

Mineral absorption by *Cymbidium* Jungfrau in the solution culture

Song Sung-Jun, Boo Chang-Ho
and U. Zang-Kual

Applied Radioisotope Research Institute, Cheju 690-756,
Korea, Department of Agricultural Chemistry, College
of Agriculture, Cheju 690-756, Korea

Abstract

$N(^{15}N)$ and $P(^{32}P)$ absorption by 2 year-old *Cymbidium* Jungfrau in solution culture were investigated. Growth, photosynthesis, 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. 67% 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. Nitrogen 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 130-fold lower than that of barley. Greater shoot length and bulb diameter, and higher fresh weight, photosynthesis 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 but Ca 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, depended on the grower's own experience. Furthermore it has been generally assumed that orchid plants required little fertilizer because of their slow growth^{1,2}. It was found that however, a similar amount of mineral nutrients as for other plants was essential in doing tissue culture of orchids^{3,4}. Monthly fertilizer application resulted in optimal growth and flowering in pot culture⁵. Weekly liquid fertilization was best for orchid growth in the fir bark⁶.

Solution culture has often led to excellent growth and productivity^{7,8}. Although solution culture has been introduced in the commercial orchid cultivation to promote orchid growth and to increase cut flower quality, there is only a limited information on mineral nutrition of orchids. Therefore, more information on nutrient absorption and distribution 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 growth⁹ but inhibits flowering¹, thus reducing flower production. Also, the optimal nutrient requirement may vary with species and varieties^{10,11}.

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

1. 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 × 23.4, H × 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 ¹⁵N as NO₃-N and 35 μCi of ³²P everyday for 3 days. At the end of the third day leaves, bulbs and roots were cut and dried at 70 °C. Half of the dried samples was digested in H₂SO₄-H₂O₂ and the ³²P activity was counted for 2 min in a liquid scintillation counter (Packard 2700TR, USA)^{6,16,17}. The second half of the samples for ¹⁵N measurement was stored for about 6 months for the decay of ³²P (more than 10 times of the half life time of ³²P). After that period the samples were ground to fine powder by using a roller mill. 20 mg of ground power was loaded in the elemental analyzer (Fisons Instrument EA1108CHNSO, Italy) attached with the mass spectrometer (VG Isotec Sira II, English) to determine the ¹⁵N⁶.

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

Two old-year old *Cymbidium* plants were transplanted in the pots (17.7 × 23.4, H × D cm) containing bark or rockwool and grown in the vinyl house for 200 days. During the vegetative growth period (100 days after transplantation) 300 ml of nutrient solution containing 3.27 mM KNO₃, 1.65 mM Ca(NO₃)₂·4H₂O, 2.72 mM NH₄H₂PO₄ and 0.55 mM MgSO₄·7H₂O 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 KH₂PO₄, 1.50 mM Ca(NO₃)₂·4H₂O, 1.42 mM NH₄H₂PO₄ and 1.50 mM MgSO₄·7H₂O was given to each pot to reduce N concentration in the nutrient solution to the half. 2.3 μM Fe-EDTA, 48.5 μM H₃BO₃, 8.96 μM MnSO₄·4H₂O, 1.74 μM ZnSO₄·7H₂O and 0.08 μM Na₂MoO₄·2H₂O as micro nutrients were added in the nutrient solution during the whole experimental period. On the other hand 20 g 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 transplantation shoot height and bulb diameter were measured. Plants were harvested at 100 days and 200 days after transplantation and the percentage of fresh weight increase was determined. Next, plants were divided into leaves, bulbs and roots and dried at 70 °C. Dried samples were digested in H₂SO₄-H₂O₂²¹. Nitrogen was determined colorimetrically by indophenol blue²¹. 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 transplantation the content of chlorophyll was measured (Minolta chlorophyll meter SPAD-502, Japan). Photosynthesis was analyzed by the LI-COR photosynthesis measuring system (LI6200, USA).

3. Statistical analysis

A SAS program was used for statistical treatment; mean values were compared with Duncan's multiple range test at 5% level¹³.

Results and discussion

1. Absorption and redistribution of nitrogen (¹⁵N) and phosphorus (³²P)

Cymbidium differs from most monocotyledon plants by their morphology and physiological properties. *Cymbidium* roots are enveloped by a fleshy velamen layer acting like a sponge when wet¹¹ and, therefore, can 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 the 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 low light saturation point⁶, it is grown conventionally in the vinyl house under 30 – 50% reduced sunlight using black nets. But, especially in spring and autumn *Cymbidium* is exposed to full sunlight to accumulate higher assimilate in the plant, thus vegetative

growth and flowering capability being enhanced⁹).

Therefore, absorption and redistribution of nitrogen (¹⁵N) and phosphorus (³²P) of *Cymbidium* were compared under the different light intensities (table 1, 2). The amount of N

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

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

Light treatment	Plant part	Nabsorption and redistribution($\mu\text{g} / \text{g fw} \cdot \text{d}$)				
		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

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

Light treatment	Plant part	Pabsorption and redistribution($\mu\text{g} / \text{g fw} \cdot \text{d}$)				
		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
	Total	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
	Total	2.30	4.93	3.66	3.19	14.1

* ; no root

absorbed was higher in the full sunlight than 60% of the full sunlight. Most N was absorbed in the bulbs, and in 0.5 or 1 year–old daughter plants showing vigorous growth. However, P absorption depending on light intensity was opposite to that of N. Most of P absorbed was present in the root and P redistribution to the bulbs or leaves was quite lower than that of N. P absorbed and redistributed was the highest in 0.5 years old daughter plant which seemed to be metabolically most active.

by the Michaelis–Menten equation¹⁰⁾ [$I = (I_{\text{MAX}} \cdot C) / (K_M + C)$], 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 $K_M = 4.58 \mu\text{M}$ and $I_{\text{MAX}} = 163 \mu\text{mol g}^{-1} \text{fw d}^{-1}$ in 35 day–old normal barley plant¹¹. $272 \mu\text{M}$ P in nutrient solution supplied for *Cymbidium* in this study was used for P absorption per day was calculated as $160 \mu\text{mol g}^{-1} \text{fw}$ ($4.97 \text{ mg g}^{-1} \text{fw}$).

From the data, it follows that P absorption rate of *Cymbidium* was 130-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 estimation.

On the other hand, P absorption of *Cymbidium* was higher at 10 a.m. to 13 p.m. than at 7 a.m. to 10 a.m. or 1 p.m. – 16 p.m, which indicated that nutrient uptake of orchid was related with light intensity (table 3).

Table 3. P absorption by *Cymbidium* Jungfrau during daytime

Time	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

bulb diameter were obtained in the solution culture with bark or granular rockwool than in the conventional pot culture.

As shown in table 4, 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 capacities¹¹⁾. Since the granular bark used for mature *Cymbidium* has poor water dispersion, a special device is 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 dispersion¹⁴⁾ and good contact of roots with nutrients. Only an arrow dripper was enough for a wool medium. Therefore, in this experiment a self-made 6 hole punched tube was installed around the plants in the

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 (%)		Photosynthesis	Chlorophyll content
	I ⁴	II ⁵	I ⁴	II ⁵	I ⁶	II ⁷		
	SBC ¹	64.3a ^b	80.7a	2.76a	3.50a	56.0b		
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; Conventional pot culture using bark

³; 180 days after transplantation

⁴; 200 days after transplantation

⁵; Solution culture using granular rockwool

⁶; 60 days after transplantation

⁷; 100 days after transplantation

⁸; Duncan's multiple range test at 5% level

2. Growth, photosynthesis, chlorophyll content and mineral composition of *Cymbidium* solution and conventional pot-cultured

1) Growth

At 60 days after transplanting there was no significant difference in growth between the culture methods. At 180 days longer shoot length and bigger

pot filled with bark medium, giving the same growth as good as in rockwool.

2) Photosynthesis and chlorophyll content

Photosynthesis and chlorophyll content were significantly higher in the solution culture than in the conventional pot culture. Especially, granular rockwool used as potting medium gave higher photosynthesis rate and chlorophyll content than bark (table 4).

3) Mineral composition

Mineral composition of *Cymbidium* plants taken at 100 and 200 days after transplantation was 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 years old *Cymbidium* during the vegetative growth(100 days

after transplanting), and bulb expansion and flowering stage(100days 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 2.72–3.24g, 0.53–0.63g, 2.08–2.67g, 0.67–0.92g and 0.5–0.65g, respectively. Therefore, N, P, K, Ca and Mg absorptions per day were estimated as 7.15–9.75mg, 1.55–2.05mg, 3.35– 6.20mg, 3.35–4.60mg, 1.25–2.00mg, respectively.

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	1.01	0.17	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
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
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

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.

Cultivation 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	0.32	0.47	0.09	0.14
	Root	2.30	2.72	0.53	0.64	1.96	2.08	1.00	1.37	0.38	0.50
SRC ²	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	2.34	3.24	0.43	0.63	1.86	2.65	1.16	1.62	0.44	0.65
CPC ³	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	0.29	0.44	0.32	0.48	0.06	0.12
	Root	1.40	1.73	0.21	0.32	0.96	1.75	1.03	1.25	0.37	0.45

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

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(¹⁵N)의 흡수는 자연광의 60% 광도에서 보다 자연광에서 많았고, 인(³²P)의 흡수는 이와 반대의 경향을 나타냈다. 흡수된 질소(¹⁵N)는 벌브에 가장 많이 존재하였고 인(³²P)은 뿌리와 벌브에 많이 있었으며 앞으로 재분배된 양은 10% 정도였다. 2년생 어미주 보다는 0.5 또는 1년생 새끼주에서 질소(¹⁵N)와 인(³²P)의 흡수가 더 많았다. 심비디움의 인 흡수율은 보리의 경우 보다 약 130배정도 낮았다. 심비디움의 초장, 벌브 크기, 생체증가율, 광합성 능, 엽록소 함량은 바크 또는 락울을 배지로 이용하는 양액 재배가 일반 관행재배 보다 더 높았다. 특히, 양액 재배에서 사용된 바크와 락울간에 생육과 무기물함량이 차이를 보이지 않았는데, 이는 바크 배지에서 양액의 분산을 용이하도록 6개의 구멍이 뚫린 튜브로 양액을 관주했기 때문이라고 생각된다. 또한, 질소, 인, 칼륨, 마그네슘의 함량은 양액 재배에서 높았으나 칼슘은 관행과 차이가 없었

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