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Effects of Selenate and Sulfate Ion Interaction in Nutrient Solution on the Growth of *Artemisia mongolica* var. *tenuifolia*

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배양액 내의 Selenate 와 Sulfate 이온의 상호작용이 참쑥의 생육에 미치는 영향 [1)]

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Abstract

This study was carried out to investigate the interaction of selenate and sulfate ion in nutrient solution supplyed with selenate ion.

At early growth stage, the growth of Mongolian wormwood was best at 3mM sulfate ion and 2㎎/ℓ Na_2SeO_4 treatment. As they were grown and matured, at the later growth stage, the effect of antagonism between selenate and sulfate ion on the growth of each plant decreased. At supplying with selenate ion in nutrient solution, the uptake of selenate by plant had negative correlation with sulfate ion concentration in nutrient solution. The higher sulfate ion concentration, the less selenium uptake. However, the effect of antagonistic interaction of selenate and sulfate ion on the selenium uptake increased with plant age. Whereas, the uptake of sulfate ion had positive correlation with sulfate ion concentration in nutrient solution at supplying with selenate ion in nutrient solution. The uptake of sulfate ion increased with increase of sulfate ion concentration in nutrient solution. The effect of this interaction with selenate and sulfate ion increased with growth and maturity of plant. However, at 3mM sulfate ion concentration in nutrient solution, sulfate ion concentration in plant tissue decreased markedly.

Key words : hydroponics, selenate ion, sulfate ion, antagonism, nutrition, *Artemisia mongolica* var. *tenuifolia*

[1)] 본 실험은 농림수산부 시행 농림수산특정연구사업의 일부로 수행된 것임.

Introduction

Mongolian wormwood(*Artemisia mongolica* var. *tenuifolia*) is a member of Compositae family and it can be used for flavoring rice cakes and for biomedicine. The main constituents of essential oil are cineole, camphor, thujone, caryophyllene, borneol, coumarin and linalool. Essential oil from this plant has been widely used for biomedicine as alternatives, astringents, bittertonics, carminative, cathartic, demulcant, diuretic, emollient, expectorant, nervine and stimulant.

Selnate and sulfate ion have a similar physical and chemical properties(Combs and Combs, 1986). Conversely, Se has the ability to replace S in plant metabolism (Trelease et al., 1960). Uptake of SO_4^{2-} and SeO_4^{2-} was shown to be controlled by the same carrier with similar affinity for both ions(Leggett and Epstein, 1956). At supplying with Se in nutrient solution, the uptake of both sulfate and selenate anions appears to compete for the same binding sites. Selenate and sulfate ion are absorbed, transported in plant xylem sap or metabolized to protein compounds and then transported into upper portions of the plant via similar mechanism.

The objective of this study was to evaluate the effect of selenate and sulfate ion in nutrient solution on the growth of *A. mongolica* var. *tenuifolia* and to investigate selenate and sulfate ion uptake at supplying with Se.

Materials and Methods

This study was carried out in the glasshouse of Korea University. Mongolian wormwood(*A. mongolica* var. *tenuifolia*) was propagated by cutting of sucker and grown with the commercial substrates(Supermix, Nong Kyung Co.) for horticultural crops. At the third leaf stage, the produced uniform seedlings were transplanted into water for 3 days. Thereafter they were treated with half-strength nutrient solution for hardening. The hardened tansplants were planted to bed in deep flow culture(DFC) system. Treatments were supplied with nutrient solution containing 0, 0.5, 1, 2, and 3mM of sulfate ion. Modified nutrient solution was used, which is developed for herb plants by European Vegetable R & D Center in Belgium. The composition of this nutrient solution showed at table 1. The nutrient solution was circulated by a pump with 24h-timer in interval 15 min per hour. The nutrient solution was replaced with fresh solution every 15 day in early growth stage and every 10 day in later growth stage.

Table 1. The composition of nutrient solution for herb plants developed by European Vegetable R & D Center in Belgium.

Macro nutrient	mM	Micro nutrient	μM
NO_3-N	18.0	B	26.5
K	11.0	Fe	100.0
H_2PO_4-P	2.0	Cu	0.4
Ca	4.5	Zn	3.7
Mg	1.0	Mn	5.0
S	1.0	Mo	0.5

1. Experiment of selenate and sulfate ion interaction at early growth stage

Mongolian wormwood was cut on 10 Apr. 1997. The plants were planted into bed in DFC system, they were treated with nutrient solution containing 0, 0.5, 1, 2, and 3mM of SO_4^{2-}. After 5 days, all were added with 2㎎/ℓ Na_2SeO_4. And they were harvested after 20 days from treatment.

2. Experiment of selenate and sulfate ion interaction at later growth stage

On 18. Apr. 1997, Mongolian wormwood was propagated by cutting. They were planted to bed in DFC system andthen treated with 0, 0.5, 1, 2 and 3mM of SO42- with using modified nutrient solution for herb plants. After 30 days, all were added with 2㎎/ℓ Na2SeO4 and harvested 20 days after treatment.

To investigate apparent growth, plant height, leaf length, leaf width, root length and fresh weight(top & root) were measured. The essential oil content was analyzed by steam distillation method by Letchamo (1992). The sulfate ion content was analyzed by modified method of Commitee of Culture Analysis(1983). The Se content was determined by fluorometric method of Whetter and Ullrey(1978). Data was analyzed by the Duncan's multiple range tests of SAS program.

Results and Discussion

1. The effect of interaction of SeO_4^{2-} and SO_4^{2-} at early growth stage

For production high functional vegetables, at supplying with Na_2SeO_4 2㎎/ℓ in nutrient solution, the growth of *A. mongolica* var. *tenuifolia* showed a tendency of increase with increasing sulfate ion concentration(Table 2). In Mongolian wormwood, the growth was best at 3mM sulfate ion concentration in presence of 2㎎/ℓ Na_2SeO_4 in nutrient solution.

Selenate uptake decreased as increase of sulfate ion concentration in presence of 2㎎/ℓ Na_2SeO_4 in nutrient solution(Fig. 1). Adding SO_4^{2-} might be lowered SeO_4^{2-} absorption and transport. This result agreed with that of Hurd-Karrer(1938) and

Table 2. The effects of SeO_4^{2-} and SO_4^{2-} interaction on the growth of *Artemisia mongolica* var. *tenuifolia* at early growth stage.

SO_4^{2-} (mM) + $Na_2SeO_4^{2-}$ 2㎎/ℓ	Top length (cm)	Leaf length (cm)	Leaf width (cm)	Number of leaf	Root length (cm)	Fresh weight (g)		T/R ratio
						Top	Root	
0	12c[z]	3.7c	3.3c	9.3c	12.6d	1.4c	0.7c	2.00b
0.5	17.0b	7.1b	6.2b	17.3bc	17.0cd	5.5c	3.4bc	1.62c
1	20.1ab	7.4b	6.2b	31.7ab	22.4c	12.9b	4.7ab	2.74a
2	20.4ab	7.6ab	7.6ab	28.3abc	28.6b	11.8b	5.0ab	2.36b
3	22.5a	9.2a	9.2a	43.3a	40.1a	20.4a	6.8a	3.00a

[z] Means separation within columns by Duncan's multiple range test, at 5% level

Mikkelsen et al.(1989). They reported that the addition of elemental S, SO_4^{2-}, or gypsum reduced plant SeO_4^{2-} uptake. Sulfur can influence Se accumulation in plants. Two anions have been reported that have a similar structural and chemical property and compete for carrier of membrane with similar affinity. Sulfate ion uptake increased with increase of sulfate ion concentration in presence of 2㎎/ℓ Na_2SeO_4 in nutrient solution(Fig. 2). Dean and William(1997) suggested that the antagonistic relationship occurred at a $1SO_4^{2-}$: $1SeO_4^{2-}$ ratio. At the lower Se concentration, the more SO_4^{2-} uptake and accumulation in leaf and bulb tissues in onion. The antagonistic effect of sulfate appeared to be responsible for reducing Se toxicity at the protein level.

However, recently it has been reported that selenium and SO_4^{2-} tissue concentrations were positively related to solution Se(Banuelos, 1990) and a synergistic relationship between sulfate and selenate. The synergistic interaction between sulfate and selenium relates to an increase in shoot sulfur concentrations with increasing supply of selenium at low sulfate levels.

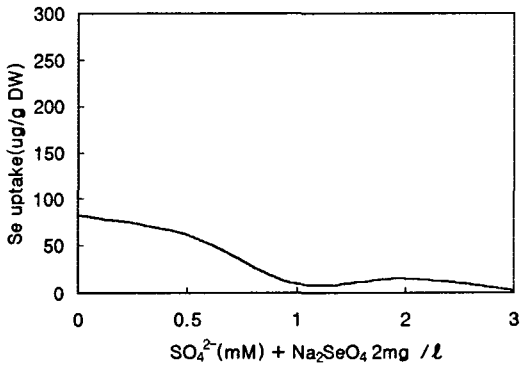

Fig. 1. The effect of SO_4^{2-} and SeO_4^{2-} interaction on the uptake of Se in *Artemisia mongolica* var. *tenuifolia* at early growth stage.

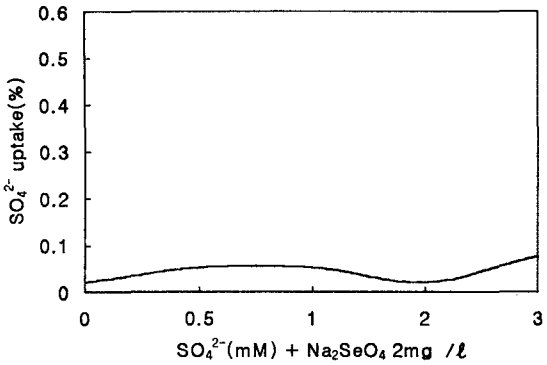

Fig. 2. The effect of SO_4^{2-} and SeO_4^{2-} interaction on the uptake of SO_4^{2-} in Artemisia mongolica var. *tenuifolia* at early growth stage.

2. The effect of interaction of SeO_4^{2-} and SO_4^{2-} at later growth stage

At later growth stage showed no significant difference among treatments. The increase of growth due to sulfate ion concentration, at early growth stage, was gradually decreased and did not change any more as plant grown and matured(Table 3). That is, the effect of the antagonistic interaction between selenate and sulfate on the growth of Mongolian wormwood decreased.

Therefore, it is thought that the toxicity of selenium may decrease as growing and maturity of plants.

The selenium uptake markedly decreased with increase of sulfate ion concentration in presence of 2㎎/ℓ Na_2SeO_4 in nutrient solution in Mongolian wormwood. And the extent of uptake of Se was still more than that of at early growth stage. Increased Se uptake with increasing plant age was consistent with previous finding for wheat(Triticum aestivum)(Singh, 1994) and rice(Oryza sativa 'M101')(Mikkelsen et al., 1989). Dhillon and Dhillon(1991) reported that the selenium content was highest during the early stages of growth, but decreased and then did not change up to maturity.

Table 3. The effects of Se and SO_4^{2-} interaction on the growth of *Artemisia mongolica* var. *tenuifolia* at later growth stage.

SO_4^{2-} (mM) + $Na_2SeO_4^{2-}$ 2㎎/ℓ	Top length (cm)	Leaf length (cm)	Leaf width (cm)	Number of leaf	Root length (cm)	Fresh weight (g)		T/R ratio
						Top	Root	
0	55.1c[z]	10.8a	6.6b	66.0c	29.7b	11.6c	5.5c	2.11b
0.5	72.3b	12.0a	8.2a	299.0a	53.6a	33.4a	14.6b	2.29b
1	78.0b	12.0a	8.2a	215.0b	48.7a	21.6b	6.2c	3.48a
2	73.4b	12.2a	7.6ab	305.3a	51.7a	30.6a	17.4b	1.76c
3	90.0a	12.8a	8.8a	310.0a	48.7a	11.2c	28.9a	0.39d

[z] See Table 2.

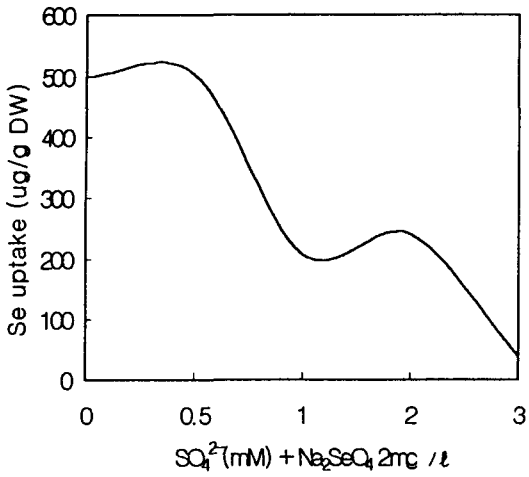

Fig. 3. The effect of SO_4^{2-} and SeO_4^{2-} interaction on the uptake of Se in *Artemisia mongolica* var. *tenuifolia* at later growth stage.

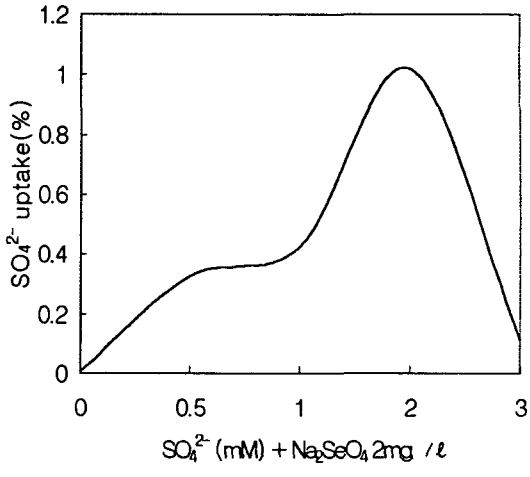

Fig. 4. The effect of SO_4^{2-} and SeO_4^{2-} interaction on the uptake of SO_4^{2-} in *Artemisia mongolica* var. *tenuifolia* at later growth stage.

The sulfate uptake, at later growth stage, increased as increase of sulfate ion concentration and the extent of uptake was more than that of at early growth stage(Fig 4). It is considered that Mongolian wormwood might not uptake more sulfate ion at later growth stage but they might be accumulate the sulfate ion in tissue during growth period. However, at 3mM of sulfate ion concentration in nutrient solution, the uptake of sulfate by plant drastically decreased.

At later growth stage, in Mongolian wormwood, the essential oil content was best at sulfate 0.5 mM and Na_2SeO_4 2㎎/ℓ treatment, but higher sulfate ion concentration resulted in decrease of essential oil content(Fig. 5). Therefore, selenate and sulfate interaction might influence on the essential oil content, secondary metabolite, as well as growth and nutrient uptake. For that reason, more detailed research about relation of selenate and quality of vegetables should be carried out for production of high functional vegetables.

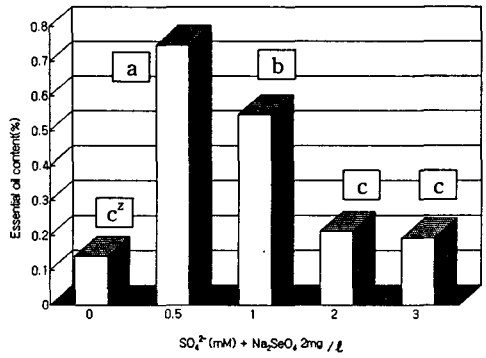

Fig. 5. The effect of SO_4^{2-} and SeO_4^{2-} interaction on the essential oil content in *Artemisia mongolica* var. *tenuifolia* at later growth stage
[z] See Table 2.

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摘　　要

고기능성 채소 생산을 위해 항산화효과가 뛰어난 셀레니움을 식물체내로 주입시 배양액 내에서 발생할 수 있는 황산이온과의 상호작용은 식물체의 생장은 물론 식물에 의한 적정 수준의 셀레니움의 흡수에 영향을 미칠 수 있다. 따라서 본 실험은 양액내의 셀레니움과 황산이온이 *Artemisia*속 식물에 미치는 영향을 알아보고자 수행되었다. 벨기에의 채소연구소에서 개발한 허브 양액을 이용하여 황산이온 농도를 0, 0.5, 1, 2, 3mM 로 변형시킨후 각각에 Na_2SeO_4 2㎎/ℓ를 첨가하였다.

생육초기에는 Na_2SeO_4 2㎎/ℓ 처리시 3mM 황산이온 농도에서 가장 좋은 생육을 보여주었다. 그러나 생육 후기로 갈수록 셀레니움과 황산이온과의 길항작용의 효과는 점차 감소하여 생육에 있어서 유의적인 차이를 보이지 않았다.

Na_2SeO_4 2㎎/ℓ처리시 SO_4^{2-} 처리에 따른 셀레니움 흡수에 있어 배양액내의 SO_4^{2-}의 농도가 높아질수록 두 이온간의 길항작용으로 인하여 셀레니움의 흡수는 감소하였으며 생육단계에 의한 반응은 생육초기에는 셀레니움 흡수 감소의 폭이 적었으나 생육후기로 갈수록 흡수 감소의 폭은 현저하였다.

Na_2SeO_4 2㎎/ℓ처리시 SO_4^{2-}처리에 따른 황산이온의 흡수는 배양액 내의 황산이온 농도의 증가에 따라 흡수도 증가하였다. 또한 생육후기로 갈수록 그증가의 폭은 더 컸으나 3mM의 높은 농도에서는 황산이온의 흡수가 급격히 감소하였다.