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# Translocation of Glyphosate in Strawberry Stolons

**Gerald R. Leather and J. Ray Frank**

*Agricultural Research Service, U.S. Department of Agriculture, Weed Science Research, Ft. Detrick, Bldg. 1301, Frederick, MD 21701*

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***Abstract.*** **Field growing nonfruiting strawberries (*Fragaria* x*ananassa* Duch. 'Midway') were treated with (*methyl*-$^{14}$C) glyphosate [*N*-(phosphono-methyl)glycine] applied to the leaves of runner plants rapidly developing at the nodes of stolons. Seven days after application, $^{14}$C was distributed throughout the stolon and untreated new runner plants. The greatest accumulation of $^{14}$C was found in the stolon and in the runner plants distal to the application site. When the distal runner plant was treated, most of the $^{14}$C was recovered from the application site. Depending upon the treatment, from 2.9% to 11.5% of the recovered $^{14}$C activity was located in the mother plant.**

Glyphosate has been shown to be effective for interrow weeding of strawberries, with no observed effects on crop yield or injury to the mother plants from herbicide intercepted by stolons (2). Previous reports of glyphosate mobility in crop plants (4) and weed species (1, 3, 6, 7, 9) indicated to us that residue may accumulate in mother plants and fruit of strawberry from the application of this herbicide to the interrow stolons.

Rioux et al. (6) 1st reported that glyphosate was phloem-mobile and that translocation could be followed by visible symptoms of toxicity in quackgrass [*Agropyron repens* (L.) Beauv.]. Sprankle et al. (9) suggested that glyphosate moved in the assimilate stream as would be expected of a phloem-mobile substance. Haderlie et al. (4) traced the absorption and translocation of $^{14}$C-glyphosate in maize (*Zea mays* L.) and soybean [*Glycine max* (L.) Merr.]. They reported that 7% of the total applied $^{14}$C was translocated within 48 hr from an assimilate-exporting leaf in a source-to-sink pattern. Claus and Behrens (1) measured $^{14}$C-glyphosate accumulation in quackgrass rhizome buds and found the largest amounts in buds most distant from the mother plant.

This study was conducted to determine if glyphosate, applied to leaves of runner plants, would translocate into the mother plant or follow the pattern observed in quackgrass rhizomes. The results reported here and elsewhere (2) will be used to obtain a label amendment permitting the use of glyphosate for interrow weeding in strawberries.

Stolons with one or 2 runner plants were randomly taken from a single 8-row plot of 'Midway' plants (11 × 34 m). Methyl-$^{14}$C glyphosate (2.01 mCi/mM, 97.5% purity) was applied to designated runner plants in 4 treatments, 6 stolons each, as follows: 1) single runner plant stolon, 2) older runner plant of a 2-runner plant stolon, 3) both runner plants of a 2-runner plant stolon, and 4) younger runner plant of a 2-runner plant stolon (Fig. 1). The (*methyl*-$^{14}$C)glyphosate solution, containing 0.5% (v/v) Tween 20 [polyoxyethylene (20) sorbitan monolaurate] and technical grade glyphosate was applied at a glyphosate concentration of $4.7 \times 10^{-2}$ M containing $55 \times 10^{-2}$ μCi/ml $^{14}$C. A single droplet (0.05 ml) of solution was applied to each of 6 expanded leaflets on a runner plant. The average high and low temperatures during the 7-day treatment period were 28° and 12°C, respectively. Total rainfall which occurred during the experiment was 3.8 mm.

Plants were harvested after 7 days and separated into mother plant, runner plants, and stolons, each dried at 60°C and ground in a Wiley mill. After mixing thoroughly, 500-mg samples of each segment were combusted according to the procedure of Peterson (5). Efficiency of combustion was 99.5% as determined by a $^{14}$C standard sample. Samples then were assayed for $^{14}$C by liquid scintillation counting. The data are expressed on a total dry weight basis for each sample.

We recovered an average of 15.5% of the applied $^{14}$C in this study. Sandberg et al. (7) reported up to 47% loss of $^{14}$C-glyphosate from treated leaves, and attributed the loss to possible microbial action. The loss of recoverable $^{14}$C by microbial action, exudation, and degradation in soil (8), were the probable causes of the low recovery.

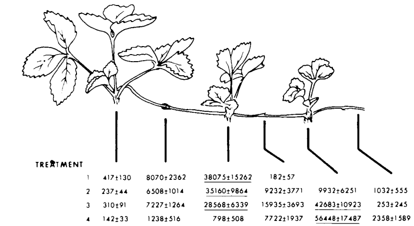


Fig. 1. Concentration (DPM/g, dry weight) of $^{14}$C in strawberry stolons and mother plants 7 days after application of (*methyl*-$^{14}$C)glyphosate. **1**) Single runner plant stolon (366,300 DPM). **2**) Two runner plant stolon, younger treated (366,300 DPM). **3**) Two runner plant stolon, both treated (732,600 DPM). **4**) Two runner plant stolon, older treated (366,300 DPM). Concentrations are (±) SE of the mean.

The concentrations of $^{14}$C in the mother plants, stolons, and runner plants are shown in Fig. 1. The highest concentration remained in or on the treated runner plants followed by very low amounts in stolons, untreated runner plants, and mother plants. The greatest concentration of $^{14}$C in the mother plant occurred when labeled glyphosate was applied to a single-plant stolon. The presence of a 2nd runner plant enhanced the distal movement of $^{14}$C, with the greatest accumulation in the 2nd actively growing runner plant. There was little difference in the concentrations found in the internodes of the stolon proximal to the treated runner plant. Increased movement occurred from the site of application when only one runner plant was treated. There was a high $^{14}$C concentration in the stolon internode between the treated runner plants and an increase in the amount found in the mother plant over that when a single runner plant of a 2-runner plant stolon was treated. Little $^{14}$C translocation occurred when the expanded distal runner plant was treated.

Table 1 shows the distribution of $^{14}$C as a percentage of the total recovered. Analysis of the data for untreated portions of the stolons showed a significantly lower percentage of $^{14}$C in the mother plant when the younger runner plant was present and treated than was found in single-runner plant stolons or those where the younger runner plant was not treated. An increased percentage of $^{14}$C was

Table 1. Percentages of total recovered $^{14}$C in strawberry plants and stolons 7 days after treatment with (*methyl*-$^{14}$C)glyphosate.

| | Plant section analyzed (% of total DPM/plant) | | | | | |
|---|---|---|---|---|---|---|
| Treatment | Mother plant | 1st & 2nd internode | Older runner plant | 3rd internode | Younger runner plant | 4th internode |
| 1 | 11.5 b[z] | 5.0 b | 79.7[y] | 3.8 a | ---[x] | --- |
| 2 | 4.1 ab | 5.4 b | 79.4[y] | 3.6 a | 7.0 | 0.4 a |
| 3 | 2.9 a | 2.6 a | 41.2[y] | 3.7 a | 49.5[y] | 0.1 a |
| 4 | 3.3 a | 0.8 a | 6.8 | 6.2 a | 79.8[y] | 3.1 a |

[z]Mean separation within columns by Duncan's multiple range test, 5% level. Data were analyzed as DPM of $^{14}$C and expressed as the mean percentage of total recovered from 6 plants.
[y]Treated runner plant.
[x]Single-runner plant stolon.

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found in the 1st internodes if the younger runner plant was not present or treated (Table 1). These results, based on field application of (*methyl*-$^{14}$C)glyphosate, indicate that glyphosate is translocated into expanding runner plants, and the amount of $^{14}$C translocated into the mother plant depended upon the site of application of the (*methyl*-$^{14}$C)glyphosate. We suggest from these results that interrow weeding of nonfruiting strawberry with glyphosate does not pose a residue problem from translocation of this herbicide when spray is intercepted by the stolons and runner plants. The results also confirm those reported previously (2) that injury to the mother plants does not occur because there is little translocation of glyphosate from the stolons.

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# Ascorbic Acid, Riboflavin, and Thiamin Content of Strawberries during Postharvest Handling

**D.E. Hudson[1] and M.M. Mazur[2]**
*Agricultural Research Service, U.S. Department of Agriculture, New Brunswick, NJ 08903*

**P.A. Lachance[3]**
*Rutgers University, New Brunswick, NJ 08903*

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***Abstract.*** **California and Florida strawberries from wholesale and retail stores in the greater New York area were analyzed for ascorbic acid (AA), riboflavin, and thiamin upon arrival. Retail samples also were analyzed after 3 days of simulated consumer storage at 5.5° and 90% RH. Locally-grown New Jersey strawberries were analyzed the day of harvest and after 4 and 7 days of storage at 5.5°C and 90% RH. Levels of AA in California and Florida berries were, on average, 8 mg/100 g fresh weight lower in wholesale than in retail samples. The average AA content of New Jersey berries was 31 mg/100 g fresh weight less than combined values of berries from California and Florida. Riboflavin levels in all samples were about 80% less than reported in standard nutrient tables. Thiamin was higher than reported in standard tables.**

Strawberries, one of our most popular fruit, are available almost year-round. In metropolitan New York, 19,274 MT were received in 1981, 98% of which came from California and Florida (5, 10). The strawberry is 11th in ascorbic acid (AA) content, 17th in riboflavin, and 36th in thiamin among 42 fruit and vegetables ranked for nutritive value (11). These water soluble vitamins are affected by temperature, moisture, light, oxygen, internal enzyme activity, and acidity. Commodity handling conditions between harvest and consumption also affect vitamin content (12). Thiamin in solution is destroyed by storage at room temperature at pH 7 or higher (4). Riboflavin is destroyed rapidly by light (3). Ascorbic acid is relatively stable. In one early study, strawberries stored for 2 days at 24°C and 5 days at 4° retained 90% and 95% of their AA (9).

This research was conducted to determine concentrations of thiamin, riboflavin, and AA in strawberries from California and Florida, obtained from 4 wholesale warehouses and 6 retail stores in metropolitan New York. Also analyzed were berries from 3 New Jersey growers. 'Tufts', 'Douglas', and 'Pajaro' strawberries from California and Florida, were grown under polyethylene mulch with trickle irrigation and fertilization, and were matured under higher soil pH and cooler temperatures than 'Raritan', 'Earliglow', and 'Guardian' strawberries grown under matted row culture in New Jersey. Berries from California and Florida were in transit for 2 to 5 days at 1° to 2°C in refrigerated trucks. New Jersey berries were placed on ice and transported in 1 to 2 hr to New Brunswick. Maturity of freshly-harvested New Jersey berries was similar to that of California and Florida berries at retail level.

In 1981 and 1982, analyses for thiamin, riboflavin, and AA in each category of berries were replicated a total of 16 to 19 times. Six 1-pint (0.55 liter) containers were taken at random from a flat of wholesale berries and analyzed the day of arrival in New York. Two pints were purchased at each of 6 different retail stores, one pint analyzed the day of purchase, the other stored 3 days at 5.5°C and then analyzed. Strawberries from 3 New Jersey growers were analyzed the day of harvest and after 4 and 7 days of storage at 5.5° and 90% RH. Berries were prepared for extraction by capping and comminution.

A continuous flow Technicon Autoanalyzer II (Technicon Industrial Systems, Tarrytown, N.Y.) was used to analyze strawberries for thiamin, riboflavin, and ascorbic acid (14, 15, 16). A different mixing manifold and proper light filters were required for each vitamin.

A modification of methods of Defibaugh et al. (7) and Technicon (16) was used for thiamin analysis. Samples (20 g) were extracted with 100 ml of 0.1 M HCl and blended for 3 min at 20,500 rpm in a microblender. Blended extracts were autoclaved for 30 min at 121°C, adjusted to pH 4.3 with 1.25 M sodium acetate, and 50 ml of the extract was diluted to 100 ml with pH 4.3 metaphosphoric acid. Extracts were filtered through Whatman 2V filter paper and analyzed fluorometrically. Analysis of thiamin was based on potassium ferricyanide oxidizing thiamin in extracted filtrate to thiochrome. Thiochrome fluoresces in ultraviolet light at 435 nm after excitation at 365 nm. To obtain blank values, the tube supplying potassium ferri-

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[1]Research Horticulturist.
[2]Biological Aide, USDA Horticultural Crops Quality Research, Building 6021, Rutgers Univ.
[3]Professor of Food Science.