BRIEF COMMUNICATION

Translocation of ^{14}C-(labelled) photosynthates in groundnut (*Arachis hypogaea* L.) infected with *Macrophomina phaseoli* (Maub) Ashby

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Abstract

At various intervals after inoculation of the roots of groundnut plants with the fungus *Macrophomina phaseoli*, $^{14}CO_2$ was administered to branch 2 (from the base) of the plants in the light. The effects of the disease on the translocation of ^{14}C-photosynthates out of the source branch to the rest of the plant were studied 24 h after labelling. As the plant aged and the disease symptom development became more evident, an increasing percentage of the fixed ^{14}C-photosynthates was exported from branch 2 of the inoculated plants (IP) compared to the non-inoculated plants (NIP). The apex, main stem, and branch 1 of NIP imported more of the total fixed ^{14}C throughout the developmental stages of the plant except for day 10 after inoculation when branch 1 of IP imported almost 76 % of the total fixed ^{14}C. The roots of IP were the major sink and imported higher percent of the total fixed ^{14}C than the roots of NIP.

Additional key words: branches; root.

The pattern of photosynthate translocation from plants infected by both obligate and facultative parasites has been studied (Doodson *et al.* 1964 - *Puccinia stiiformis* on wheat; Pozsar and Kiraly 1966 - rust infected plants; Thrower and Thrower 1966 - *Uromyces fabae* on broad bean; Coffey *et al.* 1970 - tomato infected with *Alternaria solani*). The pattern of distribution of ^{14}C was always markedly altered as a result of infection. However, little information is available on the carbon distribution pattern in groundnut due to infection. Groundnut pods with seeds are formed as a consequence of swelling of root tips induced by the translocation of photosynthates from leaf blades *via* stems. During plant growth cycle, carbon fixed by the leaf is transported to the roots that serve as the major photosynthetic sink and storage organ. The amount of photosynthate produced by the leaves and its proportion that is moved to the roots greatly influence the size and number of pods. This situation is a function of the health-state of the plant.

The present paper describes the variation in the distribution of ^{14}C at different stages of growth and infection development of the groundnut plants. Groundnut (*Arachis hypogaea* L.) of the erect Spanish Valencial cultivar was grown from seeds obtained from Department of Crop Protection, Faculty of Agriculture, Ahmadu Bello University, Zaria, Nigeria. This cultivar is susceptible to *Macrophomina phaseoli* (Narayana and Seshadri 1954, Feakin 1967). The seeds were sown in 15-cm plastic pots and left in the field. The experimental design was a randomised block with four replications. The plants were infected when they were 10-d-old following the method of Moniz *et al.* (1956). Forty-eight-hour mycelial mat of the *M. phaseoli* was carefully scooped with a sterile spatula. The mat was carefully wounded by pricking with sterile needle, by lifting the soil near the roots of the plants. The fungus was allowed to remain undisturbed *in situ* by covering with light soil layer. The control plants were pricked with needle but no inoculum was introduced. The plants were watered daily with care to avoid disturbance of the inoculum and excess water. The effect of infection on the translocation of ^{14}C-photosynthates was determined following the method of Khan (1981). Four replicates of both the healthy (NIP) and infected (IP) plants were randomly selected and fed with $^{14}CO_2$. Branch 2 of each plant was enclosed in a chamber of polyethylene bag in which a small glass tube

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(1.8 cm^3) was adhered to with cellotape (towards the closed upper end about 12 cm from the tip). The open end of the bag was lined with a layer of thin foam and was closed with a pair of bulldog clips after insertion of the branch 2. Each of the enclosed branches was then supplied with 185 Bq of aqueous solution of radioactive $Na_2{}^{14}CO_3$ using a hypodermic needle fitted to an algal micrometer syringe. To release the labelled carbon dioxide, excess of 1 M hydrochloric acid (HCl) was introduced into the $Na_2{}^{14}CO_3$ through a hypodermic syringe by piercing it through the polyethylene bag. The hole made by the syringe was sealed immediately with a piece of cellotape. The plants photosynthesised in $^{14}CO_2$ atmosphere for one hour, afterwards the chamber was removed. The plants then photosynthesised in normal atmosphere for further 23 h. They were then harvested and divided into treated branch, branch 1, leaves, stem, roots, and apex. These components were dried at 60 °C and dry mass was assayed according to Khan (1981). Analysis of variance (*Anovar*) and independent *t*-test were carried out to determine significant difference between the variables. For test of significance between pairs of variables, Duncan's Multiple Range Test (DMRT) and least significant difference (LSD) were used.

The export rates of the fixed ^{14}C-photosynthates for inoculated plants from the treated branch were 13, 17, 49, 20, and 22 % for the studied days after inoculation, while the values for the non-inoculated plants were 6, 12, 9, 7, and 3 %, respectively. At the first two stages, 1 and 5 d after inoculation, there was no significant difference between the % of the exported ^{14}C-labelled assimilates from the treated branch of IP and NIP. From the 10^{th} d, however, the differences between the % of exported materials became significant. The treated branch of IP translocated 49, 20, and 22 % of the total ^{14}C-labelled photosynthates, more than branches of NIP (9, 7, and 3 %). The highest percentage was noticed in IP on day 10 when about 80 % more than in NIP was recorded.

Table 1. Total radioactivity (specific activity × mg dry mass of plant part in various parts of inoculated (IP) and non-inoculated (NIP) plants. Means of 4 replicates ± error. Plants for this experiment were inoculated 15 d after sowing. **Significant at 1 % level; *significant at 5 % level.

Plant part		Time after inoculation [d] 1	5	10	20	40
Apex	IP	53.8±15.1	138.5±53.2	78.5±16.6	682.9±189.0	199.6±35.2
	NIP	322.3±145.5	419.5±50.9	139.5±20.9*	1018.6±139.1	60.6±13.3*
Branch 1	IP	394.1±89.1	952.3±106.2	4345.7±2643.5	3562.5±931.2	717.6±92.9
	NIP	582.0±93.1	1527.2±697.9	1276.7±273.7**	4895.9±787.4	870.3±222.0
Stem	IP	1452.4±258.4	4201.2±873.2	1916.7±293.5	3466.8±796.6	2391.6±863.8
	NIP	1038.1±167.1	2594.7±201.5	2473.9±346.6	4766.7±648.8	1122.9±188.7
Leaves	IP	870.6±166.7	3401.0±1201.8	2584.1±676.8	38199.8±764.8	1848.0±531.3
	NIP	599.6±100.8	3850.2±558.5	3362.8±1107.2	11703.0±1480.3	948.5±148.2
Roots	IP	6243.5±798.0	13433.2±2189.5	10228.8±394.9	20293.1±2964.2	23371.0±5391.9
	NIP	2844.2±624.4	2800.8±2386.6	4963.4±794.4	16452.1±4673.1	3981.3±877.7
Pegs/fruit	IP	-	-	-	-	-
	NIP	-	-	-	-	41.0±159.5
Total	IP	9000.9	22126.2	47265.2	31597.5	28527.7
	NIP	5386.1	21193.5	10790.7	38667.5	7394.7

Roots were the dominant sink in both IP and NIP (Tables 1 and 2). The roots of IP imported significantly higher quantities of ^{14}C than NIP ($p>0.05$), except at the 10^{th} d when IP imported only 16 % of the ^{14}C as against 41 % by NIP.

The leaves were the next most important sink for the ^{14}C-labelled photosynthates, particularly in NIP which showed a progressive increase from initial 12 % at day 1 to 35 % at day 20 after inoculation. Thereafter the value declined. The leaves of IP imported between 4-16 % only. At 10^{th} d after inoculation, IP imported significantly less than NIP ($p>0.05$).

Stems of NIP were also important sinks and imported between 13-21 %. The values for the stem of IP ranged from 3-19 %. There was a significant difference only at the 10^{th} d after inoculation ($p>0.05$) when the treated branch of NIP imported between 7-13 % of the ^{14}C while that of IP imported 3-12 % except at the 10^{th} d after inoculation when 76 % of the ^{14}C was recovered from it. These values were significantly greater than the value recovered from branch 1 of NIP, *i.e.*, 11 % ($p>0.01$).

The apexes of IP were significant sinks throughout the experimental period, however, only between 1-6 % of ^{14}C-assimilates was recovered from the apex of the NIP. The values showed significant difference only of the 10^{th} d after inoculation ($p>0.05$). The pegs and fruits

Table 2. Pattern of distribution of ^{14}C-assimilates to various parts of inoculated (IP) and non-inoculated (NIP) plants. Means of 4 replicates ± standard error. Plants for this experiment were inoculated 15 d after sowing. **Significant at 1 % level; *significant at 5 % level.

Plant part		Time after inoculation [d] 1	5	10	20	40
Apex	IP	0.59±0.15	0.61±0.22	0.14±0.04	2.09±0.51	0.75±0.15
	NIP	5.79±2.18	2.00±0.29	1.19±0.24*	2.80±0.53	0.91±0.28
Branch 1	IP	4.50±1.01	4.40±0.55	76.10±4.24	11.68±3.50	3.08±1.12
	NIP	11.10±2.15	6.70±2.15	10.70±2.55**	12.79±1.38	11.41±2.58
Stem	IP	16.40±3.30	19.30±4.31	3.30±0.41	11.07±2.69	8.94±3.62
	NIP	19.80±3.01	12.70±1.37	21.40±4.14*	13.10±2.76	15.34±2.00
Leaves	IP	10.10±2.58	15.50±5.18	4.30±0.82	12.46±2.77	7.41±2.51
	NIP	12.30±3.13	19.30±3.45	26.20±5.76	34.47±6.43	13.77±3.22
Roots	IP	68.60±5.58	60.30±7.26	16.20±3.99	63.37±5.52	79.83±4.44
	NIP	51.02±5.75	59.40±2.86	40.60±5.06	38.10±7.38*	53.06±6.53*
Pegs/fruit	IP	-	-	-	-	-
	NIP	-	-	-	-	5.60±2.10

constituted another sink for NIP (about 6 % of the ^{14}C-photosynthates went there; IP had no pegs and fruits throughout the experimental period.

Zaki and Durbin (1965) observed that the % of total assimilated ^{14}C translocated out from the primary leaves of bean infected by obligate parasite (rust) was less than that from corresponding healthy leaves. Coffey *et al.* (1970) showed similar result with the facultative parasite *Alternaria solani*. The amount of labelled photosynthates that moved out of the diseased leaves at the highest infection was reduced to one third of that which moved out of non-inoculated leaves. Thus the assimilated ^{14}C accumulated around and at the infection sites; it was unavailable for translocation to other organs (Zaki and Durbin 1965).

However, I observed that at the early stages of infection, *i.e.*, 1 and 5 d after inoculation, there was no significant difference in the export of ^{14}C-photosynthates of IP and NIP. This showed that *M. phaseoli* had no influence in the amount of ^{14}C-photosynthates exported at this stage. After the 10th d of inoculation, IP exported almost four times the amount exported by NIP. This dramatic increase in the exported ^{14}C may be due to as yet undetermined physiological factor since the rate was not maintained during the subsequent stages. However, IP kept exporting more than NIP, *i.e.*, the amount of ^{14}C-assimilates exported at 20 and 40 d after inoculation was greater than that exported by NIP. My observation is at variance with the works of Zaki and Durbin (1965) and Coffey *et al.* (1970). In their studies, however, they inoculated source leaf with the pathogen, while I inoculated roots.

^{14}C-assimilates accumulate usually at the sites of infection following export from non-infected sites (Yarwood and Jacobson 1955, Zaki and Durbin 1956, Garraway and Pellelier 1966, Thrower and Thrower 1966). Attempts have been made to explain this phenomenon whereby there was accumulation of ^{14}C-assimilates at infection sites in terms of transpiratory and metabolic activities. According to Yarwood and Jacobson (1955) it is due to increased transpiration from infected leaves. Shaw and Samborski (1956), Thrower (1965), Thrower and Thrower (1966), and Garraway and Pellelier (1966) suggest that it is due to increased metabolic activities at infection sites. It is not clear what factors are responsible for translocation of ^{14}C-assimilates to sites of infection since it varies with type of host-parasite relationship (Yarwood and Jacobson 1955) and the stage of infection (Shaw and Samborski 1956, Gerwitz and Durbin 1965). However, I show that infection by *M. phaseoli* affected the distribution of ^{14}C-photosynthates from a treated branch in a manner similar to that reported by other workers. The bulk of ^{14}C-photosynthates was translocated to the site of infection (roots and stem) at the expense of normal metabolic sinks including the apex. The increased metabolic activity may be involved in this increased translocation of ^{14}C-labelled assimilates to the site of infection. The metabolic activity at the site of infection is that of both the host and parasite (Garraway and Pellelier 1966). Moreover, Livne and Daly (1966) observed that respiratory metabolism of infected leaves was higher than that of non-inoculated leaves. This implies that the obligate parasite contributed to the increased respiration. Glycine supplied as ^{14}C accumulated in fungus (Stoy 1963) which is in agreement with the concept that parasites contribute extensively to the altered metabolism in the host. Obviously, ^{14}C tends to be translocated more to the area of increased metabolic activity than to the area with less metabolic activity since that would mean creating a new metabolic sink.

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