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# 서양 심비디움 양액재배에서의 무기물 흡수

송성준 · 부창호[1] · 유장걸[1]
제주대학교 방사능이용연구소, 제주대학교 농과대학 농화학과

## Mineral Absorption by *Cymbidium* Jungfrau in the Solution Culture

Sung-Jun Song, Chang-Ho Boo[1] and Zang-Kual U.[1] *(Applied Radioisotope Research Institute, Ara-dong, Cheju-shi, Cheju-do 690-756, Korea, Tel: 064-754-2313, Fax: 064-755-6186. [1]Department of Agricultural Chemistry, College of Agriculture, Ara-dong, Cheju-shi, Cheju-do 690-756, Korea, Tel:064-754-3342, Fax:064-756-3351)*

**ABSTRACT** : N($^{15}N$) and P($^{32}P$) absorption by 2 year-old *Cymbidium* Jungfrau in solution culture were investigated. Growth, photosynthesis rate, chlorophyll content and mineral composition of *Cymbidium* in the solution culture with bark or granular rockwool were compared with these parameters in the conventional pot culture. Nitrogen absorption by *Cymbidium* was higher in full sunlight than in 60 % of sunlight while P absorption was higher in 60% of sunlight. Sixty seven % of N absorbed in plant was redistributed to the bulb (39%) and leaves (28%) while 46% of P absorbed was found in the bulb (36.2%) and leaves (10.2%). Accumulation of P in leaves was 3-fold lower than that of N. N and P absorption in 0.5 or 1 year- old daughter plant growing vigorously were greater than in immature daughter or mother plant. The absorption rate of phosphorus in *Cymbidium* was 350-fold lower than that of barley. Greater shoot length and bulb diameter, and higher fresh weight, photosynthesis rate and chlorophyll content were observed in the solution culture than in the conventional pot culture. Solution culture had also more content of N, P, K and Mg in leaves, bulb and root than conventional pot culture but did not that of Ca. A large part of the nutrient absorption was occurred during vegetative growth. Also, There was no difference between bark and rockwool in the solution culture due to the improvement of poor dispersion of nutrient solution in bark.

**Key words** : *Cymbidium*, nitrogen, phosphorus, ion absorption, redistribution, solution culture

### Introduction

Fertilization of orchids, so far, has depended on the grower's own experience. Furthermore it has been generally assumed that orchid plants required little fertilizer because of their slow growth[15]. It was found that however, a similar amount of mineral nutrients as for other plants was essential in doing tissue culture of orchids[7,12]. Monthly fertilizer application resulted in optimal growth and flowering in pot culture[1]. Weekly liquid fertilization was best for growth in the fir bark[5].

Solution culture has often led to excellent growth and productivity[14]. Although solution culture has been introduced in the commercial orchid cultivation to promote growth and to increase cut flower quality, there is only a limited information on the absorption and redistribution of mineral nutrition of orchids. Therefore, more information on nutrient absorption and redistribution to bulb and shoot of the orchid plant is needed for nutrition management in commercial solution culture. Inadequate supply of nutrients affects plant growth and flowering; for instance, over-fertilization of N promotes vegetative growth[9] but inhibits flowering[3], and reducing flower production. Also, the optimal nutrient requirement may vary with species and varieties[3,11].

The present study was set out to investigate the nutrient absorption and redistribution in *Cymbidium* and to obtain basic data for nutritional management in solution culture.

## Materials and Methods

### Experiments on absorption and redistribution of nitrogen($^{15}N$) and phosphorus($^{32}P$) by *Cymbidium*

Two year-old *Cymbidium* Jungfrau were transplanted in pots(17.7 x 23.4, H x D cm) containing bark or granular rockwool and placed in vinyl house under full sunlight or 40% reduced sunlight(using black nets) for 2 weeks. Next, plants were watered with 300 ml of 1/10 strength of nutrient solution with 5 atom% of $^{15}N$ as $NO_3$-N and 35 μCi of $^{32}P$ everyday for 3 days. At the end of the third day, leaves, bulbs and roots were cut and dried at 70℃ for 3 days. Halves of the dried samples were digested in $H_2SO_4$-$H_2O_2$ and the 32P activity was counted for 2 min in a liquid scintillation counter(Packard 2700TR, USA)[6,16,17]. The other halves of the samples for $^{15}N$ measurement were stored for about 6 months in the radioisotope laboratory for the decay of $^{32}P$ (more than 10 times of the half life time of $^{32}P$). After that period the samples were ground to fine powder by a roller mill. Twenty mg of ground power was loaded in the elemental analyzer (Fisons Instrument EA1108-CHNSO, Italy) attached with the mass spectrometer (VG Isotec Sira II, England) to determine the $^{15}N$[6].

### Experiments on growth and mineral composition of *Cymbidium* in solution culture using bark and granular rockwool

Two year old *Cymbidium* plants were transplanted in pots(17.7×23.4, H×D cm) containing bark or granular rockwool and grown in the vinyl house for 200 days. During the vegetative growth period (100 days after transplanting) 300 ml of nutrient solution containing 3.27 mM $KNO_3$, 1.65 mM $Ca(NO_3)_2 \cdot 4H_2O$, 2.72 mM $NH_4H_2PO_4$ and 0.55 mM $MgSO_4 \cdot 7H_2O$ as macro nutrients was supplied for each pot once a day. For next 100 days (bulb expansion and flowering phase), 300 ml of nutrient solution containing 3 mM $KH_2PO_4$, 1.50 mM $Ca(NO_3)_2 \cdot 4H_2O$, 1.42 mM $NH_4H_2PO_4$ and 1.50 mM $MgSO_4 \cdot 7H_2O$ was given to each pot to reduce N concentration to the half in the nutrient solution. Micro nutrients 2.3 μM Fe-EDTA, 48.5 μM $H_3BO_3$, 8.96 μM $MnSO_4 \cdot 4H_2O$, 1.74 μM $ZnSO_4 \cdot 7H_2O$ and 0.08 μM $Na_2MoO_4 \cdot 2H_2O$ were added in the nutrient solution during the whole experimental period. On the other hand 20g of organic fertilizer(Bokasi, Cheju organic agriculture group) were placed monthly on each pot in the conventional pot culture. Each plot consisted of three replications. At 60 days and 180 days after transplanting shoot length and bulb diameter were measured. Plants were harvested at 100 days and 200 days after transplanting and the percentage of fresh weight increase was determined. Next, plants were divided into leaves, bulbs and roots and dried at 70℃ for 3 days. Dried samples were digested in $H_2SO_4$-$H_2O_2$[2]. Nitrogen was determined colorimetrically by indophenol blue[2]. P, K, Ca, and Mg content were analyzed by the inductively coupled plasma spectrophotometer(Jobin Yvon JY138 ultrace, France).

One hundred and fifty days after transplanting the SPAD value(Minolta chlorophyll meter SPAD-502, Japan) which represents chlorophyll content indirectly was measured. Photosynthesis rate was analyzed by the LI-COR photosynthesis measuring system(LI6200, USA).

### Statistical analysis

A SAS program was used for statistical analysis; mean values were compared by Duncan's multiple range test at 5 % level[13].

## Results and Discussion

### Absorption and redistribution of nitrogen($^{15}N$) and phosphorus($^{32}P$)

*Cymbidium* differs from most mono-cotyledon plants by their morphological and physiological properties. *Cymbidium* roots are enveloped by a fleshy velamen layer acting like sponge when wet[11] and, therefore, being able to hold water and nutrients for a long time. The bulb also functions as nutrient reservoir. Therefore, nutrient absorption by roots and their redistribution to the bulb and leaves in *Cymbidium* can not be considered to be the same as those in the general monocotyledon plants. On the other hand, as *Cymbidium* has the relatively lower light saturation point[8], it is grown conventionally under 30~50 % shaded vinyl house with black nets. But, especially in spring and autumn *Cymbidium* is exposed to full sunlight to accumulate more assimilators in the plant, thus vegetative growth and flowering capability are being enhanced[8].

Absorption and redistribution of nitrogen($^{15}N$) and phosphorus($^{32}P$) of *Cymbidium* were compared under the

Table 1. N absorption and redistribution of *Cymbidium* Jungfrau as affected by the different light intensities.

| Light treatment | Plant part | N absorption and redistribution(㎍/g fw · d) | | | | |
|---|---|---|---|---|---|---|
| | | Immature shoot | 0.5 year shoot | 1 year shoot | 2 year shoot | Sum |
| 60% of sunlight | Leaf | 7.78 | 6.10 | 6.61 | 2.60 | 23.1 |
| | Bulb | 7.76 | 9.37 | 11.9 | 5.90 | 34.9 |
| | Root | -* | 6.98 | 13.9 | 9.93 | 30.8 |
| | Sum | 15.5 | 22.5 | 32.4 | 18.4 | 88.8 |
| Full sunlight | Leaf | 15.9 | 8.29 | 13.4 | 6.27 | 43.9 |
| | Bulb | 16.6 | 19.1 | 13.9 | 7.58 | 57.2 |
| | Root | - | 17.1 | 17.1 | 11.7 | 45.9 |
| | Sum | 32.5 | 44.5 | 44.4 | 25.6 | 147 |

*; no root

different light intensities(table 1, 2). The amount of N absorbed was more in the plants grown under the full sunlight than under 60% of the full sunlight. N absorption was most absorbed in the bulbs, and in 0.5 or 1 year-old daughter plants showing vigorous growth(data not shown). However, P absorption depending on light intensity was opposite to that of N. Most of P absorbed was in the root and P redistribution to the bulbs or leaves was quite lower than that of N. P absorbed and redistributed was highest in 0.5 year-old daughter plant which seemed to be metabolically active.

In general, the ion absorption rate of slow growing *Cymbidium* was thought to be low as compared with fast growing barley which is a typical monocotyledon plant. The phosphorus absorption rate of barley was calculated by the Michaelis-Menten equation[10] [$I = (I_{max} \cdot C)/(K_m + C)$, where I = absorption rate, $I_{max}$ = maximal rate of absorption, $K_m$ = Michaelis-Menten constant and is the concentration, C = concentration of ion in solution at the root surface]. There were $K_m$ = 4.58 μM and Imax=163 $\mu molg^{-1}fwd^{-1}$ in 35 day-old normal barley plant[4]. Two hundreds and seventy two μM P in nutrient solution

Table 2. P absorption and redistribution of *Cymbidium* Jungfrau as affected by the different light intensities.

| Light treatment | Plant part | N absorption and redistribution(㎍/g fw · d) | | | | |
|---|---|---|---|---|---|---|
| | | Immature shoot | 0.5 year shoot | 1 year shoot | 2 year shoot | Sum |
| 60% of sunlight | Leaf | 1.09 | 0.11 | 0.61 | 0.11 | 1.92 |
| | Bulb | 1.74 | 0.76 | 3.25 | 1.81 | 7.56 |
| | Root | -* | 7.86 | 3.15 | 3.69 | 14.7 |
| | Sum | 2.83 | 8.73 | 7.01 | 5.61 | 24.2 |
| Full sunlight | Leaf | 0.69 | 0.05 | 0.92 | 0.10 | 1.76 |
| | Bulb | 1.61 | 1.85 | 0.83 | 1.55 | 5.84 |
| | Root | - | 3.03 | 1.91 | 1.54 | 6.48 |
| | Sum | 2.30 | 4.93 | 3.66 | 3.19 | 14.1 |

*; no root

Table 3. P absorption by Cymbidium Jungfrau during daytime.

| Time(hr) | P absorption(ng/g fw · 3hr) | | | |
|---|---|---|---|---|
| | Leaf | Bulb | Root | Sum |
| 7～10 | 1.80 | 67.7 | 99.8 | 170 |
| 10～13 | 3.00 | 59.9 | 150 | 212 |
| 13～16 | 5.00 | 76.0 | 106 | 187 |

supplied for *Cymbidium* in this study was used for. P absorption per day was calculated as 160 $\mu molg^{-1}fw$ (4.97 $mgg^{-1}fw$). From the data, it follows that P absorption rate of *Cymbidium* was 350-fold lower than that of barley. In our estimation, there was no consideration on root properties between them. If the velamen layer in *Cymbidium* root had been taken off, its P absorption rate measured might be much lower than the present estimated absorption rate.

On the other hand, P absorption of *Cymbidium* was higher at 10 a.m. to 1 p.m. than at 7 a.m. to 10 a.m. or 1 p.m. to 4 p.m. , which indicated that nutrient uptake of orchid was related with light intensity(table 3).

## Growth, photosynthesis rate, chlorophyll content and mineral composition of Cymbidium solution and conventional pot-cultured

### Growth, photosynthesis rate and chlorophyll content

The solution culture with bark or granular rockwool gave longer shoot length and bigger bulb diameter than in the conventional pot culture(table 4). Also, the highest increase in percentage (%) of fresh weight was observed in the solution culture using granular rockwool, bringing about the vigorous vegetative growth. Its increase in percentage was more pronounced at the 200th day than at the 100th day.

Tree bark has been often used for orchid's pot culture as one of the best potting media because it has relatively high air and water holding capacities[11]. Since the granular bark used for mature *Cymbidium* had poor water dispersion, a special device was required for uniform watering. On the other hand, the granular rockwool showed some advantages in the solution culture, having high water holding capacity and good water dispersion[14] and good contact of roots with nutrients. Only an arrow dripper was enough for rockwool medium. Therefore, in this experiment a self-made 6 hole punched tube was installed around the plant in the pot filled with bark medium, giving the same growth as good as in granular rockwool.

Table 4. Growth, photosynthesis and chlorophyll content of *Cymbidium* Jungfrau in the solution culture using bark or rockwool and the conventional pot culture.

| Cultivation method | Shoot length(cm) | | Bulb diameter(cm) | | Increase in percentage of fresh weight(%) | | Photosynth-esis | Chlorophyll content |
|---|---|---|---|---|---|---|---|---|
| | I[4] | II[5] | I[4] | II[5] | I[6] | II[7] | | |
| SBC[1] | 64.3a[8] | 80.7a | 2.76a | 3.50a | 56.0b | 113b | 7.80a | 56.3a |
| SRC[2] | 66.4a | 80.4a | 2.89a | 3.52a | 73.2a | 131a | 9.36a | 55.3a |
| CPC[3] | 62.7b | 73.5b | 2.72a | 3.13b | 46.2c | 94.7c | 5.75b | 48.4b |

1; Solution culture using bark,
2; Solution culture using granular rockwool
3; Conventional pot culture using bark
4; 60 days after transplantation
5; 180 days after transplantation
6; 100 days after transplantation
7; 200 days after transplantation
8; Duncan' s multiple range test at 5% level

Photosynthesis rate and chlorophyll content were significantly higher in the solution culture than in the conventional pot culture.(table 4).

### Mineral composition

Mineral composition of *Cymbidium* plants taken at 100 and 200 days after transplanting is shown in table 5. N, P, K and Mg contents in leaf, bulb and root were higher in the solution culture than in the conventional pot culture. The differences were greater at the day 200 than at the day 100. However, there was no difference in Ca content between the cultivation methods. Mineral contents in leaves of *Cymbidium* grown in the solution culture were relatively sufficient while their content in leaves of *Cymbidium* grown in the conventional pot culture were not[3,11]. Therefore, the solution culture is considered to be an efficient cultivation method to maintain the optimal chemical composition in *Cymbidium*.

The amount of mineral nutrients absorbed by 2 year old *Cymbidium* during the vegetative growth(100 days after transplanting), and bulb expansion and flowering stage(100 days after vegetative growth) was calculated in table 6. N, P, K, Ca and Mg was mainly absorbed during the vegetative growth stage and their amounts were higher in the solution culture than in the conventional pot culture. In the solution culture, amounts of N, P, K, Ca and Mg absorbed during 200 days including vegetative growth, bulb expansion and flowering stage were 2.71 - 3.25 g, 0.53 - 0.63 g, 2.09 - 2.65 g, 1.37 - 1.62 g and 0.50 - 0.65 g, respectively. Therefore, N, P, K, Ca and Mg absorptions per day were estimated as 7.15 - 9.75 mg, 1.55 - 2.05 mg, 3.35 - 6.20

Table 5. Mineral composition of *Cymbidium* Jungfrau grown in the solution culture using bark or granular rockwool and the conventional pot culture.

| Cultivation method | Plant part | Mineral composition(%, dry matter base) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | N | | P | | K | | Ca | | Mg | |
| | | I[4] | II[5] | I | II | I | II | I | II | I | II |
| SBC[1] | Leaf | 1.65 | 1.96 | 0.22 | 0.29 | 1.68 | 1.40 | 0.62 | 1.0 | 1.17 | 0.26 |
| | Bulb | 1.94 | 2.01 | 0.37 | 0.38 | 1.37 | 1.43 | 1.04 | 1.16 | 0.26 | 0.35 |
| | Root | 1.91 | 1.84 | 0.59 | 0.45 | 1.96 | 1.37 | 1.02 | 0.84 | 0.68 | 0.77 |
| | Sum | 5.50 | 5.81 | 1.18 | 1.12 | 5.01 | 4.20 | 2.68 | 3.01 | 1.1 | 1.38 |
| SRC[2] | Leaf | 1.76 | 2.26 | 0.22 | 0.34 | 1.75 | 1.85 | 0.80 | 0.85 | 0.22 | 0.24 |
| | Bulb | 1.63 | 2.22 | 0.29 | 0.43 | 1.27 | 1.65 | 0.91 | 1.23 | 0.28 | 0.50 |
| | Root | 1.66 | 1.81 | 0.49 | 0.51 | 1.22 | 1.38 | 0.93 | 0.94 | 0.63 | 0.79 |
| | Sum | 5.05 | 6.29 | 1.00 | 1.28 | 4.24 | 4.88 | 2.64 | 3.02 | 1.13 | 1.53 |
| CPC[3] | Leaf | 1.35 | 1.18 | 0.17 | 0.18 | 1.13 | 1.23 | 0.82 | 0.73 | 0.18 | 0.17 |
| | Bulb | 1.07 | 0.96 | 0.21 | 0.23 | 0.64 | 0.88 | 1.08 | 0.96 | 0.22 | 0.24 |
| | Root | 1.53 | 1.35 | 0.22 | 0.23 | 0.84 | 1.23 | 1.09 | 0.83 | 0.74 | 0.64 |
| | Sum | 3.95 | 3.49 | 0.60 | 0.64 | 2.61 | 3.34 | 2.99 | 2.52 | 1.14 | 1.05 |

1; Solution culture using bark,
2; Solution culture using granular rockwool
3; Conventional pot culture using bark
4; 100 days after transplantation
5; 200 days after transplantation

Table 6. Average mineral absorption by two year-old *Cymbidium* Jungfrau plants grown in the solution culture using bark or granular rockwool and the conventional pot culture.

| Cultiva-tion method | Plant part | Mineral absorption(g/plant) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | N | | P | | K | | Ca | | Mg | |
| | | I[4] | II[5] | I | II | I | II | I | II | I | II |
| SBC[1] | Leaf | 1.06 | 1.36 | 0.16 | 0.21 | 1.04 | 1.17 | 0.42 | 0.65 | 0.11 | 0.18 |
| | Bulb | 0.66 | 0.86 | 0.13 | 0.18 | 0.45 | 0.59 | 0.31 | 0.47 | 0.09 | 0.14 |
| | Root | 0.58 | 0.49 | 0.24 | 0.14 | 0.47 | 0.33 | 0.27 | 0.25 | 0.19 | 0.18 |
| | Sum | 2.30 | 2.71 | 0.53 | 0.53 | 1.96 | 2.09 | 1.00 | 1.37 | 0.39 | 0.50 |
| SRC2 | Leaf | 1.10 | 1.62 | 0.14 | 0.25 | 1.03 | 1.54 | 0.48 | 0.69 | 0.13 | 0.20 |
| | Bulb | 0.73 | 0.98 | 0.12 | 0.19 | 0.46 | 0.71 | 0.41 | 0.58 | 0.12 | 0.21 |
| | Root | 0.51 | 0.65 | 0.17 | 0.19 | 0.38 | 0.40 | 0.27 | 0.35 | 0.19 | 0.24 |
| | Sum | 2.34 | 3.25 | 0.43 | 0.63 | 1.87 | 2.65 | 1.16 | 1.62 | 0.44 | 0.65 |
| CPC3 | Leaf | 0.62 | 0.80 | 0.08 | 0.12 | 0.52 | 0.83 | 0.38 | 0.49 | 0.08 | 0.11 |
| | Bulb | 0.32 | 0.48 | 0.06 | 0.12 | 0.19 | 0.44 | 0.32 | 0.48 | 0.06 | 0.12 |
| | Root | 0.46 | 0.45 | 0.07 | 0.08 | 0.25 | 0.47 | 0.33 | 0.28 | 0.22 | 0.21 |
| | Sum | 1.40 | 1.73 | 0.21 | 0.32 | 0.96 | 1.74 | 1.03 | 1.25 | 0.36 | 0.44 |

1; Solution culture using bark,
2; Solution culture using granular rockwool
3; Conventional pot culture using bark
4; 100 days after transplantation
5; 200 days after transplantation

mg, 3.35 - 4.60 mg, 1.25 - 2.00 mg, respectively.

In conclusion, the soilless culture was an efficient technique for promoting growth and increasing photosynthesis rate and chlorophyll content of *Cymbidium* by facilitating the mineral absorption of root. Also, the conventional pot culture system with bark can be easily converted to the solution culture by tubing the pot, which will help to save labor and manage the nutrient solution. N($^{15}$N) redistribution to leaves was more redistributed than P($^{32}$P). Therefore, nitrogen supplement should be controlled to make proper growth of orchid because nitrogen supply is important for the flowering induction[3]. The best time for suppling nutrient solution was considered to be 10 a.m. to 1 p.m. at which more nutrient uptake occured.


## 요 약

양액 재배에서 서양 심비디움(*Cymbidium* Jungfrau)의 질소와 인 흡수 및 재분배양상을 조사하였고 양액 재배와 관행인 화분 재배간의 심비디움의 생육, 광합성, 엽록소 함량, 무기물 함량을 비교하였다. 질소($^{15}$N)의 흡수는 자연광의 60% 광도에서 보다 자연광에서 많았고, 인($^{32}$P)의 흡수는 이와 반대의 경향을 나타냈다. 흡수된 질소($^{15}$N)는 벌브에 가장 많이 존재하였고 인($^{32}$P)은 뿌리와 벌브에 많이 있었으며 잎으로 재분배된 양은 10% 정도였다. 2년생 어미주보다는 0.5 또는 1년생 새끼 주에서 질소($^{15}$N)와 인($^{32}$P)의 흡수가 더 많았다. 심비디움의 인 흡수율은 보리의 경우 보다 약 350 배정도 낮았다. 심비디움의 초장, 벌브 크기, 생체중가율, 광합성 능, 엽록소 함량은 바크 또는 입상 암면을 배지로 이용하는 양액 재배가 일반 관행재배보다 더 높았다. 특히, 양액 재배에서 사용된 바크와 입상 암면간에 생육과 무기물함량이 차이를 보이지 않았다. 또한, 질소, 인, 칼륨, 마그네슘의 함량은 양액 재배에서 높았으나 칼슘은 관행과 차이가 없었고 무기물의 흡수는 주로 영양생장기간 동안에 이루어졌다.



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## References


1. Adams, J. D.(1970). A tailored plan, Amer. Orchid Soc. Bull., 39:139-142.
2. Ahn, Y. S.(1987). Plant analysis for evaluating plant nutrition, In International training workshop on soil test and plant analysis, RDA & FFTC/ASPAC.
3. Arditti, J.(1992). Fundamentals of orchid biology, John Wiley & Sons, New York, p.196-207.
4. Drew, M. C., Saker, L. R., Barber, S. A. and Jenkins, W.(1984). Changes in the kinetics of phosphate and potassium absorption in nutrient-deficient barley roots measured by a solution-depletion technique, Planta, 160:490-499.
5. Fennell, T.(1951). Food for thought on orchid feeding, Amer. Orchid. Soc. Bull., 20:455-459.
6. IAEA(1976). Tracer manual on crops and soils, Technical Reports Series No. 171.
7. Kim, K. W. and Kato, S.(1983). Morphological studies on organ formation in the *Cymbidium* shoot apex in vitro., J. Japan. Soc. Hort. Sci., 51(4):443-448.
8. Komori T. (1988). Management and basic technique of *Cymbidium*, In New technology of western orchid's cultivation, Editing Committe of Agriculture and Horticulture, Seibundou Sinkousha, pp. 33 ~ 49 (in japanese)
9. Lunt, O. R. and Kofranek, A. M.(1961). Exploratory nutritional studies on *Cymbidium* using two textures of fir bark., Amer. Orchid Soc. Bull., 30:297-302.
10. Mengel, K. and Kirkby, E. A.(1981). Principles of plant nutrition, International Potash Institute, Berne, Switzerland.
11. Poole, H. A. and Sheehan, T. J.(1982). Mineral nutrition of orchids. In Orchid biology: Reviews and perspective, ed. J. Arditti, Cornell University Press, Ithaca, p.195-212.
12. Sagawa, Y. and Shoji, T.(1966). Clonal propagation of *Cymbidium* through shoot tip culture, Amer. Orchid Soc. Bull., 35:118-122.
13. SAS Institute Inc(1985). SAS/STAT guide for personal computers, ver. 6.0ed.
14. Schwarz, M.(1995). Soilless culture management, Springer-Verlag, New York.
15. Scully, R. M.(1951). Should orchids be fertilized?, Amer. Orchid Soc. Bull. 20:137-139.
16. Song, S. J. and U. K. Z.(1996). Development of the phosphorus diagnosis method for P-fertilization of citrus tree

using $^{32}P$ bioassay, J. Kor. Soc. Hort. Sci., 37(5):691-695

17. U., K. Z. and Song, S. J.(1988). Phosphorus-status diagnosis of the crop plant using $^{32}P$ bioassay technique, Cheju. Appl. Radioisotope. Res. Inst. Ann. Report, 3:11-20