# Transportation and Distribution of Carbon and Nitrogen Nutrition in Ginger

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**Keywords:** Fertilization, $CO_2$ assimilation, Isotopic trace, Growth period, Seed-ginger, *Zinigiber officinale*

**Abstract**

**The characteristics of transportation and distribution of $^{14}C$ and $^{15}N$ in ginger were investigated. Results showed that shoots and leaves were growth centers at the seedling stage, and 80.7 % of the carbon assimilation was transferred to these parts. Afterward, the distribution rate for shoots and leaves decreased gradually with the growth, whereas the distribution rate for the rhizome increased. Up to the vigorous growth stage of rhizome carbon assimilation was mainly transported from leaves into the rhizome, thus the rhizome became growth center. The absorption and utilization of nitrogen were the same as carbon assimilates. 48.41 % of the nitrogen absorbed from fertilizer applied at seedling stage was distributed to the shoots and leaves. While 65.43 % of the nitrogen derived from fertilizer applied at vigorous growth of rhizome was distributed into rhizomes, only 32.04 % distributed into shoots and leaves. The rate of fertilizer-N utilization by ginger was quite different in different fertilizer-N application stages. The results indicated that the rate of fertilizer-N utilization increased with the delay of application. The highest utilization rate, 45.24 % was observed when fertilizer was applied during the middle period of vigorous growth, while the utilization rate was only 28.09 % when applied at seedling stage. The results also showed that the stored nutrients in the ginger seed were partly transferred to new plants in the whole process of growth. A certain proportion remained in the ginger seed itself. At the same time, a part of the carbon and nitrogen nutrition assimilated by the leaves and roots was transported back to seed-ginger. The exchange of carbon and nitrogen nutrition between the above ground parts and underground seed of ginger would be the characteristics of their transportation and distribution during ginger growth. This ensured that the seed-ginger could not be shriveled.**

## INTRODUCTION

Ginger (*Zingiber officinale* Rose) is an agamogenetic vegetable, its growth and development had particular regulation (Zhao, D.W, et al., 1981, Li, S.X., 1964). After new organ of ginger was formed, the seed-ginger was not shriveled, but enhanced its weight to curtain extent. There is a saying that "planting ginger can always sustain losses in business." This manifests that the assimilation and distribution regulation of nutrition in ginger was different with other crops. The formation of ginger rhizomes and fertility measurements had been studied before (Zhao, et al.,1992; Xu, et al., 1991; 1999, 2000), however, the characteristics of transportation and distribution of carbon and nitrogen nutrition at different growth stages of ginger had not been reported until now. Therefore, applying the isotopic trace technique, the author studied the characteristics of transportation and distribution of carbon and nitrogen nutrition at different growth stages of ginger. The source-pool relationship had also been explored, so the theories for improving cultural measurements and enhancing ginger yields could be provided.

## MATERIALS AND METHODS

The experiment was performed using "Laiwu big ginger" in the vegetable testing station of Shandong Agricultural University. One plant was seeded in one pot 30 cm high

Proc. XXVI IHC – Future for Medicinal and Aromatic Plants
Eds. L.E. Craker et al.
Acta Hort. 629, ISHS 2004
Publication supported by Can. Int. Dev. Agency (CIDA)

and 25 cm diameter, filled with 12.5 kg air-dried soil. The soil used in this study was arenaceous soil, with the following properties: pH 7.30; organic matter 1.34 %; alkaline N 78.7 $mg.kg^{-1}$; available $P_2O_5$ 52.2 $mg.kg^{-1}$; $K_2O$ 129.6 $mg.kg^{-1}$.

**Studying Method on Distribution Regulation of Carbon Nutrition**

Applications of $^{14}C$ trace technique. $^{14}CO_2$ had been used to tag the plants at seedling stage (Jun 15), stem & leaf vigorous growth stage (Aug. 8) and rhizome vigorous growth stage (Sept.18). The process was as follows: at 9:00 AM, put the need-marking part into a bag that was made of cellophane paper, inject $^{14}CO_2$ gas, after 1 hour of photosynthesis, the remaining $^{14}CO_2$ was absorbed by saturated NaOH. The tagging quality was 25 $\mu Ci.L^{-1}$. Samples were collected 48 hours later according to different organs and then put into paper bags. Immediately after sampling, all plant materials were oven-dried at 105$C^o$ 10 minutes, dried 70-80 $C^o$, weighed and ground. After triturating the dried samples and weighing 50mg, the radioactive intensity was measured with a Model Fj-2101 Liquid Scintillation Counter.

**Studying Method on Distribution and Utility Regulation of Seed-Ginger Nutrition**

Applications of $^{14}CO_2$ to gingers were made everyday from October 6th 1998 to October 10th 1998 at 9:00 AM for two hours before harvesting, then the rhizomes were stored as seeds for next year. The rhizomes were sown on April 28th 1999. The first sampling began on May 28th after the seedling emerged. Plants were sampled every twenty days. All the samples were put into paper bags according to different organs, oven-dried at 105$C^o$ for 10 minutes, dried at 70-80° C, and weighed.

The distribution ratio of different organs was calculated using the following calculation methods: $^{14}C$ distribution ratio(%)=radioactive intensity of certain organ (Bq/g) × dry matter weight of certain organ (g)/radioactive intensity of total plant (Bq/g) × total plant weight (g).

**Studying Method on Distribution Regulation of Nitrogen Nutrition**

Application of $^{15}N$ trace technique. The fertilizer in this experiment was $(NH_4)_2SO_4$, the richness of $^{15}N$ was 10.16 %. The nitrogen was applied at seedling stage (mid - June), stem & leaf vigorous growth stage (mid o- Aug.) and rhizome vigorous stage (mid - Sept.). The applied nitrogen per pot was 500 mg, 1000 mg and 300 mg, respectively. All the plant materials were sampled at specific periods during growth process, put into paper bags according to different organs, oven-dried at 105 $C^o$ for 10 minutes, dried at 70-80 $C^o$ and weighed.

Triturated the dried samples and weighed 0.5 g sample, then nitrified by $H_2SO_4$-$HClO_4$. The richness of $^{15}N$ was measured by a Model N-150 Spectrograph.

Each experiment in the paper was repeated for 3-4 times. All data in the tables were means of measured values.

## RESULTS

**The Characteristics of Carbon Assimilation Distribution at Different Growth Stages**

When the ginger ramified at the seedling stage, $^{14}C$ was used to label the main shoot. The results (table 1) showed that 80.7 % of the $^{14}C$ assimilations was transferred to the above-ground shoots and leaves, only 12.4 % was distributed to the rhizomes and roots. Furthermore, among the above-ground carbon assimilations transferred, 42.4% was contributed to the main shoots itself, and 33.8 % was transferred to the first shoots. The data manifested that shoots and leaves above-ground were growth center at the seedling stage.

At the shoot & leaf vigorous growth stage, about 70 % of carbon assimilation was used for the shoot and leaf growth, and about 24 % of carbon assimilations was used to form the rhizome. This implied that the stem and leaves were still the growth center. Whereas compared to the seedling stage, the distribution rate for shoots and leaves

decreased and enhanced for the rhizome with the growth. It was obvious that the growth center had changed to the rhizome from above-ground parts. At rhizome vigorous growth stage, most of the carbon assimilation was transferred to the rhizome, only a small part settled itself for growth. So, at this stage, the rhizome was the sink of carbon assimilations.

**The Characteristics of Nitrogen Absorption and Distribution in Different Periods of Fertilization**

As table 2 shows, the utilization rate of applied nitrogen was 28.09 % at seedling stage, 40.26 % at stem & leaf vigorous growth stage and 45.23 % at rhizome vigorous growth stage, respectively. The results indicated that the rate of fertilizer-N utilization increased with the delay of application. This was consistent with the conclusion on other plants studied before (Wang, F.J. et al., 1981, Wang, S.L. et al., 1989, Tang, L. et al., 2000). The distribution of nitrogen absorbed by ginger varied greatly in different organs. There was a close relationship between the distribution of nitrogen applied at different growth stages in different organs and the plant growth centers. At seedling stage, leaves and shoots were the growth center, so the distribution rate of nitrogen of these parts was higher than that of the later growth stages. At rhizome vigorous growth stage, the rhizome was the growth center, if the nitrogen fertilizer was applied at this period, the distribution rate of nitrogen of rhizome was higher than at seedling stage and leaf vigorous growth stage. Taking one with another, the applied nitrogen was almost distributed into shoots and leaves above-ground when shoots and leaves grew very fast at seedling and leaf vigorous stage. Afterwards, the above and underground parts both grew vigorously, so the distribution of applied nitrogen between these parts came to a balance. So it could be concluded that the effect of applied nitrogen fertilizer on different organs was different at different periods. Therefore, applied fertilizer in different stages had its own important role for different organs. It also should be pointed out that in the different stages, there was always about 3 % of the total nitrogen to be distributed into seed ginger. Which meant that not only seed ginger contributed part of carbon to plant growth at seedling stage (Xu, K., 1992), but also part of the nitrogen absorbed by plant were refluxed to seed ginger even at rhizome vigorous growth stage.

**The Source of Nitrogen of Ginger Plant and its Dynamic Variety**

As table 3 showed, the percent of nitrogen absorption amount of nitrogen at seedling stage was only 11.27 % compared to the nitrogen of whole process of ginger growth. And the fertilizer nitrogen absorbed at seedling stage was only 24.35 % of total nitrogen. The data indicated that the ginger plant required minimal fertilizer nitrogen at seedling stage, and the main source of nitrogen in the period was soil nitrogen. However, the absorption rate of nitrogen increased rapidly during the vigorous growth stages, reaching above 40 %, and then remained constant. In the whole process of growth, the absorption quantity of fertilize nitrogen was 660.91 mg per plant, the utilization rate of which was 36.72 %. The absorption of nitrogen was lower at seedling stage, so the utilization rate of fertilize nitrogen was very low, only 8.39 %.

**The Characteristics of Carbon Nutrition Transportation and Distribution in Seed-ginger**

The experiment had measured the $^{14}C$ nutrition of seed-ginger through sampling by stages. It could be seen from the result (table 4) that the stored nutrition of seed-ginger played an important role during the whole process of growth. During the whole growth process, part of the nutrition in seed-ginger was transferred into other growth parts, especially the growth center, but the quantum of nutrition transported from the seed-ginger became smaller and smaller as the growth of ginger. Therefore, what the seed-ginger nutrition mainly transferred to was shoots and leaves above-ground at seedling stage, and at rhizome vigorous growth stage was rhizome. At the shoot and leaf vigorous growth stage, the quantum of seed-ginger nutrition transferred into above-ground and underground part was approximate. At last, about 80% of nutrition remained in the plant.

## DISCUSSION

At seedling stage, lateral shoots were little, the main shoot and leaves were the major carbon assimilation organs, and 42.4 % of the carbon nutrition assimilated by the main shoot leaves was used to grow itself and 66.5 % applied to the growth of lateral shoots. At shoot and leaf vigorous growth stage, the first shoot leaves were the highest assimilation organs, and the output of assimilation nutrition was 54.4 %, which indicated that the first shoots played a more important role for plant growth than any other part. During this period, the assimilation of main shoot and leaves decreased because of the caducity, however, the output ratio still reached 61.2 %. Although the assimilation quantum of second shoots and leaves was higher than that of main shoot leaves, the output was lower, only 29.6 %. At rhizome vigorous growth stage, the output quantum of first and second shoots was higher, 58.9 % and 47.7 % of the total assimilation, respectively. The third shoots had little contribution to plant growth, and 71.9 % of the assimilation remained to use the growth of itself. During this period, about 90 % of the output assimilation from all kind of shoots was still transferred into rhizomes.

The utilization and distribution rate of applied fertilizer was quite different at different growth stages and in different organs. At seedling stage, the nitrogen absorbed by ginger was a little, and the fertilizer nitrogen was even less, which was related to puniness of plant, low absorptive ability of roots besides some nitrogen may be contributed by the seed-ginger (Xu, K., 1992). However, the distribution rate of fertilizer nitrogen of main shoot was high, which indicated that fertilization had an important role on promoting the main shoot growth, so fertilization stage was indispensable even if the utilization rate was low at seedling stage. At shoot & leaf vigorous growth stage fertilizer should apply heavily for promoting the balance growth of different organs. Fertilizer should not apply blindly even the high utilization rate of nitrogen at rhizome vigorous growth stage. Otherwise, it easily made over strong growth of shoots and leaves and delayed the transformation of nutrition from other parts to rhizome, eventually lower the yield.

As a common agamogenetic plant, the stored nutrient of the seed material had an important role on shooting and growing of the seedling plant. And the seed material got shriveled after the stored nutrient had depleted and new growth system formed. However, the stored nutrient of the seed-ginger had particular regulation of distribution and utilization: the stored nutrients in the ginger seed were partly transferred to new plants in the whole process of growth, and certain proportion remained in the seed ginger itself. At the same time, part of the carbon and nitrogen nutrition assimilated by the leaves and roots was transported back to seed-ginger. The exchange of carbon and nitrogen nutrition between the above ground parts and under ground seed of ginger would be the characteristics of their transportation and distribution during ginger growth. This ensured that the seed-ginger could not be shriveled.

## Literature Cited


Li, S.X. 1964. Studies on the Formation of Ginger Rhizomes. Journal of Plant Physiology. 1(2): 18-22.

Tang, L., Mi, G.H. and Zhang, F.S. 2000. Assimilation and Allocation of $^{14}C$ during Grain Formation Stage in Two Wheat Cultivars as Regulated by Nitrogen and Sink Removal. Journal of China Agricultural University. 5(1):75-79

Wang, F.J, Peng, G.Y. and Lan, L.W. 198l. Studies on the Absorption and Action of Nitrogen in Different Growth Stages of Rice by Using Isotope $^{15}N$. Agricultural Science of China.4:64-71

Wang, S.L., Peng, G.Y. and Su, B.L. 1989. Studies on the Action of Beijing Spring Rice by Using Isotope $^{15}N$. Journal of Beijing Agricultural University. 45(4):391-395

Xu, K., Zhao, D.W. and Jiang, X.M. 1991. Effects of Seed-ginger Size on the Growth and Yield of Ginger. Chinese Vegetable. 2:7-10

Xu, K. 1992. Changes of Some Physiological Index and Biochemical Matter During Growth of Ginger. Plant Physiology Communications. 28(5):395-396

Xu, K., Kang, L.M. 1999. Studies on the High Yield Culture of Ginger. Shandong Agri-cultural Science. 2: 28-29

Xu, K. 2000. Virus-free Ginger and Technique of High Yield Cultivation. Changjiang Vegetable. 6:8-9
Zhao, D.W. and Xu, K. 1992. Optimizing Technical System Schemes to Get High Yield of Ginger. Journal of Shandong Agricultural University. 23(3):221-225
Zhao, D.W. and Zhang S.L. 1981. Studies on the Rule of Growth and Development of Ginger. Journal of Shandong Agricultural College. 12(1):47-55S

## Tables

Table 1. The distribution (%) of carbon assimilation of different stems and leaves of ginger.

| Organs | Seedling stage (6-18) | Shoot & leaf vigorous growth stage (8-8) | | | Rhizome vigorous growth stage (9-18) | | | |
|---|---|---|---|---|---|---|---|---|
| | Labeled organs | | | | | | | |
| | Main shoot | Main shoot | First shoot | Second shoot | Main shoot | First shoot | Second shoot | Third shoot |
| Main shoot | 42.4 | 32.8 | 6.9 | 0.8 | 61.5 | 0.4 | 0.2 | 0.1 |
| First shoot | 38.3 | 22.1 | 45.6 | 2.8 | 0.8 | 41.1 | 1.9 | 1.7 |
| Second shoots | - | 13.9 | 18.7 | 70.4 | 0.2 | 0.9 | 52.3 | 2.8 |
| Third shoots | - | - | - | - | 0 | 0.1 | 2.8 | 71.9 |
| Rhizomes | 12.4 | 23.6 | 25.6 | 23.9 | 34.5 | 56.6 | 42.4 | 23.3 |
| Roots | 2.1 | 4.7 | 1.2 | 0.8 | 2.5 | 0.6 | 0.3 | 0.2 |
| Seed-ginger | 4.8 | 2.9 | 2.1 | 1.3 | 0.5 | 0.3 | 0.1 | 0 |

Table 2. Influence on the absorption and distribution of nitrogen in different period of fertilization.

| Organs | Total nitrogen (mg/plant) | | | Labeled nitrogen (mg/plant) | | | Rate of nitrogen distribution (%) | | | Rate of nitrogen utilization (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | II | III | I | II | III | I | II | III | I | II | III |
| Main shoots | 93.80 | 97.51 | 86.85 | 15.76 | 21.09 | 3.95 | 11.39 | 5.25 | 2.91 | 3.15 | 2.11 | 1.31 |
| Lateral shoots | 526.09 | 577.98 | 539.45 | 51.23 | 158.55 | 39.52 | 37.02 | 39.42 | 29.13 | 10.25 | 15.90 | 13.18 |
| Rhizomes | 548.84 | 593.85 | 659.70 | 68.60 | 216.91 | 88.81 | 49.59 | 53.94 | 65.43 | 13.72 | 21.69 | 29.60 |
| Roots | 12.03 | 11.45 | 11.35 | 0.23 | 1.96 | 0.96 | 0.17 | 0.49 | 0.71 | 0.46 | 0.20 | 0.32 |
| Seed-ginger | 63.81 | 0.88 | 71.61 | 2.53 | 3.63 | 2.47 | 1.83 | 0.90 | 1.82 | 0.51 | 0.36 | 0.82 |
| Total plant | 1244.57 | 1351.67 | 1368.96 | 138.35 | 402.14 | 135.71 | 100 | 100 | 100 | 28.09 | 40.26 | 45.23 |

Note: I Dressing $^{15}N$ fertilization at seedling period; II Dressing $^{15}N$ fertilization at stem & leaf vigorous growth period; II Dressing $^{15}N$ fertilization at rhizome vigorous growth period.

Table 3. The source and dynamic changes of nitrogen in ginger plant.

| Duration (Month-day) | | Total nitrogen (mg/plant) | Fertilizer-N (mg/plant) | Soil-N (mg/plant) | Fertilizer-N/ Soil-N (%) | Rate of N Utilization (%) |
|---|---|---|---|---|---|---|
| Seedling stage | 6-25 | 30.91 | 5.06 | 25.85 | 16.37 | 1.01 |
| | 7-21 | 171.47 | 41.96 | 129.51 | 24.35 | 8.39 |
| Shoot & leaf vigorous growth stage | 8-20 | 672.11 | 286.45 | 355.66 | 42.62 | 19.10 |
| | 9-18 | 1174.71 | 523.82 | 650.89 | 44.59 | 29.10 |
| Rhizome vigorous growth stage | 10-17 | 1521.73 | 660.91 | 860.82 | 43.43 | 36.72 |

Table 4. The distribution (%) of carbon assimilation of seed-ginger.

| Organs | Measuring date (Month-day) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Sowing time 4-28 | Seedling stage | | | Shoot & leaf vigorous growth stage | | Rhizome vigorous growth stage | |
| | | 5-28 | 6-16 | 7-8 | 7-27 | 8-16 | 9-8 | 9-26 |
| Main shoots | - | 4.13 | 7.67 | 5.45 | 4.03 | 2.56 | 2.03 | 1.89 |
| Lateral shoots | - | - | 3.11 | 6.02 | 6.47 | 8.02 | 7.07 | 6.74 |
| Rhizomes | - | 3.56 | 4.81 | 6.19 | 7.35 | 8.92 | 11.05 | 12.32 |
| Roots | - | 0.63 | 0.79 | 1.01 | 1.24 | 1.38 | 1.41 | 1.46 |
| Seed-ginger | 100 | 91.68 | 83.62 | 81.33 | 80.91 | 79.12 | 78.44 | 77.86 |