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Position of Source Leaf Affects Translocation and Distribution of C^{14} Photo-Assimilates in Tomato

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Abstract. The relationship between source leaf position and photo-assimilate translocation and distribution was characterized for tomato (*Lycopersicon esculentum* Mill) grown in the greenhouse. Three different positions of source leaf on the stem (first node above or below the first fruit cluster and 5th node above the first fruit cluster) were tested for their influence on $^{14}CO_2$ assimilation and transfer to different parts of the plant. The leaves at the 5th node above the first fruit cluster transferred the highest (57%) proportion of C^{14} to other plant parts, followed by leaves borne on the first node below the first fruit cluster (50%), and the first node above the first fruit cluster (39%). In all treatments, fruits served as the strongest sink for C^{14}, followed by stem, leaf, and root tissues. The leaf borne on the 5th node above the first fruit cluster transferred the largest amount of C^{14} to the second fruit cluster.

Key words : C^{14} labeling, leaf position, Photosynthesis, source-sink relationship

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Introduction

Source-sink relationships for photosynthate translocation and distribution have been investigated for crop plants including muskmelon (Van Oosten et al., 1994), cucumber (Choi et al., 1997), and watermelon (Lee et al., 2000). Importance of source leaves on fruit yield and quality has been well documented for tomato (Abe et al., 1973; Evans et al., 1973; Tanaka and Fujita, 1974; White, 1967, Wolk et al., 1983). When tomato plants were 80% defoliated at the time of first bloom, yield and soluble solid content of fruits were reduced, while net photosynthesis increased in the remaining leaves (Wolk et al., 1983). Leaves borne on the fruit-bearing node and leaves borne on the first and second nodes above and below were the better sources of photosynthesis than other leaves in cucumber (Kanahama and Hori, 1980; Murakami et al., 1982). In muskmelon, Hughes et al. (1983) found that the closer the distance between the source leaf and the sink fruit the greater the amount of C^{14} compounds transferred. Heuvelink and Buiskool (1995) reported that the source-sink interaction influenced the pattern of translocation and distribution for photo-assimilates, without affecting dry matter production in tomato. Marcelis and Heuvelink (1990) found when size of the source was fixed, dry matter yield was only 70% when seven tomato fruits were left on a cluster as compared when only one fruit was left on a cluster, indicating a lower source-sink ratio stimulates development of bigger fruits. When tomato fruit clusters were formed between 8th and 9th nodes, and 11th and 12th nodes were tested as source, 80% of carbohydrates traveled to the first cluster when the 7th and 8th nodes were exposed to $^{14}CO_2$, while more labeled carbohydrates were translocated to the second fruit cluster when the 9th leaf was exposed to $^{14}CO_2$ (Shishido and Hori, 1991). They also found that photo-assimilates formed on the first leaf of the lateral shoot branch were translocated more into the fruit cluster borne on the main stem than the first fruit cluster borne on the lateral branch. Flower pruning resulted in increased total leaf area, fruit weight, and dry matter yield of tomato especially when grown with a low fogging level (Gautier et al., 2001). The objective of this study was to characterize the influence of source leaf position on photo-assimilate translocation and distribution in tomato.

Materials and Methods

This study was conducted from April to August, 2003,

in an Exolite-covered greenhouse located at North Dakota State University, Fargo, ND. Seeds of 'House-momotarou' tomato (Takii Seed Co. Kyoto, Japan) were sown in plug trays (50×30×7cm) containing commercial root substrate (Pro-Mix, product of Premere, Riviere-du-Loup, Quebec, Canada). At the time of first flower cluster formation, the seedlings were transplanted into 30-cm diam black plastic pots (volume 12,000cm^3). Tomato pots were spaced 40-cm apart on a bench. For fruit set, flowers at anthesis were sprayed with a PCPA (p-chlorophenoxy acetic acid) solution (75μg·g^{-1}). Five days after pollination, the flower clusters were thinned to have 4 fruits per cluster.

Plants were treated with $^{14}CO_2$ when the rate of fruit growth was most active (20days after pollination). Leaves borne on the first node above the first flower cluster and the first node below the first flower cluster and the leaf on the 5th node above the first flower cluster (same as the upper first leaf from the second flower cluster) were used as source leaves. Three plants were used per treatment. Each of the source leaves was placed inside a 3-liter clear polyethylene bag with the open end of the bag tightly sealed around the leaf petiole. Using a hypodermic syringe, 2ml of labeled 10mM sodium bicarbonate ($NaH_2{}^{14}CO_3$) solution was injected into the plastic bag, followed by injection of 1ml of 50% lactic acid ($C_3H_5O_3$) solution. The two chemicals were mixed to release $^{14}CO_2$ inside the sealed plastic bag as a result of neutralization. Approximately 20μCi of radioactivity was released into each bag. The needle hole made on the plastic bag during injection was immediately sealed off with a piece of a masking tape. The bags were removed when the leaves were exposed to $^{14}CO_2$ for 40min. 24hr after treatment, the treated leaves, fruits of the 1st and 2nd flower clusters, leaves (non-treated), stems, and roots were harvested separately and dried at 80°C in an oven for 3-4days. The dried tissues were pulverized using an electric grinder. Plant height, number of leaves, leaf length, leaf diameter, fresh weight, and dry weight were recorded for the treated plants. The ambient temperature and relative humidity of the greenhouse ranged from 20-30°C and 60-87%, respectively, during the 25-hr experimental period. The light intensity inside the greenhouse ranged form from 800 to 1,300μmol·m^{-2}·s^{-1} during the treatment period.

Dried tissue samples (150mg per sample) were burned at 700 to 900°C in a Harvey Biological Oxidizer (OX-400, R.J. Harvey Instrument Co., Hillsdale, NJ) for 4 minutes to release $^{14}CO_2$ and captured it, using 15ml liquid scintillation (LS) cocktail. The LS cocktail was contained 2,5-diphenyl oxazole, 2,2 (1,4-phenylene) bis (5-phenyloxazole), toluene, 2-methoxyethanol and ethanolamine. A Liquid Scintillation Analyzer (Tri-Carb 2100TR, product of Packard Bioscience Co., Meriden, CT) was used to determine C^{14} ratio activity in the sample cocktail. Measurements were made on the basis of total tissue dry weights.

Results and Discussion

Growth characteristics

The height, leaf size and numbers, and total biomass yield of tomato plants at the time of $^{14}CO_2$ labeling are shown in Table 1. Plant height, stem diameter, leaf length, fresh weight, and dry weight were no significant difference. And flowering, fruit set, and ovary development in tomato plants were as normal as those grown for $^{14}CO_2$ labeling studies.

Rate of C^{14} transfer

The pattern of C^{14} distribution into different parts of the plant as influenced by source leaf position is pre-

Table 1. Growth characteristics of tomato plants measured at the time of $^{14}CO_2$ labeling.

Treatment	Plant height (cm)	Stem diam. (mm)	Leaf length (cm)	Leaf width (cm)	No. of Leaves	Fresh weight (g/plant)	Dry weight (g/plant)
Upper 1st leaf	107^z	11.3	33	36	18	1,280	101.4
Lower 1st leaf	97	9.8	36	40	17	1,432	113.8
Upper 5th leaf	105	8.5	40	46	18	1,208	91.9

^{z}Mean separation in each column separately by Duncan's multiple range test at P=0.05.

Table 2. Distribution of C^{14} compounds in various parts of the plant after 24hr as influenced by the source leaf position on tomato plants.

Treatment	Upper 1st leaf (%)	Lower 1st leaf (%)	Upper 5th leaf (%)
Treated leaf	61.3a[z]	49.6a	43.1a
Leaf	1.3c	0.9b	0.8c
Stem	7.1c	4.5b	3.3c
Root	0.2c	0.5b	0.1c
1st cluster	29.4b	43.9a	21.3b
2nd cluster	0.7c	0.6b	31.4ab

[z]Mean separation in each column separately by Duncan's multiple range test at P=0.05.

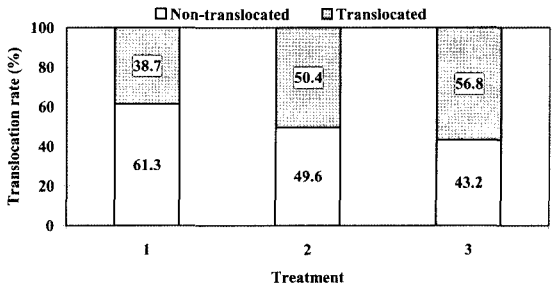

Fig. 1. Changes in the rate of C^{14} translocation from source leaf to the rest of the plant as influenced by the position of $^{14}CO_2$ labeled leaves on tomato plants, grown in the greenhouse, with the treatments indicating source leaf position: *1*-first leaf above the first fruit cluster, *2*-first leaf below the first fruit cluster, *3*-leaf on the 5th node above the first fruit cluster.

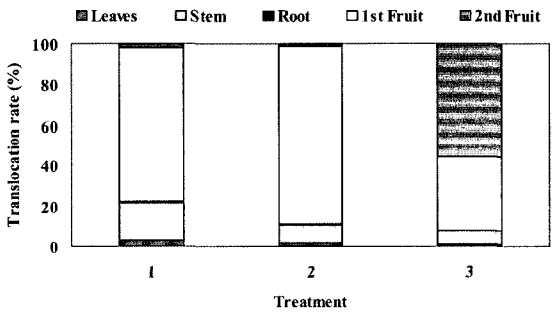

Fig. 2. Changes in percent C^{14} compounds transferred to the leaf, stem, root, and first and second fruit clusters of tomato as affected by the source leaf position treatments: *1*-first leaf above the first fruit cluster, *2*-first leaf below the first fruit cluster, *3*-leaf on the 5th node above the first fruit cluster.

sented in Table 2. The source leaf located one node above the first fruit cluster was contained 68.1% C^{14} and transferred 29.4%, 7.1%, 1.3%, 0.7%, and 0.2% C^{14}, respectively, into the first fruit cluster, stem, leaf, the 2nd fruit cluster, and roots within 24hr. The source leaf located one node below the first flower cluster was retained 49.6% C^{14} and transferred 43.9%, 4.5%, 0.9%, 0.6%, and 0.5% C^{14}, respectively, to the first fruit cluster, stem, leaves, the 2nd fruit cluster, and roots. The source leaf located on the 5th node above the first fruit cluster was retained 43.2% C^{14} and transferred 21.3%, 31.4%, 3.3%, 0.8%, and 0% C^{14}, respectively, into the first fruit cluster, the 2nd fruit cluster, stem, leaf, and root tissues in 24hr. In general, the ranking of C^{14} sink strength was fruit cluster, stem, leaf, and root tissues in a descending order. The overall result of this experiment is similar to the findings of Shishido and Hori (1991) who reported that, when tomato fruit clusters formed between the 8th and 9th nodes, and the 11th and 12th nodes were tested as sinks, 80% of carbohydrates traveled to the first cluster when the 7th and 8th nodes were exposed to $^{14}CO_2$, while more labeled carbohydrates were translocated to the second fruit cluster when the 9th node leaf was labeled with $^{14}CO_2$.

The proportions of total C^{14} remaining in the source leaf and transferred into the rest of the plant are shown in Fig. 1. The highest proportion (56.8%) of total C^{14} was translocated out of the source leaf in 24hr when it was located on the 5th node above the first fruit cluster. A similar proportion (50.4%) of C^{14} was also transferred to the rest of the plant in 24hr from the source leaf located just below the first fruit cluster. When the source leaf was located just above the fruit cluster, only 38.7% of total C^{14} was translocated into the rest of the plant in 24hr. The result of this experiment is similar to the findings of Shishido and Hori (1991).

Percent distributions of translocated C^{14} in sink organs of the plant as influenced by source leaf position are shown in Fig. 2. When $^{14}CO_2$ was fed to the leaf above the first fruit cluster, 76.0%, 18.4%, 3.3%, 1.8%, and 0.5% of C^{14} were found, respectively, in the first fruit cluster, stem, leaf, the second fruit cluster, and root tissues. Similarly, When $^{14}CO_2$ was fed to the first leaf below the first fruit cluster, the distribution of translocated C^{14} was 87.1%, 8.9%, 1.8%, 1.3%, and 1.0%, respectively, in the first fruit cluster, stem, leaf, second

fruit cluster, and root tissues. When the source leaf was located on the 5th node above the first fruit cluster, the highest proportion of total C^{14} transferred was contained in the second fruit cluster (55.2%), followed by first fruit cluster (37.4%), stem (5.8%), leaf (1.5%), and roots (0.1%). These findings agree with earlier reports that sinks are supplied by the nearest sources (Tanaka and Fujita, 1974; Kanahama and Hori, 1980; Murakami et al., 1982). In muskmelon, the closer the distance between the source and the sink, the greater the amount of C^{14} translocated (Hughes et al., 1983). Further investigation may be needed to elucidate the nature of C^{14} translocation under a wide range of light intensity, humidity, and diurnal temperature fluctuations.

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