Translocation of Photosynthetically Assimilated ^{14}C in Peanut (**Arachis**) Genotypes[1]

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ABSTRACT

Two experiments were conducted, one in the field and one in a growth chamber to determine the range of translocation of ^{14}C labeled photosynthate among peanut genotypes. Single attached leaves of peanut genotypes, which differed in photosynthetic rates, were exposed to $^{14}CO_2$ in the field and in a growth chamber. A significant difference in translocation was found among the genotypes in the growth chamber experiment with a range of 22 to 45% of assimilated ^{14}C translocation from the exposed leaf in 6 hours. The average translocation percentage of two cultivated genotypes (**Arachis hypogaea** L.), common to both experiments, was 27.2 in the field and 41.9 in the growth chamber. By comparison two wild species, **A. pintoi** Krap. et Greg. (Unpubl.) and **A. villosulicarpa** Hoehne translocated an average of 19.4% in the field and 27.4% in the growth chamber. However, **A. monticola** Krap. et Rig., a wild species included in the growth chamber experiment, had a translocation percentage similar to the cultivated species. A significant positive correlation (r=+0.79) was found between the rates of translocation and net photosynthetic rates.

Additional key words: **Arachis hypogaea,** photosynthate, groundnut.

Slow translocation may cause an accumulation of assimilate in photosynthetic tissue which in turn may reduce photosynthesis of plant leaves. Chatterton (3) concluded, on the basis of a negative correlation between net photosynthesis and specific leaf weight of alfalfa (*Medicago sativa* L.), that photosynthesis may be reduced due to accumulation of assimilate in leaves. Hartt (6) reported that a decrease in photosynthetic rate of detached sugar cane (*Saccharum offinarum* L.) leaves was associated with an increase in sucrose content. Hofstra and Nelson (7) found that C_4 species, such as tropical grasses, exported more than 70% of the assimilated ^{14}C in six hours of translocation as compared to 45 to 50% for C_3 species which had lower photosynthetic rates than C_4 species. A direct relationship between photosynthesis and translocation has not always been observed in comparison of genotypes. Evans and Dunstone (5) reported that wild diploid species of wheat (*Triticum* species) had higher rates of photosynthesis but lower translocation rates than the modern hexaploid cultivars of *Triticum aestivum* L.

This investigation was undertaken to determine the variation in translocation of photosynthetically assimilated ^{14}C among selected peanut genotypes.

Materials and Methods

Individual leaves of peanut genotypes grown under field conditions were exposed to $^{14}CO_2$ on September 4, 11, and 18, 1972. Six genotypes consisting of three wild species and three cultivated genotypes which showed a wide range of net photosynthesis (15 to 37 mg CO_2 dm^{-2} hr^{-1}) in previous studies (2) were used. The three wild species used were **A. pintoi** Krap. et Greg. (Unpubl.) P.I. No. 338314), **A.** sp. (**glabrata**? cv. arb) (P. I. No. 118457), and **A. villosulicarpa** Hoehne (P. I. No. 263396) and the cultivated genotypes were 'Florunner', a US cultivar, a genotype from Tanganyika, Africa (referred to as "Tang"), (P. I. No. 149268) and a genotype from India called 'Samrala' (P. I. No. 290570). Leaves of three plants of each genotype were exposed to $^{14}CO_2$. Cultivation of plants and

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technique of photosynthesis measurements have been reported (2). Plants were labeled in three replications; the first was at 105 days of age, the second at 112 days, and the third at 119 days after planting.

In a growth chamber experiment the same genotypes were used, except Samrala was replaced by **A. monticola** Krap. et Rig. (P. I. No. 263393) and **A. villosulicarpa** was replaced by another introduction (P. I. No. 336984) of the same species. All plants were grown from seed sown in pots containing about 15 kg of soil. Four replications of each genotype were planted in the greenhouse on July 17, 1973. The plants were moved to a growth chamber 24 days after planting. The plants remained in the growth chamber for 30 days at 48.4 Klux light intensity provided by cool white fluorescent lamps. The plants were subjected to 14 hours of light and 10 hours of darkness with temperatures of 30 ± 2 and 24 ± 2 C during light and dark periods, respectively. Beginning September 13, 1973, leaves on separate plants were exposed to $^{14}CO_2$ on three consecutive days between 10 a.m. and 2 p.m. EST.

Plant weights were much greater in the field than in the growth chamber since they were at a more advanced growth stage (Tables 1 and 2). Field plants of **Arachis hypogaea** were heavily fruited, whereas wild species had very little fruit. None of the plants in the growth chamber experiment had appreciable quantities of fruit, except Florunner.

An air-tight plexiglass chamber, with dimensions of 15

Table 1. Dry weight of plant parts (g/plant) from Arachis genotypes in the field (1972).

Species	Plant part: Roots	Leaves	Stems	Fruit	Total
A. pintoi	1.9 ± 0.6[2]	10.9 ± 3.6	11.6 ± 3.1	0.4 ± 0.1	24.8 ± 7
A. sp. (glabrata?)[3]	9.0 -	9.1 -	5.2 -	0.3 -	23.6 -
A. villosulicarpa (P.I.No.263396)	11.3 ± 5.6	60.8 ± 20.0	60.8 ± 22.0	1.3 ± 1.6	134.2 ± 48
A. hypogaea					
1. Tang	5.3 ± 1.4	110.2 ± 25.2	110.0 ± 32.8	68.2 ± 84.3	293.7 ± 144
2. Florunner	5.5 ± 2.0	61.9 ± 30.1	55.0 ± 22.3	91.3 ± 55.0	213.7 ± 105
3. Samrala	9.8 ± 8.1	129.2 ± 63.2	144.9 ± 87.6	162.0 ± 80.6	445.9 ± 238

[1] 105 to 115 day-old plants.

[2] Weight of plant part ± standard deviation.

[3] Only two observations were made for A. sp. (glabrata?).

Table 2. Dry weight of plant parts (g/plant) from Arachis genotypes in the growth chamber (1973).

Species	Plant part: Roots	Leaves	Stems	Fruit	Total
A. pintoi	0.3 ± 0.2[2]	1.3 ± 0.5	0.8 ± 0.7	.02 -	2.4 ± 1.6
A. sp. (glabrata?)	0.5 ± 0.2	3.3 ± 1.5	1.4 ± 0.8	-[3]	5.2 ± 2.4
A. villosulicarpa (P.I.No.336984)	1.4 ± 1.0	5.5 ± 3.8	4.1 ± 2.9	.01 -	11.0 ± 7.9
A. monticola	2.0 ± 1.1	18.2 ± 4.7	11.5 ± 3.3	1.5 ± 0.4	33.2 ± 8.8
A. hypogaea					
1. Tang	2.6 ± 0.6	19.6 ± 5.3	13.3 ± 6.0	0.8 ± 0.4	36.3 ± 11.7
2. Florunner	2.2 ± 1.1	16.8 ± 3.3	10.1 ± 2.4	5.7 ± 3.4	34.8 ± 8.4

[1] 55 day-old plants.

[2] Weight of plant part ± standard deviation.

[3] Blanks indicate either no data were available or insufficient plant material.

x 15 x 7 cm was used for $^{14}CO_2$ labeling. A nylon thread network across the lid and in the body of the chamber held the leaf in a horizontal position. The top was hinged to close over an attached leaf, with rubber gaskets to provide a seal. A small fan installed inside the chamber maintained a constant air movement. Chamber temperature was maintained at 30 ± 2 C by circulating water through a copper coil in the chamber. The leaves received $^{14}CO_2$ between 10 a.m. and 1 p.m. EST on clear days, with light intensity above 48.8 Klux.

A plastic container, with 1 ml of an aqueous solution of $NaH^{14}CO_3$, was placed in one corner of the leaf chamber. The solution contained 50 μ ci of $NaH^{14}CO_3$ per ml with a specific activity of 60 mci per mM. One ml of 6N HCl was injected with a syringe through a serological stopper to generate $^{14}CO_2$. Third leaf from the tip of a branch was allowed to assimilate $^{14}CO_2$ for 15 minutes. Following the assimilation period, the leaf was removed from the chamber and allowed to photosynthesize in the light for 6 hours. The plants were then harvested and divided into: 1) treated leaf, 2) treated branch leaves, 3) treated branch stems, 4) treated branch fruit, 5) other branch leaves, 6) other branch stems, 7) other branch fruit and, 8) roots. The separated plant parts were frozen and subsequently freeze-dried.

The dried plant material was ground to pass a 20-mesh screen. Carbon-14 in the plant material was determined according to a procedure described by Ashley (1) as follows. A sample of tissue (0.1 g) from each plant part in each replication was wrapped in blotting paper and placed in a one liter suction flask enriched with oxygen. After igniting the sample by using a Thomas-Ogg infrared ignition apparatus, 10 ml of ethanolamine-ethanol (2:1) solution was injected through a serological stopper for the absorption of $^{14}CO_2$. After about 30 minutes, a one ml aliquot of the solution was transferred to a vial. Fifteen ml of a cocktail consisting of 6.0 g PPO (2,5-diphenyloxazole) and 60 mg of POPOP (1,4-bis[2-(5-phenyloxazole)]-benzene) per liter of toluene were added. One ml of ethanol was also added to the vial to clear the solution. Radioactivity was determined by liquid scintillation counting.

Carbon-14 recovered from all parts of a plant, including treated leaf, was added to arrive at total ^{14}C fixed in the plant. Carbon-14 recovered from all plant parts, except the treated leaf, was taken as translocated. Percentages in various plant parts were calculated on the basis of ^{14}C translocated from the treated leaf. Treatments were arranged in a completely randomized experimental design.

Results and Discussion

A significant difference in ^{14}C translocation (percent of total ^{14}C recovered in plant parts other than the labeled leaf) among peanut genotypes was found in the growth chamber study (Table 3) but not in the field (Table 4). *Arachis pintoi* and *A.* sp. (*glabrata*?) translocated a significantly lower percentage of ^{14}C in the growth chamber experiment than other genotypes except *A. villosulicarpa*. The percentage translocated by *A. pintoi* and *A.* sp. (*glabrata*?) was approximately one-half of that translocated by *A. hypogaea* (Table 4). The lack of significant differences among genotypes in the field study may have been due to the variability in ^{14}C translocation within genotypes. Standard deviations are about twice as great in the field experiment. The cultivated genotypes generally had higher translocation percentages than wild species, except that translocation of *A. monticola* was similar to Tang and Florunner in the growth chamber study. The

Table 3. Total ^{14}C, ^{14}C translocated and percent distribution of ^{14}C-photosynthate translocated in 6 hours in the growth chamber study.

Plant part	A. pintoi	A. sp. (glabrata?)	A. villosulicarpa (P.I.No.336984)	A. monticola	A. hypogaea Tang	A. hypogaea Florunner
Total ^{14}C in plant, DPM x 10^{-4}	1080c*	1141c	1070c	2014b	2910a	2601ab
^{14}C translocated, DPM x 10^{-4}	260c	239c	340c	805b	1326a	1005ab
Percent ^{14}C translocated	23.6b	22.1b	31.3ab	40.3a	44.8a	39.1a
Percent distribution of translocated ^{14}C in plant parts						
Roots	1.7± 1.3	2.1± 0.7	2.7± 1.5	1.1±0.6	3.7± 2.3	2.0± 8
Leaves	22.8±11.4	32.2±20.4	38.8±12.8	53.4±7.4	43.1±14.8	33.9±11.7
Stems	75.4±12.1	65.6±20.2	58.4±11.6	43.8±7.7	50.9±15.5	49.1± 7.7
Fruit	0.2-	0.0-	.01-	1.7±0.7	2.2± 1.7	15.0±10.1
Treated branch stem						
1st 15 cm from tip	72.2±12.5	55.3±21.1	44.2±11.9	26.3±4.1	29.6±20.8	32.8±13.1
2nd 15 cm from tip	1.1-	3.3-	3.0± 2.4	0.8±0.2	5.6± 2.8	4.3± 0.8
3rd 15 cm from tip	-	-	-	0.5-	0.3-	1.4-
4th 15 cm from tip	-	-	-	0.1-	-	0.1-
5th 15 cm from tip	-	-	-	0.2-	-	-
Treated branch and sub-branch stems	73.3±12.4	58.7±20.7	49.8±15.3	33.4±8.6	37.6±19.9	40.5±11.4

* Numbers in each row followed by the same letters are not significantly different at the 5% probability level.

Table 4. Total ^{14}C, ^{14}C translocated and percent distribution of ^{14}C-photosynthate translocated in 6 hours in the field study.

Plant part	A. pintoi	A. sp.[1] (glabrata?)	A. villosulicarpa (P.I.No.263396)	A. hypogaea Tang	A. hypogaea Florunner	A. hypogaea Samrala
Total ^{14}C in plant, DPM x 10^{-4}	2651ab*	1411	1951b	3894a	3457ab	3365ab
^{14}C translocated, DPM x 10^{-4}	616a	147	413a	900a	1098a	798a
Percent ^{14}C translocated	18.7a	10.2	20.1a	23.4a	31.0a	23.0a
Percent distribution of translocated ^{14}C in plant parts						
Roots	1.3± 1.5	4.3	9.5± 2.7	2.4± 1.9	2.2± 1.1	1.5± 0.8
Leaves	5.9± 7.6	19.4	24.0±14.7	8.6± 6.8	20.5± 7.6	14.2±13.1
Stems	88.7±14.9	61.9	63.6±13.8	54.3± 6.4	46.3±12.5	52.5± 8.1
Fruit	3.9-	14.5[2]	2.9± 2.0	34.6±11.9	30.9± 5.2	31.8±17.4
Treated branch and sub-branch stems	86.1±17.8	60.3	60.9±14.8	51.2±4.5	44.9±13.4	48.4± 8.7

* Numbers in each row followed by the same letters are not significantly different at the 5% probability level.

1/ Only two observations recorded for A. sp. (glabrata?).

2/ Percent ^{14}C in A. sp. (glabrata?) fruit is based on flowers only.

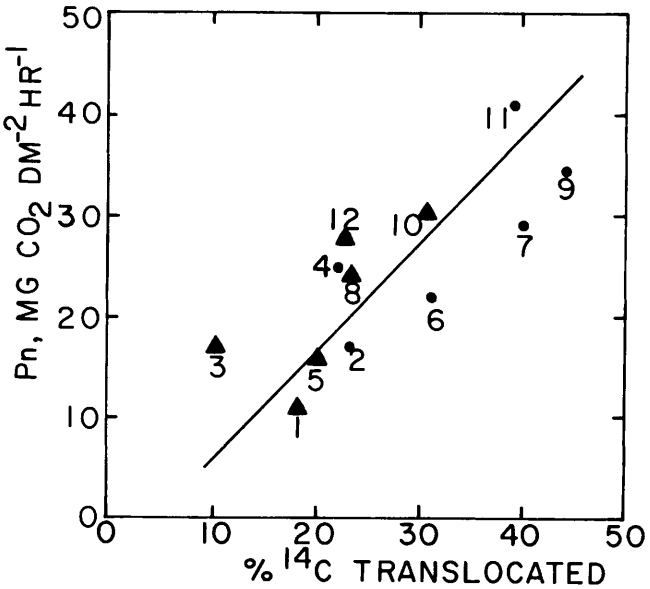
range of ^{14}C translocation from labeled leaves was from 10.2 for *A.* sp. (*glabrata*?) to 31.0% for Florunner in the field and from 22.1% for *A.* sp. (*glabrata*?) to 44.8% for Tang in the growth chamber study. Translocation percentages for *Arachis* species were similar to those of other C_3 species, with approximate percentages of 25 for soybean in 6 hours (4) and 32 for cotton in 8 hours (1).

The relationship between ploidy level and translocation is not clear among the 5 species of *Arachis* studied. Two diploid species, *A. pintoi* and *A. villosulicarpa,* had lower translocation percentages than tetraploid species, *A. monticola* and *A. hypogaea. A.* sp. (*glabrata*?), a tetraploid, however, translocated amounts of ^{14}C similar to those translocated by the two diploid species. Evans and Dunstone (5) found lower translocation rates for diploid than for tetraploid and hexaploid *Triticum* species.

Wild species, except *A. monticola,* retained a greater percentage of exported ^{14}C in their stems as compared to leaves (Table 3 and 4). This is particularly true of treated branch stems (the stem supporting the treated leaf) of wild species which retained 50% or more of the ^{14}C with *A. pintoi* retaining more than 70% in treated branch stems (Table 3). *A. hypogaea* and *A. monticola* retained about 50% or less of exported ^{14}C in treated branch stems. The retention of ^{14}C in the treated branch stems of peanut genotypes varied inversely with the translocation of ^{14}C from the treated leaf. The higher percentage of ^{14}C in the treated branch stems of *A.* sp. (*glabrata*?), *A. pintoi* and *A. villosulicarpa* indicates that sinks in other plants parts were relatively weak in these species, or that their translocation capacity is less than that of *A. hypogaea* and *A. monticola.*

The ^{14}C content decreased logarithmically from

Figure 1. Relationship between the percentage of ^{14}C translocated in 6 hr and maximum rates of net photosyntheis (Pn) in Arachis genotypes (r=0.79). Numbers in the graph represent genotypes as follows: A. pintoi-1 and 2, A. sp. (glabrata?)-3 and 4, A. villosulicarpa-5 and 6, A. monticola-7, A. hypogaea - Tang-8 and 9, Florunner-10 and 11, Samrala-12. In the field, translocation value for A. sp (glabrata?) was based on only 2 observations. Circles represent growth chamber data; triangles, field data.



the tip towards the base of the stem attached to the treated leaf (Table 3). The trend for a decrease in ^{14}C from tip to base of treated branch stems was more pronounced in the wild species, excluding *A. monticola*, than in *A. hypogaea*. The high concentration of ^{14}C in the distal end of the stem may have been due to an active meristem at the tip or due to attachment of the treated leaf to this portion of the stem or both.

It might be expected that translocation rates would be related to size of the sinks which have demand for photosynthate. The growth rates of *A. monticola* and *A. hypogaea* were higher than wild species as indicated by the total plant weights (Table 2). Greater accumulation of dry matter by *A. monticola* and *A. hypogaea* may imply greater sink demand during growth of these species. Cultivated genotypes also had more fruit than wild species particularly in the field study (Table 1). In *A. hypogaea* 31 to 34% of ^{14}C-photosynthate was translocated to fruit in field study, while only 3 and 4% was translocated to fruit in *A. pintoi* and *A. villosulicarpa*, respectively. Reasons for differences in translocation rates among peanut genotypes are not known, but translocation may be related to differences in sink size, both reproductive and vegetative.

Translocation also appeared to be related to photosynthesis. A significant correlation ($r = +0.79$) was found between the rates of translocation and photosynthesis for all the genotypes studied (Figure 1). Translocation rates for field grown plants were plotted against photosynthesis measured in the field in 1972 and translocation rates of growth chamber plants were plotted against average rates of photosynthesis of plants grown in pots in 1971 and 1972 (2). This relationship between photosynthesis and translocation is similar to one reported by Hofstra and Nelson (7) for photosynthesis and ^{14}C-translocation in several C_3 and C_4 species. An inverse relationship between these two characteristics was reported, however, for *Triticum* species (5).

The low photosynthesis rates in those peanut genotypes having low ^{14}C-translocation percentages may have resulted from the slower translocation. Although the evidence is not conclusive, the high levels of ^{14}C near the exposed leaf in the slower translocating genotypes indicates either that the plants lacked highly active sinks or had inefficient translocation systems or both. Based on the patterns of ^{14}C distribution and the positive correlation between translocation percentage and net photosynthesis it appears that accumulation of photosynthate may inhibit photosynthesis in some *Arachis* species.

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