

Full Length Research Paper

## Response of graded levels of calcium and magnesium on growth and flowering of *Cymbidium* hybrid 'Mint Ice Glacier'

S. K. Naik<sup>1\*</sup>, D. Barman<sup>2</sup> and N. Pathak<sup>3</sup>

<sup>1</sup>ICAR Research Complex for Eastern Region, Research Centre, Ranchi-834010, India.

<sup>2</sup>National Research Centre for Orchids (ICAR), Pakyong-737106, Sikkim, India.

<sup>3</sup>Sikkim Himalayan Orchids Limited, Tadong, Gangtok, Sikkim, India.

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The experiment was conducted to study the influence of different graded levels of calcium (Ca) and magnesium (Mg) on *Cymbidium* hybrid 'Mint Ice Glacier' during the year 2008 to 2012. Application of Ca and Mg alone or in combination significantly influenced the different growth parameters like plant height, vegetative shoot clump<sup>-1</sup> and number of leaves clump<sup>-1</sup> as well as flowering parameters like spike length, rachis length, number of floret spike<sup>-1</sup> and number of spikes clump<sup>-1</sup>. The different growth parameters recorded significant value at higher doses of Ca (300 and 500 mg kg<sup>-1</sup>). However, there was no significant difference in growth character between Mg at 100 and 300 mg kg<sup>-1</sup>. The highest plant height, vegetative shoot clump<sup>-1</sup> and number of leaves clump<sup>-1</sup> were 75.1, 12.6 and 45.3 cm, respectively in the treatment Ca<sub>500</sub>Mg<sub>300</sub>. Application of Ca at lower doses (100 and 300 mg kg<sup>-1</sup>) had significant influence on flowering parameter compared to Ca at 500 mg kg<sup>-1</sup>. The number of standard spikes (70 to 100 cm) gradually increased with increasing doses of Ca (0 to 500 mg kg<sup>-1</sup>) and Mg (0 to 300 mg kg<sup>-1</sup>). However, the number of intermediate spikes (60 to 70 cm) increased with increasing doses of Ca and decreased with increasing doses of Mg. The highest spike length, rachis length, number of floret spike<sup>-1</sup> and number of spikes clump<sup>-1</sup> were 90.5, 62.1, 18.5 and 7.9 cm, respectively in the treatment Ca<sub>500</sub>Mg<sub>300</sub>. The nutrient content of growing media as well as in *Cymbidium* leaf gradually increased with increasing doses of Ca and Mg. The correlations studies indicated that all the growth and flowering parameter were better correlated with Mg than Ca.

**Key words:** *Cymbidium*, calcium, flowering, growth, magnesium.

### INTRODUCTION

Orchids have long been attractive plants to many people because of their wide variety of shapes and patterns, exotic colours, long-lasting flowers and fragrance. *Cymbidium* orchids are known for unparallel beauty,

attractive colour, long lasting waxy flowers used for indoor decoration and corsages. Nowadays, they are gaining popularity as decorative pot plants with smaller but equally high quality flowers. In North eastern

\*Corresponding author. E-mail: sushantanaik7@gmail.com. Fax: +916512260141.

Himalayas, areas lying between 1500 to 2000 m from sea level are suitable for *Cymbidium* cultivation (Pradhan et al., 1995). Sikkim is harnessing the opportunity of cultivating *Cymbidium* as cut flower owing to its climatic advantage. Majority of *Cymbidiums* are cool growing plants, however, capable of growing faster when exposed to warm temperature (Barman et al., 2008). During the period of growth, they take nutrients at an accelerated rate. Calcium (Ca) is thought to function as a secondary messenger in the transmission and transduction of several environmental signals acting as intracellular metabolic agent (Harper et al., 2004). Due to its high affinity to calmodulin and other calcium-binding-proteins, this nutrient might directly control several physiological processes (Hepler and Wayne, 1985).

Magnesium (Mg), besides being the central atom of the chlorophyll molecule, representing approximately 10% of the total foliar Mg (Hopkins, 1995), is also a co-factor of most enzymes acting on phosphorylated substrates, making it very important in energy metabolism. Enzymatic reactions acting on the carboxylic group, nucleotide transfer, some dehydrogenises, mutases and lyases are also processes stimulated by Mg (Mengal and Kirkby, 1987). There are various fertilizers mixtures that can be used for orchids. Research results show that various concentrations of water-soluble fertilizer, applied weekly by fertilization, are satisfactory for plant growth and development of *Phalaenopsis* (Wang and Gregg, 1994; Wang, 1996; Amberger-Ochsenbauer, 1997; Wang, 2000), *Cymbidium* (Zhao et al., 2001; Barman et al., 2008), *Dendrobium* (Bichsel et al., 2008), and *Laelia* (Rodrigues et al., 2010). Micronutrients present in the water supply and the media are almost always sufficient for orchids, even when actively growing. The macronutrients like nitrogen (N), phosphorus (P) and potassium (K), Ca and Mg are in low supply, though in fairly high demand. Therefore, these elements are regularly supplemented in orchid culture. Tanaka et al. (1989) reported that nutrient uptake by *Cattleya* hybrid was 19.3% for N, 2.7% for P, 149.7% for K, 16.5% for Ca and 85.2% for Mg from the applied fertilizer of rapeseed oil cake + bone meal (1:1) in the pot containing sphagnum moss.

It has been reported that growth of the *Dendrobium phalaenopsis* is severely affected by the omission of N, P, K, Ca and Mg in nutrient solution and the leaves drop before deficiency symptoms appear (Poole and Sheehan, 1982). Further, they investigated the importance of Mg for orchid growth and the N: P: K: Mg ratio of 12:1:15:3 and 1.25:0.4:0.75:0.1 has been suggested for *Phalaenopsis* and *Cattleya*, respectively. Mg deficiency is frequently detected in tropical orchids grown under full sun in field. The N:P:K:Mg ratio of 13:3:11:1 has been recommended for *Aranda* 'Noorah Alsagoff'. The mineral nutrients, particularly Ca and Mg are required for proper development and maturity of pseudobulb of *Cymbidium* hybrid. The pseudobulb of orchid acts as storage for water, mineral and carbohydrate and thus control flowering in orchid (Ng

and Hew, 2000). Most studies on major nutrients of orchids are with the genera *Cattleya*, *Cymbidium*, *Epidendrum*, *Dendrobium* and *Phalaenopsis*. However, information on secondary nutrients is very rare. Seeing the importance of secondary nutrients in quality cut flower production of other flowers, the present investigation was carried out to study the influence of different graded levels of Ca and Mg on growth and flowering of *Cymbidium* hybrid 'Mint Ice Glacier'.

## MATERIALS AND METHODS

The experiment was carried out at farms of Sikkim Himalayan Orchids Limited, Assamlingzey, Sikkim during the year 2008 to 2012. One-year-old tissue cultured plants of *Cymbidium* 'Mint Ice Glacier' were planted singly in the plastic pots and kept inside the poly house during the year 2008. The temperature during the winter season (November to March) varied from 10 to 15°C and during wet season (April to October) varied from 15 to 25°C. The sterilized media used for growing *Cymbidium* was the mixture of leaf mould, cocochips and brick pieces at 4:2:1 ratio in treated pot. Different graded levels of Ca and Mg were applied from 3<sup>rd</sup> year onwards along with the recommended NPK. The treatments comprised of 4 levels of Ca (0, 100, 300 and 500 mg kg<sup>-1</sup>) and 3 levels of Mg (0, 100 and 300 mg kg<sup>-1</sup>). The different graded levels of Ca and Mg were prepared from Ca nitrate [Ca(NO<sub>3</sub>)<sub>2</sub>] and Mg sulphate (MgSO<sub>4</sub>.7H<sub>2</sub>O), respectively. The amount of N supplied through Ca nitrate is deducted from the recommended dose of N-P-K to maintain the required N-P-K. All the treatments were given uniform dose of 30:10:10 NPK during 1<sup>st</sup> year and 20:20:20 NPK during 2<sup>nd</sup> year of planting for boosting vegetative growth. The fertilizer dose of 15:30:30 NPK was given to all the treatments at the flower development phase. All the fertilizer solution were applied at 15 days interval, while fertilizers were restricted to monthly once in winter season (November to February).

Flowering in the *Cymbidium* hybrid was started in the year 2010 to 2011 and the experiment was continued up to 2011 to 2012. Growth parameter (plant height, vegetative shoot clump<sup>-1</sup> and number of leaves clump<sup>-1</sup>) and flowering parameter (number of spikes plant<sup>-1</sup>, number of floret spike<sup>-1</sup>, spike length and rachis length) were recorded for 2 consecutive years of 2010 to 2011 and 2011 to 2012. Growing media and plant parts were collected from all the treatments at the time of vegetative and flowering stage. All the collected samples were dried in shade and finally in hot air oven at 65°C, ground and passed through 80-mesh sieve. Dried samples (1.0 g) were digested with diacid mixture (HNO<sub>3</sub>: HClO<sub>4</sub> = 9:4; Jackson, 1973). After digestion of samples, the total N was determined by micro kjeldahl method (Bremner, 1965), total P was determined by Vanodomolybdo-phosphoric yellow colour method (Jackson, 1973), total K was determined by flame photometer method (Jackson, 1973), total Ca and Mg were determined by versanate method (Hesse, 1971).

The experiment was set up in a completely randomized design (CRD) with factorial concept and replicated thrice. Results were statistically analyzed by analysis of variance using the statistical computer programme MSTATC.

## RESULTS AND DISCUSSION

### Growth parameter

Application of Ca from 100 to 500 mg kg<sup>-1</sup> significantly [F (3, 24) = 3.0, p ≤ 0.05] influenced the plant growth

**Table 1.** Effect of different graded levels of Ca and Mg on growth parameter of *Cymbidium* hybrid.

Treatment	Plant height (cm)		Vegetative shoot clump <sup>-1</sup>		No. of leaves clump <sup>-1</sup>	
	2010 - 2011	2011 - 2012	2010 - 2011	2011 - 2012	2010 - 2011	2011 - 2012
<b>Ca levels</b>						
Ca <sub>0</sub>	61.70 <sup>B†</sup>	64.68 <sup>C</sup>	10.03 <sup>C</sup>	11.02 <sup>C</sup>	39.57 <sup>B</sup>	40.97 <sup>B</sup>
Ca <sub>100</sub>	62.50 <sup>B</sup>	66.60 <sup>B</sup>	10.17 <sup>C</sup>	10.97 <sup>C</sup>	40.30 <sup>B</sup>	41.73 <sup>B</sup>
Ca <sub>300</sub>	62.80 <sup>B</sup>	67.72 <sup>B</sup>	10.62 <sup>B</sup>	11.45 <sup>B</sup>	41.63 <sup>A</sup>	43.33 <sup>A</sup>
Ca <sub>500</sub>	64.32 <sup>A</sup>	70.30 <sup>A</sup>	11.00 <sup>A</sup>	11.75 <sup>A</sup>	42.33 <sup>A</sup>	44.35 <sup>A</sup>
<b>Mg levels</b>						
Mg <sub>0</sub>	60.54 <sup>C</sup>	64.96 <sup>C</sup>	9.35 <sup>C</sup>	10.11 <sup>C</sup>	40.09 <sup>B</sup>	41.70 <sup>B</sup>
Mg <sub>100</sub>	62.49 <sup>B</sup>	66.40 <sup>B</sup>	10.70 <sup>B</sup>	11.50 <sup>B</sup>	41.56 <sup>A</sup>	43.33 <sup>A</sup>
Mg <sub>300</sub>	65.46 <sup>A</sup>	70.61 <sup>A</sup>	11.31 <sup>A</sup>	12.28 <sup>A</sup>	41.23 <sup>A</sup>	42.76 <sup>AB</sup>
<b>Interaction</b>						
Ca <sub>0</sub> Mg <sub>0</sub>	60.20 <sup>e</sup>	63.00 <sup>g</sup>	8.65 <sup>f</sup>	9.40 <sup>g</sup>	38.75 <sup>e</sup>	40.05 <sup>f</sup>
Ca <sub>100</sub> Mg <sub>0</sub>	60.25 <sup>e</sup>	64.10 <sup>fg</sup>	8.95 <sup>f</sup>	9.65 <sup>g</sup>	40.00 <sup>cde</sup>	41.35 <sup>def</sup>
Ca <sub>300</sub> Mg <sub>0</sub>	60.45 <sup>e</sup>	65.35 <sup>ef</sup>	9.70 <sup>e</sup>	10.45 <sup>f</sup>	40.85 <sup>bcde</sup>	42.20 <sup>bcdef</sup>
Ca <sub>500</sub> Mg <sub>0</sub>	61.25 <sup>de</sup>	67.40 <sup>cde</sup>	10.10 <sup>d</sup>	10.95 <sup>e</sup>	40.75 <sup>bcde</sup>	43.20 <sup>abcde</sup>
Ca <sub>0</sub> Mg <sub>100</sub>	61.40 <sup>de</sup>	63.95 <sup>fg</sup>	10.70 <sup>c</sup>	11.85 <sup>bc</sup>	40.25 <sup>cde</sup>	41.95 <sup>cdef</sup>
Ca <sub>100</sub> Mg <sub>100</sub>	62.45 <sup>cde</sup>	66.35 <sup>de</sup>	10.60 <sup>c</sup>	11.20 <sup>de</sup>	40.90 <sup>bcde</sup>	42.60 <sup>bcde</sup>
Ca <sub>300</sub> Mg <sub>100</sub>	62.70 <sup>bcde</sup>	66.95 <sup>de</sup>	10.60 <sup>c</sup>	11.30 <sup>d</sup>	42.35 <sup>abc</sup>	44.20 <sup>abc</sup>
Ca <sub>500</sub> Mg <sub>100</sub>	63.40 <sup>bcd</sup>	68.35 <sup>cd</sup>	10.90 <sup>c</sup>	11.65 <sup>c</sup>	42.75 <sup>ab</sup>	44.55 <sup>ab</sup>
Ca <sub>0</sub> Mg <sub>300</sub>	63.50 <sup>bcd</sup>	67.10 <sup>de</sup>	10.75 <sup>c</sup>	11.80 <sup>bc</sup>	39.70 <sup>de</sup>	40.90 <sup>ef</sup>
Ca <sub>100</sub> Mg <sub>300</sub>	64.80 <sup>bc</sup>	69.35 <sup>bc</sup>	10.95 <sup>c</sup>	12.05 <sup>b</sup>	40.00 <sup>cde</sup>	41.25 <sup>def</sup>
Ca <sub>300</sub> Mg <sub>300</sub>	65.25 <sup>b</sup>	70.85 <sup>b</sup>	11.55 <sup>b</sup>	12.60 <sup>a</sup>	41.70 <sup>abcd</sup>	43.60 <sup>abcd</sup>
Ca <sub>500</sub> Mg <sub>300</sub>	68.30 <sup>a</sup>	75.15 <sup>a</sup>	12.00 <sup>a</sup>	12.65 <sup>a</sup>	43.50 <sup>a</sup>	45.30 <sup>a</sup>

<sup>†</sup>Within a column, means followed by the same letter are not significantly different at the 0.05 level of probability by DMRT.

parameters like plant height, vegetative shoot clump<sup>-1</sup> and number of leaves clump<sup>-1</sup> in both years (Table 1). The plant height and vegetative shoot clump<sup>-1</sup> increased with increasing concentration of Ca. The highest plant height of 64.3 and 70.3 cm and vegetative shoot clump<sup>-1</sup> of 11 and 11.75, respectively in 1<sup>st</sup> and 2<sup>nd</sup> years were recorded with the application of Ca at 500 mg kg<sup>-1</sup>. Similar trend was observed in number of leaves clump<sup>-1</sup>. The treatment Ca at 500 mg kg<sup>-1</sup> was statistically at par with Ca at 300 mg kg<sup>-1</sup>. The results of the present investigation find supports from Dematte et al. (2000) who reported that higher concentrations of Ca up to 13.2 g kg<sup>-1</sup> was detrimental for growth of *Dendrobium* orchid. The percent increase over control concerning plant height with the application of Ca at 500 mg kg<sup>-1</sup> was 4.24 and 8.7%, in 1<sup>st</sup> year and 2<sup>nd</sup> years, respectively. Similarly, the vegetative shoot clump<sup>-1</sup> registered 10 and 6.8% increase over control in 1<sup>st</sup> and 2<sup>nd</sup> years, respectively with the above application dose of Ca. The percent increase over control in number of leaves clump<sup>-1</sup> during 1<sup>st</sup> and 2<sup>nd</sup> years was 6.8 and 8.0 with the application of Ca at 500 mg kg<sup>-1</sup>. However, at lower levels of Ca at 100 mg kg<sup>-1</sup>, all the growth parameter was statistically at par with the control in both years.

Application of Mg from 100 to 300 mg kg<sup>-1</sup> significantly [F (2, 24) = 3.4, p ≤ 0.05] influenced the plant growth parameters in both years. The plant height and vegetative shoot clump<sup>-1</sup> registered highest value with the application of Mg at 300 mg kg<sup>-1</sup> and resulted in 8.1 and 8.8% increase over control in plant height; 21 and 21.8% increase over control in vegetative shoot clump<sup>-1</sup> during 1<sup>st</sup> and 2<sup>nd</sup> years, respectively. The highest plant height of 65.46 and 70.61 cm and vegetative shoot clump<sup>-1</sup> of 11.31 and 12.28, respectively was recorded in 1<sup>st</sup> and 2<sup>nd</sup> years with the application of Mg at 300 mg kg<sup>-1</sup>. All the levels of Mg (100 and 300 mg kg<sup>-1</sup>) was significantly [F (2, 24) = 3.4, p ≤ 0.05] better than control in increasing the plant height and vegetative shoot clump<sup>-1</sup>. However, the number of leaves was statistically at par among the Mg levels of 100 and 300 mg kg<sup>-1</sup>. The highest number of leaves clump<sup>-1</sup> was 41.56 and 43.33 in 1<sup>st</sup> and 2<sup>nd</sup> years, respectively with the application of Mg at 100 mg kg<sup>-1</sup>. The results of the present investigations are in agreement with the findings of Chin (1966), who reported that omission of Mg severely reduced dry weight of *D. phalaenopsis* hybrid seedlings.

Comparing the interaction effect of Ca and Mg, the highest plant height of 68.30 and 75.15 cm recorded in

**Table 2.** Effect of different graded levels of Ca and Mg on flowering parameter of *Cymbidium* hybrid.

Treatment	Spike length (cm)		Rachis length		No. of florets spike <sup>-1</sup>	
	2010 - 2011	2011 - 2012	2010 - 2011	2011 - 2012	2010 - 2011	2011 - 2012
<b>Ca levels</b>						
Ca <sub>0</sub>	69.43 <sup>D†</sup>	73.25 <sup>D</sup>	42.52 <sup>D</sup>	45.55 <sup>D</sup>	12.32 <sup>C</sup>	13.20 <sup>B</sup>
Ca <sub>100</sub>	73.82 <sup>C</sup>	76.68 <sup>C</sup>	48.52 <sup>C</sup>	50.27 <sup>C</sup>	13.82 <sup>B</sup>	15.05 <sup>A</sup>
Ca <sub>300</sub>	76.22 <sup>B</sup>	79.33 <sup>B</sup>	51.17 <sup>B</sup>	54.08 <sup>B</sup>	14.63 <sup>AB</sup>	15.58 <sup>A</sup>
Ca <sub>500</sub>	79.90 <sup>A</sup>	82.90 <sup>A</sup>	54.08 <sup>A</sup>	56.17 <sup>A</sup>	15.32 <sup>A</sup>	16.00 <sup>A</sup>
<b>Mg levels</b>						
Mg <sub>0</sub>	70.70 <sup>C</sup>	74.63 <sup>C</sup>	46.04 <sup>B</sup>	47.98 <sup>C</sup>	12.29 <sup>C</sup>	13.15 <sup>C</sup>
Mg <sub>100</sub>	73.05 <sup>B</sup>	76.13 <sup>B</sup>	47.11 <sup>B</sup>	49.89 <sup>B</sup>	13.41 <sup>B</sup>	14.43 <sup>B</sup>
Mg <sub>300</sub>	80.78 <sup>A</sup>	83.38 <sup>A</sup>	54.06 <sup>A</sup>	56.69 <sup>A</sup>	16.36 <sup>A</sup>	17.30 <sup>A</sup>
<b>Interaction</b>						
Ca <sub>0</sub> Mg <sub>0</sub>	65.25 <sup>f</sup>	70.15 <sup>h</sup>	40.10 <sup>g</sup>	42.15 <sup>f</sup>	10.50 <sup>d</sup>	10.95 <sup>c</sup>
Ca <sub>100</sub> Mg <sub>0</sub>	70.10 <sup>e</sup>	73.55 <sup>fg</sup>	45.65 <sup>f</sup>	46.55 <sup>e</sup>	12.35 <sup>c</sup>	13.55 <sup>b</sup>
Ca <sub>300</sub> Mg <sub>0</sub>	72.35 <sup>de</sup>	75.85 <sup>ef</sup>	48.15 <sup>def</sup>	50.25 <sup>d</sup>	12.80 <sup>c</sup>	13.85 <sup>b</sup>
Ca <sub>500</sub> Mg <sub>0</sub>	75.10 <sup>d</sup>	78.95 <sup>cd</sup>	50.25 <sup>cd</sup>	52.95 <sup>bcd</sup>	13.50 <sup>c</sup>	14.25 <sup>b</sup>
Ca <sub>0</sub> Mg <sub>100</sub>	70.25 <sup>e</sup>	72.50 <sup>gh</sup>	40.20 <sup>g</sup>	43.65 <sup>f</sup>	12.45 <sup>c</sup>	13.55 <sup>b</sup>
Ca <sub>100</sub> Mg <sub>100</sub>	72.85 <sup>de</sup>	76.25 <sup>def</sup>	47.45 <sup>def</sup>	50.15 <sup>d</sup>	13.20 <sup>c</sup>	14.10 <sup>b</sup>
Ca <sub>300</sub> Mg <sub>100</sub>	73.80 <sup>d</sup>	76.50 <sup>def</sup>	49.00 <sup>de</sup>	52.35 <sup>bcd</sup>	13.85 <sup>c</sup>	14.85 <sup>b</sup>
Ca <sub>500</sub> Mg <sub>100</sub>	75.30 <sup>d</sup>	79.25 <sup>cd</sup>	51.80 <sup>c</sup>	53.42 <sup>bc</sup>	14.15 <sup>c</sup>	15.20 <sup>b</sup>
Ca <sub>0</sub> Mg <sub>300</sub>	72.80 <sup>de</sup>	77.10 <sup>de</sup>	47.25 <sup>ef</sup>	50.85 <sup>cd</sup>	14.00 <sup>c</sup>	15.10 <sup>b</sup>
Ca <sub>100</sub> Mg <sub>300</sub>	78.50 <sup>c</sup>	80.25 <sup>c</sup>	52.45 <sup>c</sup>	54.10 <sup>b</sup>	15.90 <sup>b</sup>	17.50 <sup>a</sup>
Ca <sub>300</sub> Mg <sub>300</sub>	82.50 <sup>b</sup>	85.65 <sup>b</sup>	56.35 <sup>b</sup>	59.65 <sup>a</sup>	17.25 <sup>ab</sup>	18.05 <sup>a</sup>
Ca <sub>500</sub> Mg <sub>300</sub>	89.30 <sup>a</sup>	90.50 <sup>a</sup>	60.20 <sup>a</sup>	62.15 <sup>a</sup>	18.30 <sup>a</sup>	18.55 <sup>a</sup>

<sup>†</sup>Within a column, means followed by the same letter are not significantly different at the 0.05 level of probability by DMRT.

the treatment Ca<sub>500</sub>Mg<sub>300</sub> and resulted in 13.5 and 19.2% increase over control, respectively in 1<sup>st</sup> and 2<sup>nd</sup> years. There was no significant [F (6, 24) = 2.51, p ≤ 0.05] difference in plant height among the different treatments during both years. The vegetative shoot clump<sup>-1</sup> significantly [F (6, 24) = 2.51, p ≤ 0.05] increased with increasing doses of Ca and Mg. The highest number of vegetative shoot clump<sup>-1</sup> of 12.00 and 12.65 recorded in the treatment Ca<sub>500</sub>Mg<sub>300</sub> during 1<sup>st</sup> and 2<sup>nd</sup> years, respectively and resulted in 38.7 and 34.5% increase over control. There is no significant difference [F (6, 24) = 2.51, p ≤ 0.05] in vegetative shoot clump<sup>-1</sup> between Ca at 0 and 100 mg kg<sup>-1</sup> and further between 300 and 500 mg kg<sup>-1</sup> Ca irrespective of all combinations of Mg (0 to 300 mg kg<sup>-1</sup>). Application of different combinations of Ca and Mg significantly [F (6, 24) = 2.51, p ≤ 0.05] increased the number of leaves clump<sup>-1</sup> over control during both years. The highest number of leaves clump<sup>-1</sup> of 43.50 and 45.30, respectively in 1<sup>st</sup> and 2<sup>nd</sup> years recorded in the treatment Ca<sub>500</sub>Mg<sub>300</sub> and was statistically at par with Ca<sub>300</sub>Mg<sub>300</sub>, Ca<sub>500</sub>Mg<sub>100</sub> and Ca<sub>300</sub>Mg<sub>100</sub>. Application of different levels of Ca (0 to 500 mg kg<sup>-1</sup>) in absence of Mg is not statistically significant in influencing the number of leaves clump<sup>-1</sup> during both years. However, with the

application of Mg at 100 and 300 mg kg<sup>-1</sup> significantly [F (6, 24) = 2.51, p ≤ 0.05] influenced the number of leaves clump<sup>-1</sup> in combination with Ca at 500 mg kg<sup>-1</sup> and was not significant with lower levels of Ca at 100 and 300 mg kg<sup>-1</sup>.

Davidson (1960) concluded that plants lacking an external supply of K are capable of translocation of this nutrient from old tissues and re-utilizing it to meet most of the growth requirements for K by new tissues. Likewise, Ca and Mg present in old tissues are re-utilized, but to a lesser extent than K. Poole and Seeley (1978) concluded that high Mg in the presence of high Ca, have a direct effect on root growth of *Phalaenopsis* which resulted in better vegetative growth.

### Flowering parameter

Application of Ca at different levels (100 to 500 mg kg<sup>-1</sup>) significantly [F (3, 24) = 3.0, p ≤ 0.05] influenced the flowering parameter like spike length, rachis length, number of floret spike<sup>-1</sup> over control (Table 2). The spike length was recorded highest of 79.90 and 82.90 cm with the application of Ca at 500 mg kg<sup>-1</sup> and resulted in 15

and 13.2% increase over control, respectively during both years. Further, the rachis length of 54.08 and 56.17 cm recorded highest with the application of Ca at 500 mg kg<sup>-1</sup> and resulted in 27.2 and 23.3% increase over control, respectively during both years. Similarly, the highest number of florets clump<sup>-1</sup> was 15.32 and 16.00 in the treatment Ca<sub>500</sub> and resulted in 24.3 and 21.2% increase over control. However, the number florets spike<sup>-1</sup> was at par among the different levels of Ca (100 to 500 mg kg<sup>-1</sup>). Ca improves the productivity and production quality of floricultural crops (Huett, 1994; Mikesell, 1992; Starkey and Pederson, 1997; Torre et al., 1999).

The flowering parameters significantly [F (2, 24) = 3.4, p ≤ 0.05] increased over control with successive additions of Mg from 100 to 300 mg kg<sup>-1</sup> during both years. The highest spike length was 80.78 and 83.38 cm recorded in the treatment Mg<sub>300</sub> and resulted in 14.3 and 11.8% increase over control, respectively in 1<sup>st</sup> and 2<sup>nd</sup> years of flowering. The investigations showed that the rachis length gradually increased with increasing concentrations of Mg. The highest rachis length was 54.06 and 56.69 cm recorded in the treatment Mg<sub>300</sub> and resulted in 17.4 and 18.1% increase over control, respectively in 1<sup>st</sup> and 2<sup>nd</sup> years. The results also showed that the percent increase in number of florets spike<sup>-1</sup> over control was 33.3 and 32% with the application of Mg at 300 mg kg<sup>-1</sup> during both years.

The interaction effect of Ca and Mg significantly [F (6, 24) = 2.51, p ≤ 0.05] increased the spike length, rachis length and number of florets spike<sup>-1</sup> over control. Application of Ca from 100 to 500 mg kg<sup>-1</sup> irrespective of different levels of Mg significantly increased the spike length, rachis length and number of florets spike<sup>-1</sup> over control (Ca<sub>0</sub>Mg<sub>0</sub>) during both years. The highest spike length was 89.30 and 90.50 cm recorded in the treatment Ca<sub>300</sub>Mg<sub>300</sub> and resulted in 36.7 and 29.1% increase over control during both years, respectively. The spike length was statistically not significant [F (6, 24) = 2.51, p ≤ 0.05] among the Ca levels of 100 and 300 mg kg<sup>-1</sup> and further at 300 and 500 mg kg<sup>-1</sup> in combination with Mg at 0 and 100 mg kg<sup>-1</sup> during both years.

However, spike length was significant [F (6, 24) = 2.51, p ≤ 0.05] among all the levels of Ca from 100 to 500 mg kg<sup>-1</sup> in combination with Mg at 300 mg kg<sup>-1</sup> during both years. The highest rachis length was 60.20 and 62.15 cm recorded in the treatment Ca<sub>500</sub>Mg<sub>300</sub> and resulted in 50 and 47.4% increase over control during 1<sup>st</sup> and 2<sup>nd</sup> years, respectively. The spike length was not significant [F (6, 24) = 2.51, p ≤ 0.05] among the Ca levels of 300 and 500 mg kg<sup>-1</sup> at all levels of Mg from 0 to 300 mg kg<sup>-1</sup>. The number of florets spike<sup>-1</sup> recorded highest of 18.3 and 18.5 and resulted in 74.3 and 68.2% increase over control during both years, respectively. It was observed that the number of florets spike<sup>-1</sup> was not significant [F (6, 24) = 2.51, p ≤ 0.05] among all the levels of Ca from 100 to 500 mg kg<sup>-1</sup> irrespective of different levels of Mg. Application of major nutrients along with secondary

nutrients improved the quality of *Phalaenopsis* flower (Wang, 1996; Yin-Tung and Konow, 2002), *Cattleya* and *Cymbidium* (Poole and Seeley, 1978), and *Dendrobium* (Bichsel et al., 2008).

The spikes were separated into different grades of 60 to 70, and 70 to 100 cm based on intermediate and standard size in the international market of *Cymbidium* orchid (Table 3). The number of intermediate spike (60 to 70 cm) clump<sup>-1</sup> gradually increased with increasing levels of Ca from 0 to 500 mg kg<sup>-1</sup> during both years. The number of intermediate spikes clump<sup>-1</sup> were not significantly [F (3, 24) = 3.0, p ≤ 0.05] different among all the levels of Ca during 1<sup>st</sup> year, while in 2<sup>nd</sup> year, it was not found significant between the treatments Ca<sub>0</sub> and Ca<sub>100</sub>, and Ca<sub>300</sub> and Ca<sub>500</sub>. The highest number of intermediate spikes clump<sup>-1</sup> was 1.70 and 1.67 in the treatment Ca<sub>500</sub> and resulted in 21.4 and 26.5% increase over control during 1<sup>st</sup> and 2<sup>nd</sup> years, respectively. The

number of standard spikes (70 to 100 cm) clump<sup>-1</sup> gradually increased with increasing levels of Ca and it was found significant [F (3, 24) = 3.0, p ≤ 0.05] among all levels of Ca during the period of investigation. The highest number of standard spikes clump<sup>-1</sup> was 4.47 and 5.53 in the treatment Ca<sub>500</sub> and resulted in 43.7 and 41.7% increase over control during both years, respectively. It was observed that the number of intermediate spikes were more in 1<sup>st</sup> year, while the standard spikes were more in 2<sup>nd</sup> year of investigation.

Application of different graded levels of Mg significantly [F (2, 24) = 3.4, p ≤ 0.05] decreased the number of intermediate spikes clump<sup>-1</sup>, while increased the number of standard spikes clump<sup>-1</sup> over control during both years of investigation. The total number of spikes clump<sup>-1</sup> gradually increased with increasing levels of Mg. The highest number of intermediate spikes clump<sup>-1</sup> was 1.93 and 1.75 in the control treatment, respectively in 1<sup>st</sup> and 2<sup>nd</sup> years. However, the treatment Mg<sub>300</sub> recorded highest number of standard spikes clump<sup>-1</sup> of 5.11 and 5.89 and resulted in 79.3 and 48% increase over control during both years.

The interaction effect of different levels of Ca and Mg significantly [F (6, 24) = 2.51, p ≤ 0.05] increased the different grades of spikes (60 to 70 and 70 to 100 cm). The highest number of intermediate spikes clump<sup>-1</sup> was 2.35 and 2.30 recorded in the treatment Ca<sub>500</sub>Mg<sub>0</sub>. The results demonstrated that the incorporation of different levels of Ca in combination with Mg decreased the number of intermediate spikes clump<sup>-1</sup> during both years. The highest number of standard spikes clump<sup>-1</sup> was 5.70 and 6.55 recorded in the treatment Ca<sub>500</sub>Mg<sub>300</sub> and resulted in 119 and 81.9% increase over control during both the years. All the levels of Ca and Mg in combination significantly [F (6, 24) = 2.51, p ≤ 0.05] increased the standard spikes clump<sup>-1</sup> over control. Flower yield per plant and quality parameters were improved by addition of Ca and Mg in *Gerbera* (Sirin, 2011), *Alstromeria* (Smith et al., 1998), and Oriental Lily (Chang et al., 2012).

**Table 3.** Effect of different graded levels of Ca and Mg on spike production of *Cymbidium* hybrid.

Treatment	No. of spikes clump <sup>-1</sup>					
	2010 - 2011			2011 - 2012		
	60 - 70 cm	70 - 100 cm	Total	60 - 70 cm	70 - 100 cm	Total
<b>Ca levels</b>						
Ca <sub>0</sub>	1.40 <sup>B†</sup>	3.13 <sup>D</sup>	4.53	1.32 <sup>B</sup>	3.88 <sup>D</sup>	5.20
Ca <sub>100</sub>	1.65 <sup>A</sup>	4.03 <sup>C</sup>	5.68	1.37 <sup>B</sup>	4.83 <sup>C</sup>	6.20
Ca <sub>300</sub>	1.63 <sup>A</sup>	4.27 <sup>B</sup>	5.90	1.58 <sup>A</sup>	5.10 <sup>B</sup>	6.68
Ca <sub>500</sub>	1.70 <sup>A</sup>	4.47 <sup>A</sup>	6.17	1.67 <sup>A</sup>	5.53 <sup>A</sup>	7.20
<b>Mg levels</b>						
Mg <sub>0</sub>	1.93 <sup>A</sup>	2.85 <sup>C</sup>	4.78	1.75 <sup>A</sup>	3.98 <sup>C</sup>	5.73
Mg <sub>100</sub>	1.54 <sup>B</sup>	3.96 <sup>B</sup>	5.50	1.39 <sup>B</sup>	4.65 <sup>B</sup>	6.04
Mg <sub>300</sub>	1.33 <sup>C</sup>	5.11 <sup>A</sup>	6.44	1.31 <sup>B</sup>	5.89 <sup>A</sup>	7.20
<b>Interaction</b>						
Ca <sub>0</sub> Mg <sub>0</sub>	1.50 <sup>ef</sup>	2.60 <sup>j</sup>	4.10	1.25 <sup>de</sup>	3.60 <sup>h</sup>	4.85
Ca <sub>100</sub> Mg <sub>0</sub>	1.75 <sup>cd</sup>	3.10 <sup>h</sup>	4.85	1.45 <sup>cd</sup>	3.90 <sup>g</sup>	5.35
Ca <sub>300</sub> Mg <sub>0</sub>	2.10 <sup>b</sup>	2.80 <sup>j</sup>	4.90	2.00 <sup>b</sup>	3.95 <sup>g</sup>	5.95
Ca <sub>500</sub> Mg <sub>0</sub>	2.35 <sup>a</sup>	2.90 <sup>j</sup>	5.25	2.30 <sup>a</sup>	4.45 <sup>f</sup>	6.75
Ca <sub>0</sub> Mg <sub>100</sub>	1.60 <sup>de</sup>	2.65 <sup>j</sup>	4.25	1.50 <sup>c</sup>	3.10 <sup>i</sup>	4.60
Ca <sub>100</sub> Mg <sub>100</sub>	1.85 <sup>c</sup>	3.90 <sup>g</sup>	5.75	1.25 <sup>de</sup>	4.80 <sup>e</sup>	6.05
Ca <sub>300</sub> Mg <sub>100</sub>	1.40 <sup>fg</sup>	4.50 <sup>e</sup>	5.90	1.45 <sup>cd</sup>	5.10 <sup>d</sup>	6.55
Ca <sub>500</sub> Mg <sub>100</sub>	1.30 <sup>g</sup>	4.80 <sup>d</sup>	6.10	1.35 <sup>cde</sup>	5.60 <sup>c</sup>	6.95
Ca <sub>0</sub> Mg <sub>300</sub>	1.10 <sup>h</sup>	4.15 <sup>f</sup>	5.25	1.20 <sup>e</sup>	4.95 <sup>de</sup>	6.15
Ca <sub>100</sub> Mg <sub>300</sub>	1.35 <sup>fg</sup>	5.10 <sup>c</sup>	6.45	1.40 <sup>cde</sup>	5.80 <sup>c</sup>	7.20
Ca <sub>300</sub> Mg <sub>300</sub>	1.40 <sup>fg</sup>	5.50 <sup>b</sup>	6.90	1.30 <sup>cde</sup>	6.25 <sup>b</sup>	7.55
Ca <sub>500</sub> Mg <sub>300</sub>	1.45 <sup>efg</sup>	5.70 <sup>a</sup>	7.15	1.35 <sup>cde</sup>	6.55 <sup>a</sup>	7.90

<sup>†</sup>Within a column, means followed by the same letter are not significantly different at the 0.05 level of probability by DMRT.

### Leaf nutrient status

Application of different graded levels of Ca significantly [F (3, 24) = 3.0,  $p \leq 0.05$ ] increased the nutrient content viz. N, P, K, Ca and Mg of *Cymbidium* leaf at vegetative stage during the 2 years of investigation (Table 4). It was noticed that the N content of leaf was not significant [F (3, 24) = 3.0,  $p \leq 0.05$ ] among the Ca levels of 300 and 500 mg kg<sup>-1</sup>. However, there was significant [F (3, 24) = 3.0,  $p \leq 0.05$ ] difference among the different levels of Ca in increasing the P, K, Ca and Mg content of leaf. The highest of N, P, K, Ca and Mg content of leaf at vegetative stage were 1.45, 0.47, 2.34, 2.64 and 1.24 %, respectively in the treatment Ca<sub>500</sub>. The results indicated that Ca has synergistic effect on N, P, K, Ca and Mg content of leaf. Application of Mg from 0 to 300 mg kg<sup>-1</sup> significantly [F (2, 24) = 3.4,  $p \leq 0.05$ ] increased the N, P, K, Ca and Mg content of leaf at vegetative stage. The interaction effect of applied Ca and Mg significantly [F (6, 24) = 2.51,  $p \leq 0.05$ ] increased the leaf nutrient status of *Cymbidium* hybrid over control (Ca<sub>0</sub>Mg<sub>0</sub>) at vegetative stage. The highest N, P, K, Ca and Mg content in leaf

was 1.5, 0.5, 2.4, 2.8 and 1.5%, respectively in the treatment Ca<sub>500</sub>Mg<sub>300</sub> and resulted in 22.9, 85, 48, 131 and 36% increase over control. It was observed that the N, P and Mg content in leaf were not significantly [F (6, 24) = 2.51,  $p \leq 0.05$ ] different among the Ca levels of 300 and 500 mg kg<sup>-1</sup> in combination with 0 and 100 Mg mg kg<sup>-1</sup>, whereas there is significant [F (6, 24) = 2.51,  $p \leq 0.05$ ] difference in K and Ca in the above levels of Ca and Mg. Poole and Seeley (1978) observed a synergistic effect between N and Mg content in *Cymbidium* leaves and noticed that significant increase of P and Mg content occurred when N was increased in the nutrient solution.

The leaf nutrient status varied significantly among the different levels of Ca and Mg at reproductive stage of *Cymbidium* hybrid during the period of investigation (Table 5). The mean effect of different levels of Ca significantly [F (3, 24) = 3.0,  $p \leq 0.05$ ] influenced the N, P, K, Ca and Mg content of leaf. Application of Ca at 500 mg kg<sup>-1</sup> recorded highest N, P, K, Ca and Mg content of 1.3, 0.57, 2.56, 3.6 and 1.5%, respectively. The N and Mg content of *Cymbidium* leaf at reproductive stage was found non-significant [F (3, 24) = 3.0,  $p \leq 0.05$ ] among the

**Table 4.** Effect of different graded levels of Ca and Mg on leaf nutrient status of *Cymbidium* hybrid at vegetative stage (Mean of 2 years).

Treatment	Total Nutrient content (%)				
	N	P	K	Ca	Mg
<b>Ca levels</b>					
Ca <sub>0</sub>	6.52 <sup>C†</sup> (1.29)	3.17 <sup>D</sup> (0.31)	7.54 <sup>D</sup> (1.72)	6.95 <sup>C</sup> (1.47)	5.98 <sup>C</sup> (1.10)
Ca <sub>100</sub>	6.65 <sup>B</sup> (1.34)	3.35 <sup>C</sup> (0.34)	7.78 <sup>C</sup> (1.84)	6.95 <sup>C</sup> (1.47)	6.22 <sup>B</sup> (1.19)
Ca <sub>300</sub>	6.86 <sup>A</sup> (1.42)	3.73 <sup>B</sup> (0.42)	8.02 <sup>B</sup> (1.95)	8.12 <sup>B</sup> (2.00)	6.27 <sup>AB</sup> (1.21)
Ca <sub>500</sub>	6.91 <sup>A</sup> (1.45)	3.91 <sup>A</sup> (0.47)	8.79 <sup>A</sup> (2.34)	9.35 <sup>A</sup> (2.64)	6.34 <sup>A</sup> (1.24)
<b>Mg levels</b>					
Mg <sub>0</sub>	6.63 <sup>C</sup> (1.33)	3.43 <sup>B</sup> (0.36)	7.85 <sup>C</sup> (1.88)	7.56 <sup>B</sup> (1.77)	5.36 <sup>C</sup> (0.88)
Mg <sub>100</sub>	6.75 <sup>B</sup> (1.38)	3.49 <sup>B</sup> (0.37)	7.97 <sup>B</sup> (1.94)	7.70 <sup>B</sup> (1.82)	6.37 <sup>B</sup> (1.24)
Mg <sub>300</sub>	6.83 <sup>A</sup> (1.41)	3.71 <sup>A</sup> (0.42)	8.27 <sup>A</sup> (2.08)	8.27 <sup>A</sup> (2.10)	6.88 <sup>A</sup> (1.44)
<b>Interaction</b>					
Ca <sub>0</sub> Mg <sub>0</sub>	*6.34 <sup>g</sup> (1.22)	2.98 <sup>g</sup> (0.27)	7.27 <sup>f</sup> (1.60)	6.36 <sup>h</sup> (1.23)	5.29 <sup>d</sup> (0.85)
Ca <sub>100</sub> Mg <sub>0</sub>	6.62 <sup>ef</sup> (1.33)	3.19 <sup>efg</sup> (0.31)	7.60 <sup>de</sup> (1.75)	6.84 <sup>fg</sup> (1.42)	5.38 <sup>d</sup> (0.88)
Ca <sub>300</sub> Mg <sub>0</sub>	6.80 <sup>bcd</sup> (1.40)	3.72 <sup>bc</sup> (0.42)	7.81 <sup>cd</sup> (1.85)	7.81 <sup>de</sup> (1.85)	5.35 <sup>d</sup> (0.87)
Ca <sub>500</sub> Mg <sub>0</sub>	6.75 <sup>cde</sup> (1.38)	3.85 <sup>ab</sup> (0.45)	8.72 <sup>a</sup> (2.31)	9.22 <sup>b</sup> (2.57)	5.44 <sup>d</sup> (0.90)
Ca <sub>0</sub> Mg <sub>100</sub>	6.57 <sup>f</sup> (1.31)	3.13 <sup>fg</sup> (0.30)	7.55 <sup>e</sup> (1.73)	6.80 <sup>g</sup> (1.40)	6.10 <sup>c</sup> (1.13)
Ca <sub>100</sub> Mg <sub>100</sub>	6.67 <sup>def</sup> (1.35)	3.29 <sup>ef</sup> (0.33)	7.71 <sup>de</sup> (1.81)	6.89 <sup>fg</sup> (1.44)	6.36 <sup>b</sup> (1.23)
Ca <sub>300</sub> Mg <sub>100</sub>	6.85 <sup>bc</sup> (1.42)	3.67 <sup>bc</sup> (0.41)	7.83 <sup>cd</sup> (1.86)	8.02 <sup>d</sup> (1.95)	6.47 <sup>b</sup> (1.27)
Ca <sub>500</sub> Mg <sub>100</sub>	6.92 <sup>b</sup> (1.45)	3.85 <sup>ab</sup> (0.45)	8.79 <sup>a</sup> (2.34)	9.10 <sup>b</sup> (2.50)	6.55 <sup>b</sup> (1.31)
Ca <sub>0</sub> Mg <sub>300</sub>	6.65 <sup>ef</sup> (1.34)	3.39 <sup>de</sup> (0.35)	7.79 <sup>cde</sup> (1.84)	7.68 <sup>e</sup> (1.79)	6.55 <sup>b</sup> (1.31)
Ca <sub>100</sub> Mg <sub>300</sub>	6.67 <sup>ef</sup> (1.35)	3.58 <sup>cd</sup> (0.39)	8.02 <sup>c</sup> (1.95)	7.13 <sup>f</sup> (1.54)	6.92 <sup>a</sup> (1.45)
Ca <sub>300</sub> Mg <sub>300</sub>	6.92 <sup>b</sup> (1.45)	3.80 <sup>bc</sup> (0.44)	8.43 <sup>b</sup> (2.15)	8.53 <sup>c</sup> (2.21)	6.99 <sup>a</sup> (1.48)
Ca <sub>500</sub> Mg <sub>300</sub>	7.06 <sup>a</sup> (1.51)	4.05 <sup>a</sup> (0.50)	8.85 <sup>a</sup> (2.37)	9.72 <sup>a</sup> (2.85)	7.04 <sup>a</sup> (1.50)

\*Transformed values (Arc sin<sup>-1</sup>√percent), original values in parenthesis (% nutrient).

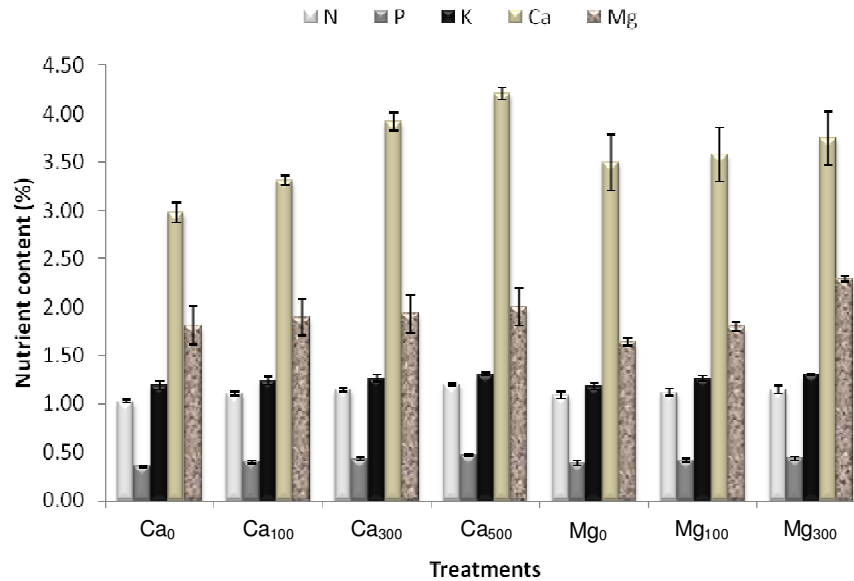
†Within a column, means followed by the same letter are not significantly different at the 0.05 level of probability by DMRT.

**Table 5.** Effect of different graded levels of Ca and Mg on leaf nutrient status of *Cymbidium* hybrid at reproductive stage (Mean of 2 years).

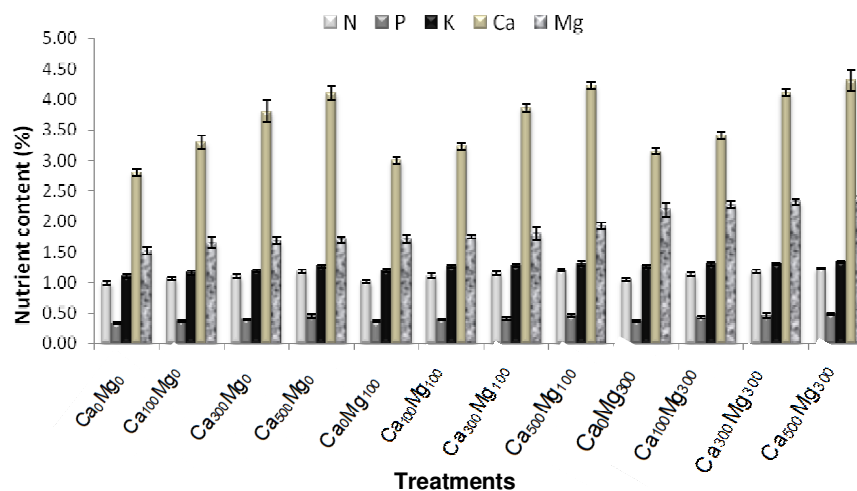
Treatment	Total Nutrient content (%)				
	N	P	K	Ca	Mg
<b>Ca levels</b>					
Ca <sub>0</sub>	6.25 <sup>C</sup> (1.19)	3.59 <sup>D</sup> (0.39)	7.99 <sup>D</sup> (1.93)	8.64 <sup>D</sup> (2.26)	6.65 <sup>C</sup> (1.34)
Ca <sub>100</sub>	6.37 <sup>BC</sup> (1.23)	3.82 <sup>C</sup> (0.44)	8.54 <sup>C</sup> (2.21)	9.16 <sup>C</sup> (2.54)	6.81 <sup>B</sup> (1.41)
Ca <sub>300</sub>	6.46 <sup>AB</sup> (1.26)	3.96 <sup>B</sup> (0.48)	8.76 <sup>B</sup> (2.33)	10.40 <sup>B</sup> (3.26)	6.95 <sup>A</sup> (1.47)
Ca <sub>500</sub>	6.56 <sup>A</sup> (1.31)	4.31 <sup>A</sup> (0.57)	9.20 <sup>A</sup> (2.56)	10.94 <sup>A</sup> (3.60)	7.06 <sup>A</sup> (1.51)
<b>Mg levels</b>					
Mg <sub>0</sub>	6.34 <sup>B</sup> (1.22)	3.84 <sup>B</sup> (0.45)	8.44 <sup>B</sup> (2.16)	9.59 <sup>B</sup> (2.81)	6.62 <sup>B</sup> (1.33)
Mg <sub>100</sub>	6.40 <sup>AB</sup> (1.25)	3.93 <sup>A</sup> (0.47)	8.68 <sup>A</sup> (2.29)	9.85 <sup>A</sup> (2.96)	6.96 <sup>A</sup> (1.47)
Mg <sub>300</sub>	6.49 <sup>A</sup> (1.28)	4.01 <sup>A</sup> (0.49)	8.76 <sup>A</sup> (2.33)	9.91 <sup>A</sup> (2.99)	7.03 <sup>A</sup> (1.50)
<b>Interaction</b>					
Ca <sub>0</sub> Mg <sub>0</sub>	*6.15 <sup>e</sup> (1.15)	3.39 <sup>f</sup> (0.35)	7.81 <sup>h</sup> (1.85)	8.33 <sup>h</sup> (2.11)	6.37 <sup>g</sup> (1.23)
Ca <sub>100</sub> Mg <sub>0</sub>	6.29 <sup>cde</sup> (1.21)	3.76 <sup>de</sup> (0.43)	8.37 <sup>ef</sup> (2.12)	9.00 <sup>f</sup> (2.45)	6.55 <sup>fg</sup> (1.31)
Ca <sub>300</sub> Mg <sub>0</sub>	6.42 <sup>abcd</sup> (1.25)	3.85 <sup>de</sup> (0.45)	8.57 <sup>de</sup> (2.22)	10.17 <sup>d</sup> (3.12)	6.72 <sup>def</sup> (1.37)
Ca <sub>500</sub> Mg <sub>0</sub>	6.50 <sup>abc</sup> (1.28)	4.29 <sup>ab</sup> (0.56)	9.00 <sup>b</sup> (2.45)	10.84 <sup>b</sup> (3.54)	6.85 <sup>cde</sup> (1.42)
Ca <sub>0</sub> Mg <sub>100</sub>	6.23 <sup>de</sup> (1.18)	3.67 <sup>e</sup> (0.41)	8.03 <sup>gh</sup> (1.95)	8.77 <sup>g</sup> (2.33)	6.72 <sup>ef</sup> (1.37)
Ca <sub>100</sub> Mg <sub>100</sub>	6.37 <sup>bcde</sup> (1.23)	3.80 <sup>de</sup> (0.44)	8.59 <sup>de</sup> (2.23)	9.21 <sup>e</sup> (2.56)	6.92 <sup>bcde</sup> (1.45)
Ca <sub>300</sub> Mg <sub>100</sub>	6.45 <sup>abcd</sup> (1.26)	3.93 <sup>cd</sup> (0.47)	8.81 <sup>bcd</sup> (2.35)	10.47 <sup>c</sup> (3.31)	7.04 <sup>abc</sup> (1.51)
Ca <sub>500</sub> Mg <sub>100</sub>	6.55 <sup>ab</sup> (1.31)	4.33 <sup>a</sup> (0.57)	9.28 <sup>a</sup> (2.61)	10.97 <sup>ab</sup> (3.62)	7.15 <sup>ab</sup> (1.55)
Ca <sub>0</sub> Mg <sub>300</sub>	6.37 <sup>bcde</sup> (1.23)	3.72 <sup>de</sup> (0.42)	8.13 <sup>fg</sup> (2.00)	8.81 <sup>g</sup> (2.35)	6.87 <sup>cde</sup> (1.43)
Ca <sub>100</sub> Mg <sub>300</sub>	6.45 <sup>abcd</sup> (1.26)	3.89 <sup>cde</sup> (0.46)	8.66 <sup>cd</sup> (2.27)	9.28 <sup>e</sup> (2.61)	6.97 <sup>abcd</sup> (1.47)
Ca <sub>300</sub> Mg <sub>300</sub>	6.50 <sup>abc</sup> (1.28)	4.09 <sup>bc</sup> (0.51)	8.91 <sup>bc</sup> (2.41)	10.55 <sup>c</sup> (3.35)	7.11 <sup>ab</sup> (1.53)
Ca <sub>500</sub> Mg <sub>300</sub>	6.62 <sup>a</sup> (1.33)	4.33 <sup>a</sup> (0.57)	9.33 <sup>a</sup> (2.63)	11.00 <sup>a</sup> (3.65)	7.18 <sup>a</sup> (1.56)

\*Transformed values ( $\text{Arc sin}^{-1}\sqrt{\text{percent}}$ ), original values in parenthesis (% nutrient). †Within a column, means followed by the same letter are not significantly different at the 0.05 level of probability by DMRT.





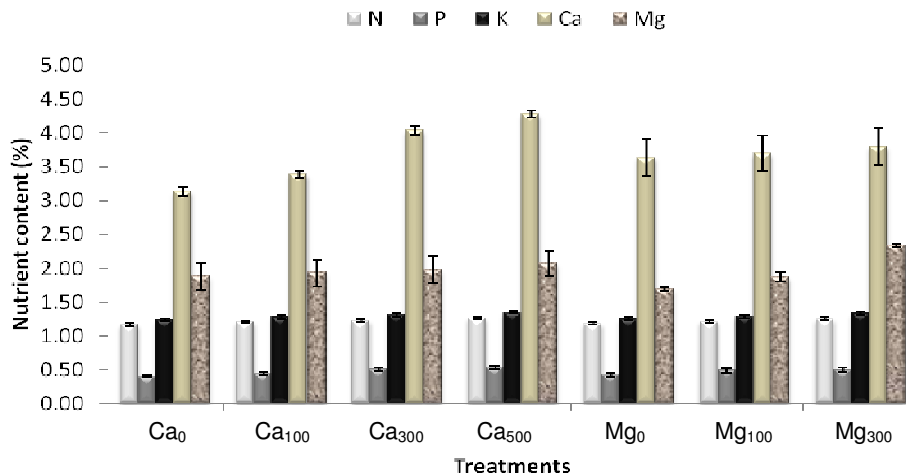
**Figure 1a.** Mean effect of Ca and Mg on nutrient composition of growing media at vegetative stage of *Cymbidium* hybrid. Bars are  $\pm$ SE.



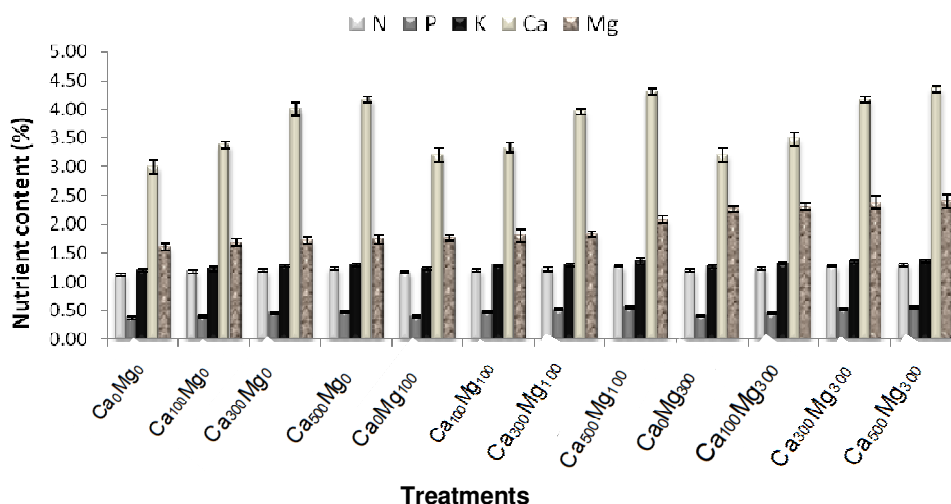
**Figure 1b.** Interaction effect of Ca and Mg on nutrient composition of growing media at vegetative stage of *Cymbidium* hybrid. Bars are  $\pm$ SE

Ca levels of 300 and 500 mg kg<sup>-1</sup>. The mean effect of Mg significantly [F (2, 24) = 3.4, p ≤ 0.05] influenced the nutrient status of *Cymbidium* leaf over control (Mg<sub>0</sub>). The highest N, P, K, Ca and Mg content was 1.28, 0.50, 2.33, 3.0 and 1.5%, respectively in the treatment Mg<sub>300</sub>. The Mg levels of 100 and 300 mg kg<sup>-1</sup> was found non-significant [F (2, 24) = 3.4, p ≤ 0.05] in nutrient content of *Cymbidium* hybrid at reproductive stage during the period of investigation. The interaction effect of Ca and Mg significantly [F (6, 24) = 2.51, p ≤ 0.05] influenced the nutrient content of *Cymbidium* leaf at reproductive stage.

The highest N, P, K, Ca and Mg content was 1.33, 0.57, 2.63, 3.65 and 1.56%, respectively in the treatment Ca<sub>500</sub>Mg<sub>300</sub> and was at par with the treatment Ca<sub>500</sub>Mg<sub>100</sub> throughout the period of investigation. The results indicated that the Ca level from 0 to 500 mg kg<sup>-1</sup> in combination with Mg at 300 mg kg<sup>-1</sup> were at par with the combination of Ca 0 to 500 mg kg<sup>-1</sup> and Mg at 100 mg kg<sup>-1</sup> throughout the period of investigation. The Mg levels of 4 to 8 g kg<sup>-1</sup> observed in the plant shoots were considered low for growth and flowering of orchid (Jones et al., 1991; Arditti, 1992).



**Figure 2a.** Mean effect of Ca and Mg on nutrient composition of growing media at reproductive stage of *Cymbidium* hybrid. Bars are  $\pm$ SE.



**Figure 2b.** Interaction effect of Ca and Mg on nutrient composition of growing media at reproductive stage of *Cymbidium* hybrid. Bars are  $\pm$ SE.

**Nutrient content of growing media**

Application of different graded levels of Ca and Mg gradually increased the nutrient of growing media during the period of investigation at vegetative stage (Figure 1a and b). The nutrient content of growing media gradually increased with increasing levels of Ca and Mg. The highest N, P, K, Ca and Mg content in the growing media with the mean effect of Ca at 500 mg kg<sup>-1</sup> was 1.2, 0.46, 1.3, 4.21 and 2%, respectively. Similarly, the above nutrient content was highest of 1.15, 0.44, 1.30, 3.75 and 2.29%, respectively with the mean effect of Mg at 300 mg kg<sup>-1</sup>. Comparing the interaction effect of Ca and Mg, it was observed that the highest N, P, K, Ca and Mg content in the growing media was 1.23, 0.48, 1.33, 4.31 and 2.36%, respectively in the treatment Ca<sub>500</sub>Mg<sub>300</sub>.

The nutrient content of growing media gradually increased with increasing levels of Ca and Mg during the period of investigation at reproductive stage of *Cymbidium* hybrid (Figure 2a and b). The highest of N, P, K, Ca and Mg content in the growing media was 1.27, 0.53, 1.34, 4.28 and 2%, respectively in the treatment Ca<sub>500</sub> mg kg<sup>-1</sup> at reproductive stage. Similarly, the mean effect of Mg at 300 mg kg<sup>-1</sup> recorded the highest of nutrient content of 1.25, 0.49, 1.33, 3.8 and 2.34%. The nutrient content of growing media gradually increased with the interaction effect of different levels of Ca and Mg at reproductive stage and recorded the highest N, P, K, Ca and Mg content of 1.30, 0.56, 1.37, 4.35 and 2.4%, respectively in the treatment Ca<sub>500</sub>Mg<sub>300</sub>. Peak et al. (1998) studied nutrient concentration in *Cymbidium goeringii* organs in 8 different media and observed that

**Table 6.** Simple correlation and linear regression equation that describe the growth and flowering parameter of *Cymbidium* hybrid (y) as a function of Ca and Mg content of growing media(x).

Nutrient content of growing media	Correlation coefficients	Linear regression equations	r <sup>2</sup>
<b>Plant height</b>			
Ca	0.656*	y = 3.607x + 52.06	0.430*
Mg	0.895**	y = 8.575x + 48.71	0.801**
<b>Number of vegetative shoot clump<sup>-1</sup></b>			
Ca	0.519	y = 1.002x + 7.258	0.269
Mg	0.847**	y = 2.849x + 5.439	0.717**
<b>Number of leaves clump<sup>-1</sup></b>			
Ca	0.875**	y = 2.503x + 32.74	0.765**
Mg	0.397	y = 1.979x + 38.00	0.157
<b>Spike length</b>			
Ca	0.719**	y = 8.655x + 44.30	0.516**
Mg	0.822**	y = 16.22x + 44.55	0.675**
<b>Number of florets spike<sup>-1</sup></b>			
Ca	0.611*	y = 2.691x + 4.494	0.372*
Mg	0.907**	y = 6.551x + 1.609	0.822**
<b>Number of spikes clump<sup>-1</sup></b>			
Ca	0.730**	y = 1.476x + 0.464	0.533**
Mg	0.816**	y = 2.702x + 0.633	0.666**

\*\* Significant at the 0.01 level, \* Significant at the 0.05 level

higher concentration of P, K and Mg was found in roots, while N and Ca was higher in leaves, when grown in sphagnum moss.

#### Correlation studies on nutrient content of growing media

The results (Table 6) show that Ca and Mg content of growing media were significantly positively correlated with growth and flowering parameter of *Cymbidium* hybrid. Between the nutrient, Mg content of growing media was more significantly positively correlated with growth and flowering parameter than Ca content of growing media. Also, Mg content of growing media recorded highest coefficient of determination (R<sup>2</sup>) and contributed 80.1, 71.7, 67.5, 82.2 and 66.6% variation towards plant height, number of vegetative shoot clump<sup>-1</sup>, spike length, number of florets spike<sup>-1</sup> and number of spikes clump<sup>-1</sup>, respectively. It has been observed that Ca and Mg content of growing media accounted for 53.3 and 66.6% variation in number of spikes clump<sup>-1</sup>. The Mg content of growing media recorded highest correlation with plant height (0.895\*\*), number of vegetative shoots clump<sup>-1</sup> (0.847\*\*), spike length (0.822\*\*), number of

florets spike<sup>-1</sup> (0.907\*\*) and number of spikes clump<sup>-1</sup> (0.816\*\*). However, the Ca content was highly correlated with number of leaves clump<sup>-1</sup> (0.875\*\*). The results of the present investigation are in agreement with the findings of Naik et al. (2006), who reported that the Ca and Mg content of orchid substratum was significantly correlated with flowering parameter of different epiphytic orchids.

#### Conclusions

The plant growth parameters like plant height, vegetative shoot clump<sup>-1</sup> and number of leaves clump<sup>-1</sup> were recorded highest value at the highest doses of Ca (500 mg kg<sup>-1</sup>) and Mg (300 mg kg<sup>-1</sup>). Further, there is no significant difference among the Ca at 300 and 500 mg kg<sup>-1</sup> in increasing the growth parameter. Hence, application of Ca at 300 and Mg at 300 mg kg<sup>-1</sup> was found suitable for vegetative growth of *Cymbidium* hybrid. The results confirmed that the flowering parameters like spike length, rachis length, number of floret spike<sup>-1</sup> and number of spikes clump<sup>-1</sup> were gradually increased with increasing doses of both Ca and Mg. Application of Mg from 0 to 300 mg kg<sup>-1</sup> resulted in increased number of standard spikes and decreased the number of

intermediate spikes. It is concluded that the combination of Ca at 500 and Mg at 300 mg kg<sup>-1</sup> was found promising for flowering and spike production of *Cymbidium* hybrid. Furthermore, there is better maintenance of nutrient in the growing media and also in the different plant parts with the above applications of Ca and Mg.

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