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STUDIES IN BIDIRECTIONAL MOVEMENT IN *VICIA FABA* L.

by

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ABSTRACT

Surgery was used to investigate bidirectional movement in a single vascular bundle of *Vicia faba* L. In one experiment it was found that radiocarbon had moved upwards and downwards via one isolated bundle when leaf one and leaf three on separate and severed plants were supplied with $^{14}CO_2$. Using $^{14}CO_2$ ^{14}C-glucose, ^{14}C-sucrose and surgery of the broad bean stem, flow of ^{14}C-products away from the source — the central part of the single bundle — took place in two directions. In the last occasion a double labelling technique was employed when ^{32}p was applied to the basal leaf of the single vascular bundle and CO_2 to the next higher leaf. After 30 minutes the tracers each applied at one end had moved past each other in a single bundle. The data suggest that simultaneous bidirectional movement of ^{14}C-products in a single vascular bundle may occur.

INTRODUCTION

That simultaneous bi-directional movement of carbohydrate might occur in plants has been suggested by many authors since 1920 but without unequivocal proof (Ho & Peel 1969b). Thaine (1964) summed up his observations of simultaneous bidirectional movement by stating that movement in single strands (within sieve tubes) was always in one direction but since there were several strands in each tube movement might be both upwards and downwards in the same sieve tube element (see Eschrich 1967). Peterson & Currier (1969) indicated that each bundle of broad bean transported fluorescein unidirectionally. Thompson et al (1979) indicated that bidirectional flow can occur in parallel veins. Fensom (1981) suggested that if bidirectional movement of photosynthate could be demonstrated to occur in a single mature sieve tube, pressure-driven mass flow could not then be its driving force. Ismail & Sagar (1981) reported reciprocal transfer of radiocarbon between a lateral branch and its parent shoot in plants of broad beans, but they indicated that the mechanism involved in this transfer is unclear.

The objective of the present study was to utilize ^{14}C to follow carbon flow in a precisely defined and single vascular bundle to determine the following parameters: (1) whether a single bundle can transport ^{14}C from an upper leaf basally and from a lower leaf apically; (2) whether a single bundle can transport ^{14}C upwards and downwards when the source of ^{14}C was its middle part; (3) the ability of a single bundle to transport ^{14}C-glucose and ^{14}C-sucrose (a) in both directions and (b) from both directions; (4) the possibility of the occurrence of simultaneous bidirectional movement in a single vascular bundle, and (5) the possible routes by which ^{14}C may move from a lower leaf to an upper leaf and from an upper leaf to a lower one.

MATERIALS AND METHODS

General

Broad bean plants were raised in a temperate glasshouse. Two seeds of broad bean (*Vicia faba* L. cv. Express Longpod) were sown per 15-cm. pot of John Innes No. 1 Compost. At the stage of 1-2 expanded leaves one plant was removed leaving one per pot.

Experiment 1

To investigate whether a single bundle of *Vicia faba* plant can transport radiocarbon from an upper leaf basally and from a lower leaf apically.

Thirty two plants were selected for uniformity at the 4-5 expanded leaf stage and surgery was carried out on half the plants so that the basal leaf (L1) and an upper leaf (L3) were connected by only a single vascular bundle. Leaf 2 (L2) and parts of the stem between L1 and L3 were excised so that one cortical bundle together with its adjacent cortical tissue and a portion of the opposite green epidermal cells were left intact (Fig. 1). The treated plants were left 2 days after surgery when the 16 healthiest plants were selected for treatment. Few plants wilted and these plants were not used for the experiment. On separate plants either L3 or L1 was supplied with $^{14}CO_2$. Both single-bundle and control plants were used. Four replicate plants were harvested 6h and 24h after $^{14}CO_2$ was supplied. Photosynthetic studies were carried out between 09.00-11.00 hrs as the natural light in the temperate greenhouse was supplemented by 400 w mercury lamps to give a daylength of 16-h. Radiocarbon dioxide was supplied to the appropriate source leaves for 1h after which the feeding chamber was removed. The treatment plant received 5 µCi of $Na_2{}^{14}CO_3$ and the general procedure of feeding was similar to that of Lovell *et al.* (1972). At harvest the components above the single bundle, the components below the single bundle and the single bundle (in the case of control plants the homologous bundle was harvested as a separate plant component) were dried at 60-70°C, weighed and ground using a pestle and mortar. Radioactivity was assayed following the methods of Jones *et al.* (1959) and Lovell (1969). The results obtained are expressed as counts per minute (cpm) and percentages of the total radio-activity exported from a treated source.

Experiment 2

To investigate whether a single separate bundle can transport assimilates upwards and downwards when the source of $^{14}CO_2$ was its middle part.

At the 4-5 expanded leaf stage ten plants were brought from the glasshouse and maintained in a growth chamber with a 15h photo-period by fluorescent lamps and a mercury lamp (8.2 k 1ux.), temperature 22±1°C. On the same day surgery was carried out so that the plants were reduced to one bundle between leaf one and leaf three (see experiment 1). Two days after surgery eight plants were treated with $^{14}CO_2$. The middle section of the isolated bundle was enclosed in a small tube as shown in Fig. 2 and allowed to assimilate $^{14}CO_2$ for 30 minutes. The operating procedure was as follows: as the syringe plunger was slightly lowered and the cork bung removed 50 µCi of $Na_2{}^{14}CO_3$ was injected with an aid of an (Agla' syringe) onto the base of the plunger and the plunger was further lowered to the 3 cm^3 mark. A small quantity of IN HC1 was then added and the cork was immediately replaced and the plunger of the syringe retained to the top position thus moving the $^{14}CO_2$ gas through into the feeding chamber. After 30 minutes the tap was opened, the plunger of the syringe pulled down, the cork bung removed, and the pump switched on so that the feeding unit was completely purged. The plants were treated one at a time. At the end of the experiment the bundle with its lower and upper leaves was separated from the rest of the plant which was discarded. Four plants were harvested and each cut into the following components:

1 — Leaf 3 (L3)
2 — The petiole of L3

3 — The upper part of the isolated bundle
4 — The middle part of the bundle (the part exposed to $^{14}CO_2$)
5 — The lower part of the isolated bundle
6 — The petiole of L1
7 — Leaf (L1)

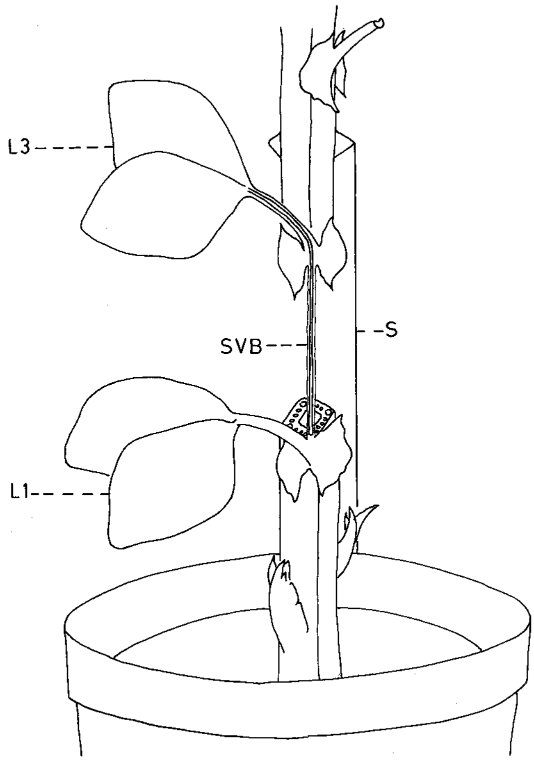


Fig. (1) *Plant material after surgery to a single bundle.*

LI Leaf I

L3 Leaf 3

SVB Separated Vascular Bundle

S stands for stake.

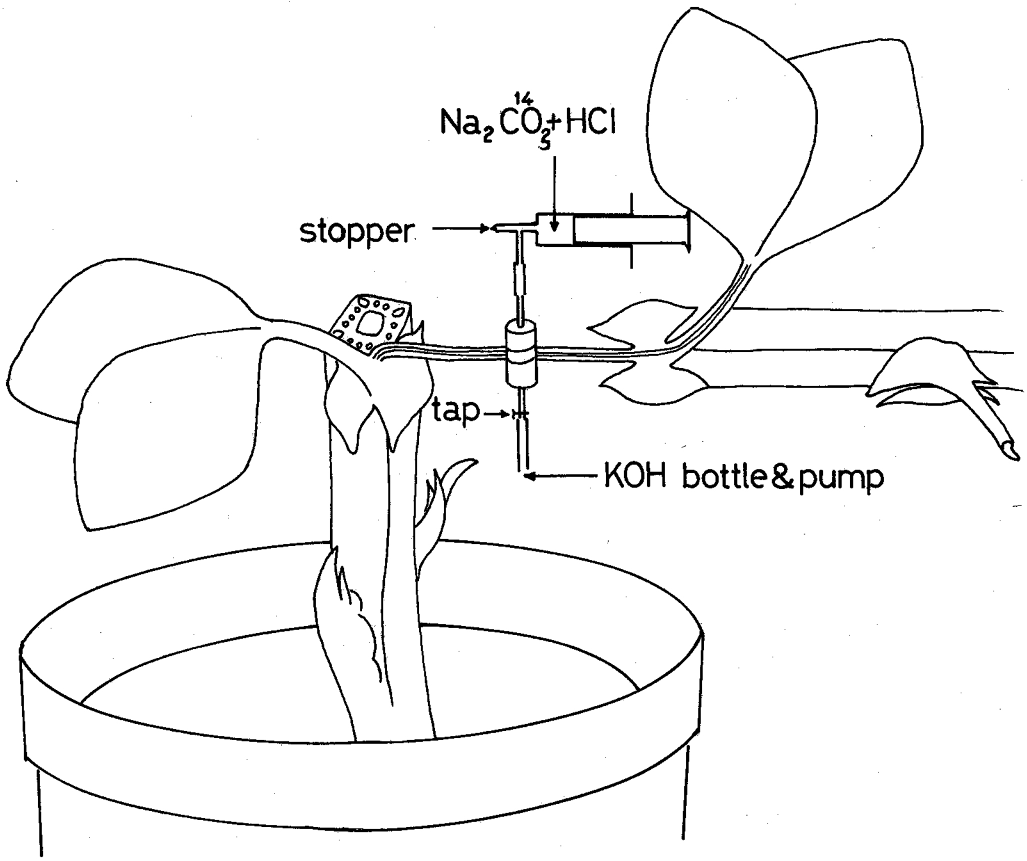


Fig. (2) *Apparatus for the feeding of the middle part of the separated vascular bundle.*

Each plant part was freeze-dried, weighed and its radioactivity assayed.

The remaining four plants were harvested as described before and the separate bundles were used for biochemical assay; two bundles were assayed for ethanol-soluble fraction and the other two for ethanol-insoluble fraction and each bundle was separated into three components:

1 — The upper part of the bundle
2 — The middle part of the bundle (the part exposed to $^{14}CO_2$)
3 — The lower part of the bundle

Extraction of sugars and starch and their determination were adapted from the methods described by Webb and Gorham (1964) and Clauss *et al.* (1964).

Experiment 3
To investigate the ability of a separated bundle to transport ^{14}C glucose and ^{14}C-sucrose (a) in both directions and (b) from both directions.

At the stage of 4-5 fully expanded leaves 20 plants were taken from the glasshouse and placed in a growth chamber with a 14h photo-period, a light intensity of 9.5 k lux. and temperature 25±^{0}C; surgery was immediately carried out so that the plants were reduced to one bundle between L1 and L3 (experiment 1). Two days later ten plants were treated with radioactive chemicals. Droplets of solutions of ^{14}C-glucose (1μCi) and ^{14}C-sucrose (2.5μCi) were applied separately as follows: (a) ^{14}C-glucose was applied on the epidermal tissue at the mid-point of the bundle (b) ^{14}C-glucose was applied at the centre of a leaflet of L3 (c) ^{14}C-glucose was applied at the centre of a leaflet of L3 (d) ^{14}C-glucose was applied at the centre of a leaflet of L1 (a) ^{14}C-sucrose was applied at the centre of a leaflet of L1. Each treatment consisted of two replicates and before applying the tracers the sites of application on the upper surface of the leaflets were rubbed with 0.5% Tween 20. A droplet of glucose or sucrose was dispensed from an Agla' syringe to give activity of 1 μCi and 2.5 μCi respectively. The experimental period was for 30 minutes after which the plants were harvested so that the bundle and its two leaves were separated from the rest of the plant. The rest of the plants and the site of application of the tracers were discarded. The required parts were freeze-dried and exposed to Kodirex X-ray film for one week.

Experiment 4
To investigate the possibility of the occurrence of simultaneous bidirectional movement in a single vascular bundle.

At the 4-5 expanded leaf stage, ten plants were brought from the glasshouse and maintained in a growth chamber (16h photoperiod, light intensity of 13.2 k lux. and temperature 25±1^{0}C). On the same day the plants were reduced to single-bundle between L1 and L3. Two days later the 4 healthiest plants were selected for treatment. In this experiment ^{32}p-labelled orthophosphate was supplied to L1 at the same time as $^{14}CO_2$ was fed to L3. The method of applying ^{32}p to a leaflet was similar to that of Marshall and Wardlaw (1973). A droplet from an 'Agla' syringe of sodium orthophosphate ($NaH_2{}^{32}PO_4$), of 3.2 μl to give an activity of 2 μCi was applied on the mid-rib of the required leaflet after its surface had been treated with 0.5% Tween 20. The experiment lasted for 30 minutes after which the unfed leaflets only, with their single-bundle, were cut from the plants. The rest of the plants and the treated leaflets were discarded. The 4 plants were severed into the following components:-

1 — The unfed leaflet of L3
2 — The petiole of L3
3 — The upper part of the isolated bundle
4 — The middle part of the isolated bundle
5 — The lower part of the isolated bundle
6 — The petiole of L1
7 — The unfed leaflet of L1

The components were prepared for radioactivity assay as in experiment 1. Each planchet was counted twice: on the first occasion without any screening of any β-rays and on the second the planchet was counted after a thick polythene disc had been placed to cover the dried material (Marshall and Wardlow, 1973). The disc reduced the penetration of β-rays of ^{14}C to only 10% but allowed 98.7% of the β-rays of ^{32}p to be detected. Thus by subtracting the second count from the first and making other necessary corrections the counts of both ^{14}C and ^{32}p were obtained from each sample.

THE VASCULAR SYSTEM PREPARATION

The vascular system of the shoot of broad bean was investigated by using the tissue clearing techniques of Grieve (1936), Fuchs (1963) and Mullins (1970). Shoots with 5-6 expanded leaves were cut at the transitional zone of the stem and root and the cut end immediately put into a solution of 0.5% basic fuchsin. The shoots were left to take up the dye till it was clearly visible in the veins of the young expanding leaves, when the plants were passed through graded alcohol (80%, 95% and absolute). Finally the plants were cleared by bathing in lactophenol for 2-3 days.

RESULTS

Experiment 1
After either 6h or 24h there were no significant differences between leaves in respect of total ^{14}C recoveries (Table 1) but there were significant differences between treatments. The direction of movement of radiocarbon exported from fed leaves is shown in Table 2. It is clear that ^{14}C-labelled products were moved both apically and basally through the bundle. Six hours after feeding began 16% of the carbon exported from L1 of single bundle plants were recovered apically compared with 30% moved apically from L1 of intact plants (difference is not significant). After 24h, 20% of the carbon exported from L1 of single-bundle plants was recovered apically but 56% moved apically from L1 of intact plants; the difference is significant at $P = 0.05$. Of the carbon exported from L3 of single-bundle plants 28% and 22% had been moved basically after 6h and 24h respectively, but in intact plants more radiocarbon had moved basally (54%) after 6h than after 24h (39%); this difference is significant at $P = 0.05$. After 6h more radiocarbon was recovered basally from intact plants than from single-bundle ones ($P = 0.05$) but after 24h there was no significant difference between these treatments. The radiocarbon in the single bundle whether intact or separated was the same for the basal leaves and was also the same for the upper leaves, i.e. there was no significant difference between treatments.

Experiment 2
Fig. 3 shows that $^{14}CO_2$ was fixed by the central part of the separated bundle and that ^{14}C was moved in both directions away from the site of application. Activity expressed in cpm mg^{-1} declined progressively up and down the bundle. Radioactivity was detected in both mature leaves. When fixation was complete after about 30 minutes the middle part of the bundle (fed part) contained 53% ethanol-soluble fraction and only 4% of the ethanol-insoluble fraction. The upper part of the bundle and the lower part contained 28% and 19% of the ethanol-soluble fraction respectively. No ethanol-insoluble fraction was detected in the lower or upper part of the bundle (Table 3).

Experiment 3
When ^{14}C-glucose was applied at the centre of the bundle, radioactive $^{14}C$was moved upwards to L3 and downwards to L1 (Plate 1A). When ^{14}C-glucose (Plate 1B-a) and ^{14}C-sucrose (Plate 1C-a) were applied separately to a leaflet of L1 radiocarbon was moved upwards and when they

Table 1.

Total ^{14}C fixed (CPM X 10^3) by source leaves. Values are means of three replicates ±S.E. given.

	L1 (Basal)		L3 (Upper)	
	Control	**Single-bundle**	**Control**	**Single-bundle**
6 h	469.6±27.2	446.8±24.7	446.7±28.1	465.4±25.6
24 h	348.4±42.3	321.9±18.9	337.2±25.1	312.3±41.1

Table 2.

The effects of treatment and time on the direction of transport of exported 14C (%) and the percentage of radiocarbon recovered from the single bundle. (Values are means of three replicates) ±S.E. given.

	L1 (Basal)				L3 (Upper)			
	Control plants		**Single-bundle plants**		**Control plants**		**Single-bundle plants**	
	6 h	**24 h**	**6 h**	**24 h**	**6 h**	**24 h**	**6 h**	**24 h**
Up	28±10	54±7	16±3	20±5	46±3	61±5	60±10	70±10
(in bundle)*	2	2	4	3				
Down	70±10	44±7	81±3	77±5	42±3	31±5	28±10	22±10
(in bundle)**					12	8	12	8

* *When L1 was fed the single bundle was above the fed leaf.*

* *When L3 was fed the single bundle was below the fed leaf.*

Table 3.

Distribution of ethanol-soluble and ethanol-insoluble ^{14}C in a single bundle of broad bean following assimilation of $^{14}CO_2$ for 30 minutes. Results are the mean of 2 replicates.

	The upper part of the bundle	**The middle part of the bundle**	**The lower part of the bundle**
Ethanol-soluble (%)	28	53	19
Ethanol-insoluble (%)	0.0	4	0.0

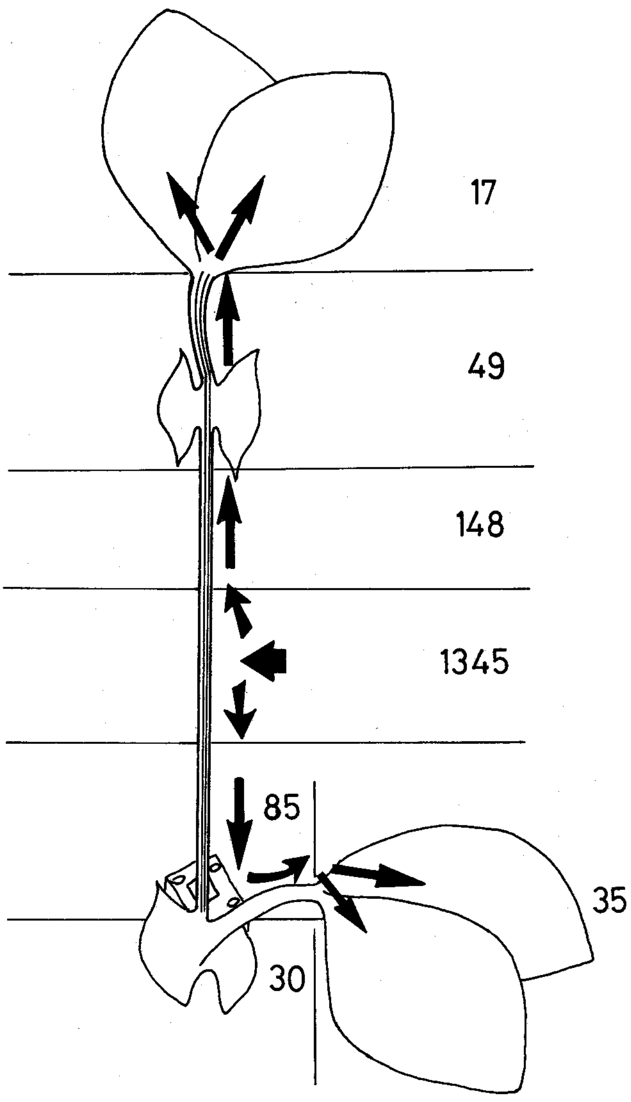


Fig. (3) *The movement of C^{14}-products in both directions when the source of CO_2 was the central part of the single bundle.*

➡ *Indicates the treated part of the bundle.*

→ *The upward and downward movement of radiocarbon.*

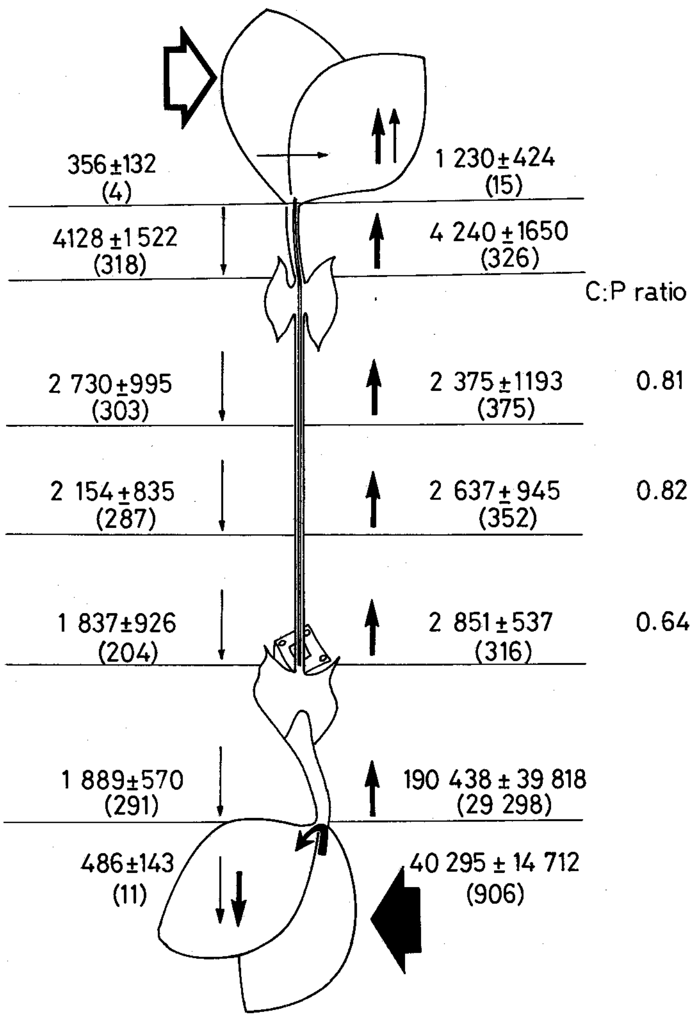


Fig. (4)

The bi-directional movement of carbon and phosphorous when an upper leaflet was fed with $^{14}CO_2$ and a lower leaflet with ^{32}P. Values shown on the left hand are cpm±S.E. for ^{14}C and values on the right hand are cpm±S.E. for ^{32}P. Values in parenthesis are cpm mg^{-1}. The ^{14}C:^{32}P ratio along the separate bundle is also shown.

Leaflet treated with $^{14}CO_2$ | *^{14}C movement*

Leaflet treated, with ^{13}P | *^{32}P movement*

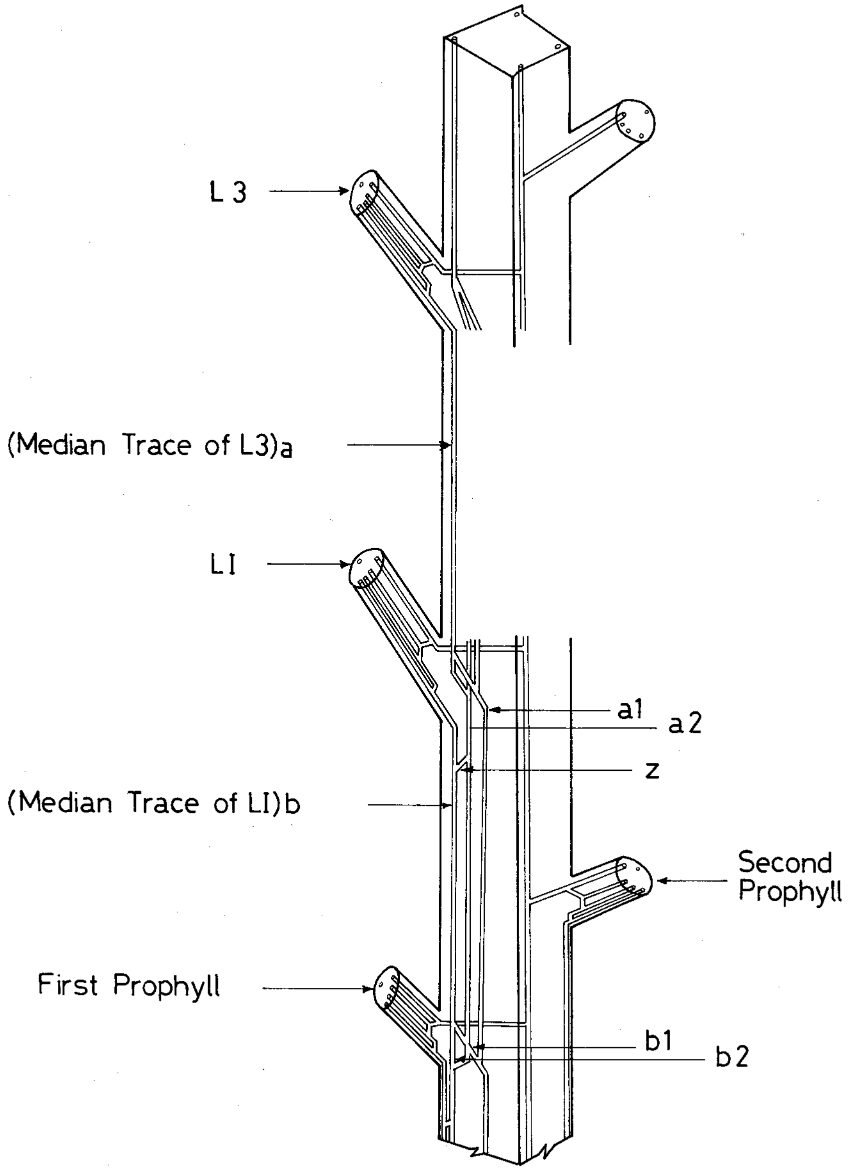


Fig. (5)

Possible routes through which a tracer may move from L1 to L3 from L3 to L1.

a_1 and a_2: halves of the median trace of L3.

b_1 and b_2: halves of the median trace of LI.

Z: anastomosis between the splitting median trace of LI and the median trace of LI.

were applied separately to a leaflet of L3 (Plate 1B-b and Plate 1C-b), ^{14}C was moved downwards. The separated bundle was heavily labelled when transport occurred basally and poorly labelled when transport was towards the apex.

Experiment 4

Fig. 4 records the recoveries of ^{14}C and ^{32}P and their inter-relationships when both were applied concurrently in one treatment. It can be seen that the gradient of the activity of ^{14}C was the reverse of that of ^{32}P and that the concentration of each tracer declined away from its site of application. The ratio of ^{14}C:^{32}P along the single-bundle (at its upper, middle or lower part) for each treatment did not differ significantly (any differences in the ^{14}C:^{2}P ratio for each separate treatment cannot be taken to be statistically significantly different, since they were based on mean counts of high standard errors.) Within 30 minutes ^{14}C-assimilates and ^{32}P compounds had travelled in opposite directions and over distances greater than 10 cm. The unfed leaflet of L1 beside accumulating an enormous amount of ^{32}P was also found to contain ^{14}C. Likewise the unfed leaflet of L3 beside receiving some radiocarbon was also found to contain some ^{32}P.

DISCUSSION

The reduction of the vascular system to a single-bundle between adjacent leaves on the same orthostichy had no affect on the amount of $^{14}CO_2$ fixed by the leaves tested nor on the amounts of radiocarbon exported from them and the fed leaves supplied some radiocarbon to the various sinks.

Reducing the system to one bundle still allowed movement from L1 upwards and L3 downwards. The movement of ^{14}C appears to have been bi-directional via one isolated bundle for ^{14}C-labelled compounds had been moved from L3 to the basal parts of the plant and from L1 to the apical regions. These results contrast markedly with those of Peterson & Currier (1969) who reported that each bundle of broad bean transported fluorescein unindirectionally.

There was evidence that when the middle part of the bundle was a source of assimilates (Fig. 3), flow of ^{14}C-products away from that source took place in two directions (although not bidirectionally). This finding is again at variance with the Peterson & Currier (1969) demonstration but consistent with the results of Fensom & Davidson (1970) for *Heracleum sphondylium* where sucrose moved in a single sieve tube in both directions away from the site of application. Following feeding with $^{14}CO_2$ to the middle part of the bundle ethanol-soluble compounds (sucrose-fructose and glucose) were identified as the main mobile sugars, which were transported up and down the vascular bundle. The results show that 53% of these sugars was still remaining in the fed part of the bundle and that $^{14}CO_2$ was fixed as ethanol-soluble compounds. The nature of the compounds retained by a fed leaf has been described by several authors. Clauss et al (1964) for soybean, Webb & Gorham (1964) for straight necked squash and Ashley (1972) for cotton showed that the initial rapid rate of export of radiocarbon by a leaf coincided with the disappearance of ^{14}C-ethanol-soluble compounds from the fed leaf. In this particular experiment the source of C-compounds was a bundle and not a leaf. The proximity of the photosynthesizing tissues to transporting conduits appears to be an important factor in the rapid removal of assimilates from sources to sites of utilization (Crookston & Moss, 1974; Gallaher et al, 1975). In the present experiment when ^{14}COQS22 was supplied to the central part of the epidermal tissue covering the single separated bundle over 45% of the ethanol-soluble ^{14}C-compounds were exported in 30 minutes, a performance only matched by some C-4 plants. A very small proportion of ethanol-insoluble compound was detected in the fed part of the bundle, and as has already been noted some of fixed carbon is always irreversibly incorporated into cell wall polysaccharide, (Porter, 1966).

The movement of radiocarbon supplied as $^{14}CO_2$ to the middle of a separated bundle might have been in the gaseous phase and it was felt necessary to repeat the study using tracers other than $^{14}CO_2$. ^{14}C-labelled glucose and ^{14}C-labelled sucrose were applied in solution. The results obtained were similar and confirmed those of $^{14}CO_2$ treatments, i.e. a single-bundle transported ^{14}C-labelled compounds apically and basally from a common source. Although Peterson & Currier (1969) by using fluorescein rather than a naturally occurring substance overcame the problem of creating a source, their results may have occurred either because fluorescein is transported in sieve tubes by a process different than that by which naturally occurring substances are moved (Ho & Peel, 1969b) or because of a lower sensitivity of the fluorescein method (Fritz, 1973).

As a logical extension of the present investigation a further experiment was carried out using double-labelling techniques (^{14}C and ^{32}P) to examine whether two tracers each applied at a distance from the other would move towards and pass each other in a single-bundle. The results showed that radiocarbon moved within the single-bundle basally past ^{32}P while ^{32}P moved apically. Movement was bi-directional and from the evidence of the gradients simultaneous. Fig. 5 shows the possible routes by which a tracer may move from L1 to L3 and from L3 to L1. A tracer applied to L1 may (i) move down through (b) across (z) to (a_2) and up (a), thence to L3, (ii) move down (b) then either (b_1) or (b_2) into (a_1) or (a_2); and thence through (a) to L3. Both routes may be used simultaneously. When a tracer is applied to L3 it may either (i) move down in (a) through (a_1) or (a_2). From (a_2) it may cross (z) and enter (b) thence to L1 or (ii) move down through (a) then via (a_1) or (a_2) to (b_1) or (b_2) thence to (b) and L1. Both possibilities exist simultaneously.

The movement observed in this investigation was bi-directional, appeared to be simultaneous and was in a single separate vascular bundle. From the present study it is possible to conclude only that simultaneous bi-directional movement in a single bundle can occur. The significance of the demonstration of such bidirectional movement in a single bundle suggests that simultaneous bidirectional movement in a single file of sieve tubes cannot be excluded as a tenable hypothesis (Trip & Gorham, 1968).

REFERENCES

Ashley, D.A. 1972. ^{14}C-labelled photosynthats translocation and utilization in cotton plants. Crop Sci. 12: 69-74.

Clauss, H., Mortimer, D.C. and **Gorham, P.R.** 1964. Time-course study of translocation of products of photosyntheses in soybean. Plant Physiol. 39: 269-273.

Crookston, R.K. and **Moss, D.W.** 1974. Interveinal distance for carbohydrate transport in leaves of C-3 and C-4 grasses. Crop Sci. 14: 123-125.

Eschrich, W. 1967. Bidirktionelle Translocation in Siebrohren. Planta 73: 37-49.

Fensom, D.S. and **Davidson, R.H.** 1970. Micro-injection of ^{14}C sucrose into single living sieve tubes of *Heracleum*. Nature 227: 887-888.

Fensom, D.S. 1981. Problems arising from a Munch-type pressure flow mechanism of sugar transport in phloem. Can. J. Bot. 59: 425-432.

Fritz, E. 1973. Microautoradiographic investigations on bidirectional translocation in the phloem of *Vicia faba.* Planta 112: 169-179.

Fuchs, C.H. 1963. Fuchsin staining with NaOH clearing for lignified elements of whole plants or plant organs. Stain Tech. 38: 141-144.

Gallaher, R.N., Ashley, D.A. and **Brown, R.H.** 1975. ^{14}C-photosynthate translocation in C-3 and C-4 plants as related to leaf anatomy. Crop Sci. 15: 55-59.

Grieve, B.L. 1936. A staining and maceration method of tracing the path of the vascular bundles of herbaceous plants and its application in observations on the distribution of *Bacterium solanaceatum* in relation to epinastic curvatures in petioles of tomato and potato plants. Proc. Roy. Soc. Vic. 49: 72-75.

Ho, L.C. and **Peel, A.J.** 1969. Investigation of bi-directional movement of tracers in sieve-tubes of *Salix viminalis* L. Ann. Bot. 33: 933-844.

Ismail, A.M.A. and **Sagar, G.R.** 1965. The reciprocal transfer of radiocarbon between a lateral branch and its parent shoot under normal and stress conditions in plants of *Vicia faba* L. J. Hort. Sci. 56: 155-159.

Jones, H. and **Eagles, J.E.** 1962. Translocation of ^{14}carbon within and between leaves. Ann. Bot. 31: 661-671.

Jones, H., Martin, R.V. and **Porter, H.K.** 1959. Translocation of ^{14}carbon in tobacco following assimilation of ^{14}carbon dioxide by a single leaf. Ann. Bot. 23: 493-508.

Lovell, P.H., Oo, H.T. and **Sagar, G.R.** 1972. An investigation into the rate and control of assimilate movement from leaves in *Pisium sativum.* J. exp. Bot. 23: 255-266.

Lovell, P.H.1969. Interrelationships of cotyledonary shoots in *Pisium sativum.* Physiol. Plant. 22: 506-515.

Marshall, C. and **Wardlaw, I.F.** 1973. A comparative study of the distribution and speed of movement of ^{14}C assimilates and foliar-applied ^{32}P-labelled phosphate in wheat. Aust. J. Biol. Sci. 26: 1-13.

Mullins, M.G. 1970. Transport of ^{14}C-assimilates in seedlings of *Phaseolus vulgaris* L. in relation to vascular anatomy. Ann. Bot. 34: 889-896.

Peterson, C.A. and **Currier, H.B.** 1969. An investigation of bidirectional translocation in the phloem. Physiol. Plant 22: 1238-1250.

Porter, H.K. 1966. Leaves as collecting and distribution agents of carbon. Aust. J. Sci. 29: 39-40.

Thaine, R. 1964. The protoplasmic streaming theory of phloem transport. J. exp. Bot. 15: 470-484.

Thrower, S.L. 1962. Translocation of labelled assimilates in soybean II. The pattern of translocation in intact and defoliated plants. Aust. J. Biol. Sci. 15: 629-649.

Thompson, R.G., Fensom, D.S., Anderson, R.R., Drouin, R. and **Leiper, W.** 1979.

Translocation of ^{11}C from leaves of *Helianthus, Heracluem nymphoides, Ipomoea, Tropaeolum, Zea, Fraxinus, Ulnus, Picea* and *Pinus;* comparative shapes and some fine structure profiles. Can. J. Bot. 57: 845-863.

Trip, P. and **Gorham, P.R.** 1968. Bidirectional translocation of sugars in sieve tubes of squash plants. Plant Physiol. 43: 877-882.

Webb, J.A. and **Gorham, P.R.** 1964. Translocation of photosynthetically assimilated ^{14}C in straight-necked squash. Plant Physiol. 39: 663-672.

Plate I

THE MOVEMENT OF ^{14}C-GLUCOSE AND ^{14}C-SUCROSE VIA A SINGLE BUNDLE IN BOTH DIRECTIONS AND FROM BOTH DIRECTIONS

In separate plants ^{14}C-glucose (1 μCi) was applied on the central part of a single bundle, to the lower leaf (leaflet) or to an upper leaf (leaflet). ^{14}C-sucrose (2.5 μCi) was applied to a lower leaf (leaflet) or to an upper leaf (leaflet).

A ^{14}C-glucose applied on the central part of a single bundle

B-a ^{14}C-glucose applied at the centre of the leaflet (L1)

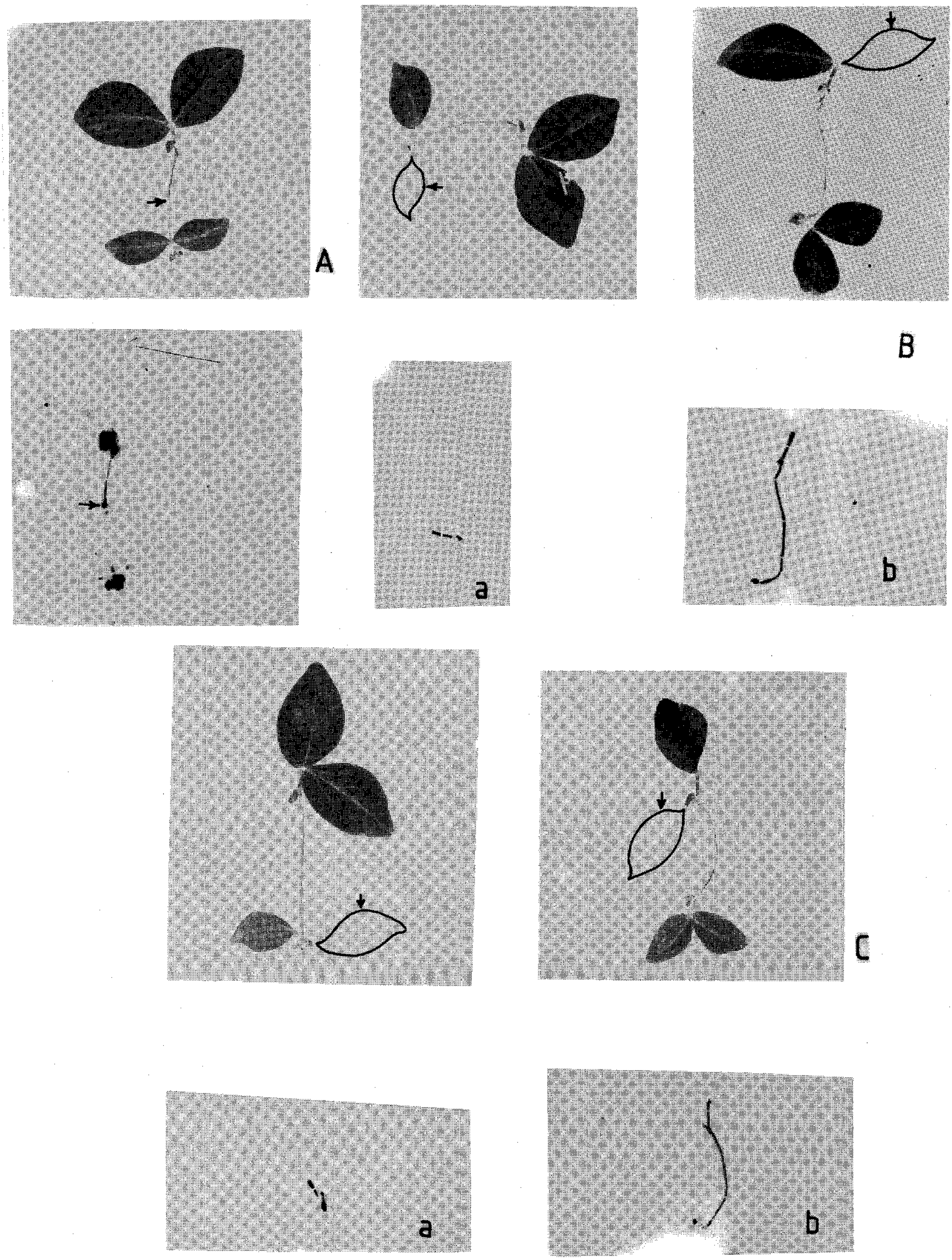
B-b ^{14}C-glucose applied at the centre of the leaflet (L3)

C-a ^{14}C-sucrose applied at the centre of the leaflet (L1)

C-b ^{14}C-sucrose applied at the centre of the leaflet (L3)

Plants above, autoradiographs below.

Arrows indicate the fed regions.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دراسات في الانتقال الثنائي في نبات الفول

احمد محمد علي اسماعيل

تم استئصال جزء من ساق نبات الفول بين الورقتين الاولى والثالثة حيث تركت حزمة وعائية واحدة فقط ثم اجريت التجارب الآتية :

١ ـ اضيف الكربون المشع في هيئة (ك ١ ٢) في أحدى التجارب للورقة الأولى وفي تجربة ثانية للورقة الثالثة وقد اظهرت النتائج أن ثاني إكسيد الكربون قد تحرك في كلا الاتجاهين عبر نفس الحزمة الوعائية إلى أعلى الورقة الأولى والى اسفل من الورقة الثالثة .

٢ ـ عندما اضيف ثاني إكسيد الكربون المشع والجلوكوز المرقم بالكربون المشع والسكر المرقم بالكربون المشع كل على حدة الى منتصف الحزمة الوعائية الواحدة (مصدر) إنتقل الكربون المشع في اتجاهين مختلفين نحو الورقة الأولى تارة ونحو الورقة الثالثة تارة أخرى .

٣ ـ عندما اضيف الفوسفور المشع على هيئة فوسفات الصوديوم للورقة الأولى واعطى ثاني إكسيد الكربون المشع للورقة الثالثة وفي نفس الوقت ـ إتضح أن الفوسفور المشع قد انتقل إلى أعلى مارا بالكربون المشع الذي إنتقل إلى أسفل كما أمكن تمييز نشاط اشعاعي لكلا النظيرين في نفس الحزمة الوعائية أثناء انتقالهما .

يتبين من التجارب السابقة أن هناك حركة ثنائية متزامنة ومتواقتة للمركبات العضوية وغير العضوية وان هذا الانتقال يمكن حدوثه عبر حزمة وعائية واحدة .