fertilizers on vegetative growth and flowering of phalaenopsis orchids. *Scientia Horticulturae*, 65(96), 191–197.

Wang, Y. T. (1998). Impact of salinity and media on growth and flowering of a hybrid *Phalaenopsis* orchid. *Scientia Horticulturae*, 33(2), 247-250.

Wang, Y. (2000). Impact of a High Phosphorus Fertilizer and Timing of Termination of Fertilization on Flowering of a Hybrid Moth Orchid. *Scientia Horticulturae*, 35(1), 60–62.

Wang, Y. (2007). Potassium Nutrition Affects Phalaenopsis Growth and Flowering. *Scientia Horticulturae*, 42(7), 1563–1567.

Wang, Y., & Konow, E. A. (2002). Fertilizer Source and Medium Composition Affect Vegetative Growth and Mineral Nutrition of a Hybrid Moth Orchid. *Scientia Horticulturae*, 127(3), 442–447.

Watanabe, D. (2002). *Orchids: Manual of Cultivation.* São Paulo, SP, Brazil: Orquidophile Association of São Paulo.

Yen, C. Y. T., & Starman, T. W. et al. (2008). *Timing of Nutrient Termination and Reapplication for Growth , Flower Initiation , and Flowering of the Nobile Dendrobium Orchid [2008]*. Journal of the American Society for Horticultural Science, 133(4), 501–507.

Zong-Min, M., Ning, Y., Shu-Yun, L., & Hong, H. (2012). Nitrogen requirements for vegetative growth, flowering, seed production, and ramet growth of paphiopedilum armeniacum (Orchid). *HortScience*, 47(5), 585–588. https://doi.org/10.21273/hortsci.47.5.585