# Influence of Organic Fertilizer on Growth and Vitamin E Content of Traditional Vegetable, *Codonopsis lanceolata*

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## Abstract

*Codonopsis lanceolata* (Sieb. et Zucc.) Trautv. is wild vegetable found in East Asian countries and considered valuable, especially among the Korean people. The effects of organic fertilizer application on the yield and quality of rhizome were investigated under Andosol condition. Commercial barnyard manure fermented with crushed bark, beef cattle dung, and leaf mold of Japanese oak were applied at the rates of 0, 5, 10, 15, and 20 $g \cdot m^{-2}$. Barnyard manure enhanced the fresh weight of rhizome, but decreased the vitamin E content. The C/N ratio in the soil surface up to the depth of 30 cm, which was controlled by the application ratio of barnyard manure and leaf mold, drastically influenced the rhizome yield. Total N, soluble P, exchangeable K, Ca, and Mg, however, did not significantly affect the rhizome yield. There was significantly negative correlation between the fresh weight of rhizome and the α-tocopherol (vitamin E) content at harvest time. The highest vitamin E content was observed with the leaf mold application rate of 10 $g \cdot m^{-2}$, and the contents achieved at 9–10 $mg \cdot DM^{-1}$. The nitrogen supply from the soil to plants influenced primarily the yield and quality as vegetable or drug. The vitamin E content under higher soil C/N ratio was one of the highest among commercial vegetables in the common Japanese food market.

*Keywords: α-tocopherol, East Asia, fertilizer application, wild vegetable*

## Introduction

Food must always be safe and nutritious. Traditional vegetables grown on organic farms are becoming popular in markets in East Asian countries. The organic cultivation of vegetables has increased because organic farming benefits human health and is also effective for the conservation of agricultural environments.

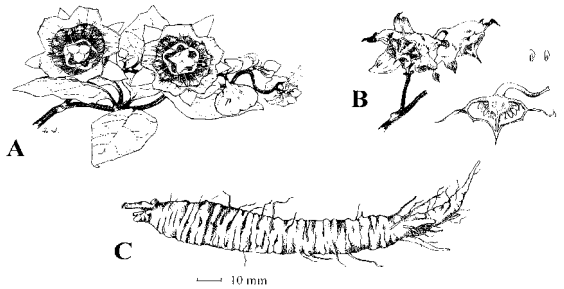
*Codonopsis lanceolata* (Sieb. et Zucc.) Trautv. is a perennial climbing herb that is a popular fancy vegetable in high demand among organic foods in Korea. On the other hand, it is recognized as a rare and quaint wild plant mainly inhabiting mountainous areas in Japan (Figure 1). *C. lanceolata* is chemotaxonomically similar to *Codonopsis pilosula* (Wang *et al*., 1995), which is a major source of the traditional Chinese drug “dangshen” (Iwai *et al.* 1992; Namba *et al.*, 1992a, 1992b). The natural population of *C. lanceolata* is distributed throughout shaded and humid sites in Korea, China, and Japan. Many farmers domesticate, produce, and sell *C. lanceolata* for its rhizome vegetable, which is used in a distilled spirit, traditional medicine, or as a foodstuff in Korea. The Korean common name for this plant is “deo-deog.” Korean and Chinese people have been carefully protecting and fostering *C. lanceolata* as a useful vegetable and drug since ancient times (Park and Lee 1991; Pemberton and Lee 1996; Sakamoto 1998).

*C. lanceolata* is also used as a minor vegetable and in a distilled spirit in Central Japan (Inoue 1998a; 1998b). Furthermore, the native Ainu people use it as a familiar vegetable, drug, and medicinal plant (Shiraoi Ainu Museum 1989; Annetai *et al*. 1996; Fukuoka and Sato 1995; Hayashi 1968). The common Japanese name for *C. lanceolata* is “tsuru-ninjin;” “tsuru” means vine and

“ninjin” means rhizome. The Ainu names are “chir-muk” and “tope-muk”. Local names in Central Japan include “tou-do,” “to-dog,” and “jii-sob”.

The cultivation area of *C. lanceolata* has increased to over 1000 ha in South Korea because the edible rhizome has a good aromatic flavor (Lee *et al*. 1996), good texture, and high antioxidant activity (Maeng and Park 1991). However, the chemical composition of the rhizome fluctuates according to the cultivation conditions; at present, the optimal soil conditions for producing high-quality rhizomes are unknown. For providing a high-quality vegetable for healthy functional foods, productivity testing is important to clarify the effects of organic fertilizer application rate on the yield and vitamin E content, which is responsible for the antioxidant activity of *C. lanceolata* rhizomes.

In this study, field experiments were carried out to investigate the effects of commercial barnyard manure fermented with crushed bark, beef cattle dung, or leaf mold of Japanese oak on the rhizome yield and α-tocopherol (vitamin E) content in *C. lanceolata* rhizomes at the end of 1 growing season.




A: inflorescence and vine; B: capsule and single seed; C: rhizome
The plant sample was collected atu Yong Weoul in Kangwon province of Korea

Figure 1. *Codonopsis lanceolata* (Sieb. et Zucc.) Trautv. (family Campanulaceae).

## Materials and Methods

The experimental field was located at Shinshu University, Minamiminowa Village, Nagano Prefecture, Japan (alt. 740 m, 35°N and 138°E). The soil taxonomy and texture are Andosol and clay loam according to the FAO/UNESCO and international systems, respectively. Commercial barnyard manure that was fermented with crushed bark (80%), cattle dung (20%), and leaf mold of Japanese oak was prepared before seeding. Table 1 shows the chemical compositions of the soil and organic fertilizer. Two organic fertilizers were applied at rates of 0, 5, 10, 15, or 20 $g \cdot m^{-2}$ and plowed to a depth of 35 cm below the soil surface just before transplanting the seedlings. The experimental design was a random block design with 4 replicates. For all treatments, the plot size was 100 × 100 cm with 15 cm spacing between individuals. A nylon net was placed to allow the vines to climb.

Samples from the local population in Young Weoul, Kang Weon Province, South Korea were prepared, and seedlings with 4 leaves were transplanted into each plot in early May. Rhizomes were harvested in early November.

Soil samples were collected to a depth of 30 cm before and after fertilization and air-dried at room temperature. The total carbon and nitrogen contents of the soil were determined using a C-N corder (Yanaco, MT700). Ammonium-N and $NO_3$-N in the soil were extracted with 2 N KCl solution and measured by Bremner’s method. Soluble P in the soil was determined by Truog’s method. Exchangeable K, Ca, and Mg were extracted with 1 N acetic ammonium solution and measured by

atomic absorption spectrochemical analysis. Total α-tocopherol (as vitamin E) content in the rhizome was measured by high-performance liquid chromatography (HPLC).

Table 1. Chemical properties of soil fertilizer

| Constituent | Soil | Organic fertilizer | |
|---|---|---|---|
| | | Barnyard manure | Leaf mold |
| pH ($H_2O$) | 6.3 | 7.1 | 6.8 |
| EC (ms) | 0.06 | 2.2 | 0.5 |
| CEC (me) | 22.5 | 36.7 | 44.6 |
| Total N | 0.5 | 2.2 | 0.9 |
| Total C | 9.3 | 23.8 | 23.8 |
| C/N ratio | 17.3 | 10.9 | 25.9 |
| Inorganic N ($NO_3$) | 2.4 | 11.6 | 0.2 |
| Inorganic N ($NH_4$) | 0.7 | 5.8 | 1.8 |
| Soluble P | 17.7 | 787.8 | 58.9 |
| Exchangeable K | 41.6 | 56.6 | 25.1 |
| Exchangeable Ca | 398.4 | 302.3 | 239.1 |
| Exchangeable Mg | 50 | 29.2 | 18.7 |

Table 2. Correlation between chemical component in soil and rhizome yield

| Constituent | Correlation coefficient | significant |
|---|---|---|
| Total N | 0.58 | P < 0.100 |
| Total C | 0.22 | |
| Soulble P | 0.47 | |
| Exchangeable K | 0.23 | |
| Exchangeable Ca | 0.05 | |
| Exchangeable Mg | 0.04 | |
| C/N ratio | -0.90 | P < 0.001 |

## Results

During the growth period, the precipitation on the site was 600 mm, mean air temperature ranged from 10–24°C, and mean solar radiation was approximately 15000 $J \cdot cm^{-2} \cdot day^{-1}$.

The application ratio of barnyard manure and leaf mold strongly influenced the rhizome yield at harvest time. The barnyard manure increased the rhizome yield, whereas fermented leaf mold decreased the yield. The correlation between the soil chemical conditions after fertilization and rhizome weight at harvest time was analyzed using all of the data (Table 2). There was a significant negative correlation between C/N ratio and rhizome weight (Figure 2). On the other hand, total N, total C, soluble P, and exchangeable K, Ca, and Mg in the soil after fertilization did not significantly affect the rhizome yield. The C/N ratio in the soil from the surface to a depth of 30 cm, which was controlled by the application ratio of barnyard manure or leaf mold, strongly influenced the rhizome yield.

Barnyard manure increased the fresh weight of rhizomes but decreased the vitamin E content (Figure 3). There was a significant negative correlation between the fresh weight and vitamin E content of rhizomes ($p < 0.001$). The highest vitamin E content occurred with the application of 10 $g \cdot m^{-2}$ leaf mold (9–10 $mg \cdot DM^{-1}$). The nitrogen supply from the soil to plants primarily influenced the yield and quality of the rhizome as a vegetable or drug. The vitamin E contents produced under higher soil C/N ratios are one of the highest among commercial vegetables available in the Japanese food market.

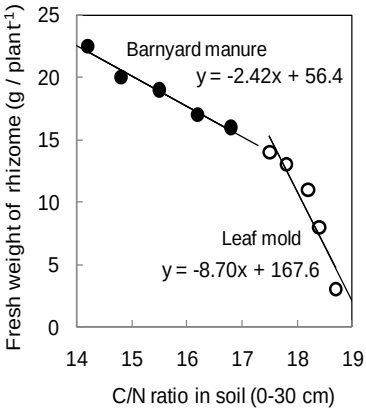



Figure 2. Relationship between C/N rations soil and rhizome yield.

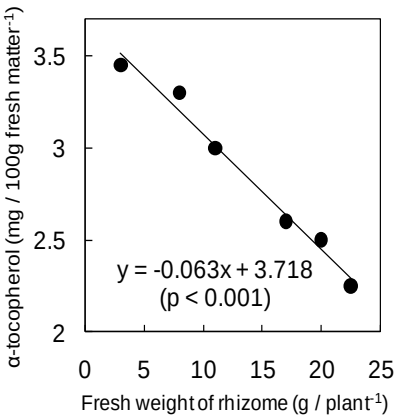



Figure 3. Relationship between rhizome yield and α-tocopherol.

## Discussion

The natural habitat of *C. lanceolata* is cool shaded forest floor in mountainous areas in Korea and Japan. In this experiment, moderate amounts of rhizomes were harvested in only 1 growing season and despite a lack of shade, suggesting that the climate of the experimental field is favorable for both vegetative growth and rhizome production. Lee *et al*. (1996) reported that shading decreases the growth but improves the aromatic constituents. Our results and the previous report suggest that shading and the fermented organic fertilizers favor production of high-quality vegetables.

Our survey in South Korea (Sakamoto *et al.*, 1998) revealed that organic farmers in Kangwon Province have developed an organic fertilizer consisting of saw dust, rice bran, and rice chaff; it is mixed and fermented over 1 year and applied at a rate of 6 $g \cdot m^{-2}$ before seeding. The key technique of the organic manure production is considered to maintain the soil C/N ratio around 17% in the case of Andosol soils according to our results.

Wang *et al.* (1995, 1996) report that *C. lanceolata* is chemotaxonomically similar to *C. pilosula* and contains many polysaccharides that exhibit immunomodulatory effects. Maeng and Lee (1991) also report that the ethanol extract from *C. lanceolata* rhizome possesses effective antioxidant activity that is stronger than that of extracts from *Panax ginseng* C. A. Meyer. In addition, they point out that *C. pilosula* rhizome exhibits protective action on experimentally induced gastric ulcers in rats (Wang *et al.*, 1997). These reports and our present results suggest that the rhizome of *C. lanceolata* is a healthy food. Despite the trade-off between rhizome yield and quality, organic farming with an organic fertilizer that supplies nitrogen slowly is considered valuable in commercial food production.

*C. lanceolata* is also a traditional wild vegetable eaten by the Ainu people in Northern Japan. The screening research of the chemical composition in wild plants used by the Ainu revealed that the species has the highest vitamin E content among 67 tested species (Annetai *et al.*, 1996). It is also reported that most edible wild plants have vitamin E contents less than 0.5 $mg \cdot 100\ g^{-1}$ fresh weight; on the other hand, vitamin E content of the rhizome of *C. lanceolata* is 2.38 $mg \cdot 100\ g^{-1}$ fresh weight. Our results show that greater amounts of vitamin E are present in smaller rhizomes produced under higher C/N ratios due to the fermented leaf mold. Since the vitamin E contents of *C. lanceolata* are one of the highest among commercial vegetables in the Japanese food market, the vegetable is expected to be gradually accepted as a worthwhile healthy food.

Many wild species of Campanulaceae are believed to be useful ingredients in drugs that maintain the human health while being functional foods among Asian peoples. For example, many species of *Platycodon*, *Campanula*, and *Adenophora* are popular as traditional crude drugs and foods. Many Korean people and researchers of Korean herbal medicines believe that *C. lanceolata* is a functional food that has anti-cancer activity. Hata *et al.* (1998) point out that many edible wild plants in Akita prefecture, Japan induce cell differentiation, including the activity of the human leukemia cell line (HL60), which is a useful model system for drug screening. However, Inoue (2003) reports that the ethanol-soluble fraction from the rhizome of *C. lanceolata* does not exhibit the nitroblue tetrazolium reduction activity for the human promyelocytic leukemia cell line HL60 or neutrophil activity. In addition, the rhizomes do not inhibit melanine synthesis in mouse melanoma cell line B16. More investigation is required from other perspectives regarding the anti-cancer activity of *C. lanceolata* rhizomes to establish its status as a healthy food.

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*-- back to Table of Content --*