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Upward and Lateral Translocation of ^{32}P Supplied to Roots of Apple and Citrus Tress

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Abstract

^{32}P was supplied to the roots of stem-ringed 1-year-old apple trees and 2-year-old citrus trees on which bark segments were isolated above and below the ring. ^{32}P was translocated to shoots and leaves although considerable translocation occurred especially in wood and bark tissues. The accumulation of ^{32}P in isolated bark segments indicated that the occurrence of these materials in this tissue was via radial translocation from xylem tissue, and that the main upward translocation pathway of ^{32}P supplied to roots is through the xylem.

요 약

이중환상박피한 1년생 사과나무와 2년생 은주밀감나무 뿌리를 4시간, 20시간동안 ^{32}P 용액에 침지시킨 후 박피된 부위의 윗부분과 아랫부분의 각 부위별로 ^{32}P의 축적을 조사하여 비교하였으며 영양분의 수평이동이 되는가를 구명하였다. 목질부 이동이 쉽게되어 잎과 줄기에도 ^{32}P가 많이 축적되었다. 체관부의 조사결과로 박피로 고립시켰던 부위가 고립되지 않은 부위보다 ^{32}P의 농도는 약했으나 ^{32}P가 이동 축적된 결과를 얻었다. 이와같은 결과로 볼때 영양분(P)의 이동은 수직(Upward)으로 이동되는 반면 일부는 수평(Lateral)으로 이동된다는 것이 확실하였다.

Introduction

Phosphorus is highly mobile suggesting the possibility of a circulation in a plant[1, 2, 3]. Phosphorus mobility is, perhaps, an essential feature of plant growth. Phosphorus is a necessary participate in such important metabolic schemes, synthesis of starch, glycolysis, fats, and proteins[6]. Since the use of radioactive tracers, several different pathways for the transloction of salts have been dis-covered[1, 2, 3, 10]. Translocation of ^{42}K and ^{32}P in xylem and phloem has been demonstrated in several ways[1, 2, 3, 10].

The absorption, metabolism, and translocation of urea in apple trees have been demonstrated, and the urea and its metabolites are transported[9, 11] through the xylem to aerial tissues. During this translocation process, urea and these metabolites also move to the phloem[11] probably through ray cells

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and possibly cambium[7]. Recently, Shim *et al.*[9] have studied the upward and lateral translocation of urea-^{14}C supplied to roots of apple trees.

We report here experiments using a new approach to ring and improved techniques of seperation and detection of ^{32}P which allow a more precise determination of upward and lateral translocation of ^{32}P.

Materials and Methods

One-year-old M_2 apple(Malus pumila Rehd, cv Milling Merta M_2) trees and 2-year-old citrus (Citrus unshiu Marc cv Onzu) trees were used for experiments. A completely removed 1 cm ring of bark was prepared with each stem 8cm from the soil. Two segments of bark were then isolated from the intact bark by removing an additional 0.3-cm-wide strip of bark from both sides and distal or proximal to the ring (Fig. 1). This resulted in trees which were ringed with vertically discontinuous phloem[11] and with phloem isolated from both acropetal and basipetal as well as lateral phloem translocation. Radical connections with intact xylem were not interrupted. All areas from which the bark was removed were covered with Para-film to prevent desiccation.

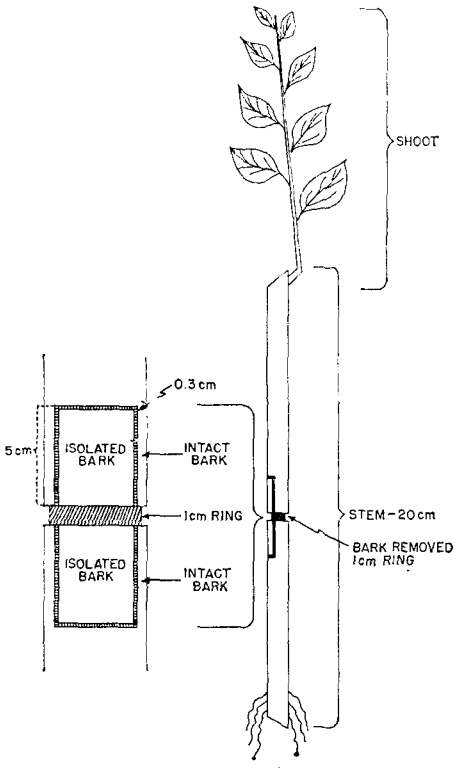

Fig. 1. Diagram of method of ringing and bark isolation of apple and citrus trees used in 4-and 20-hr experiments.

After ringing, the trees with washed roots were placed in a closed flask containing 400 ml of a modified Hoagland's solution with 3 m Curie $H_3{}^{32}PO_4$ at PH 6.1 and allowed to absorb ^{32}P for 4 or 20 hrs. The tree was then removed from the flask and washed ^{32}P quickly from the root surface. The trees were separated into leaves, shoots, roots, stem bark (isolated and intact) above and below the ring. and wood segments above and below the ring (Fig. 1). Tissues were placed in dry oven at 80°C for 24 hrs. The dried tissues were ashed at 700°C for six hrs. Radioactivity of plant sample was determined with a Geiger-Muller Counter.

Result

A. Apple trees

Table 1. *Distribution of ^{32}P among fractions of leaf, shoot, stem and roots tissues of apple trees supplied with ^{32}P solution.*

Tissue \ Time	4 hr	20 hr
Root	32.91	44.35
Stem wood	0.56	8.20
Stem bark	0.30	7.58
Shoot	0.17	11.75
Leaf	0.07	18.90

Radioactivity cpm$\times 10^{-3}$/g dry wt.

Table 2. Distribution of ^{32}P among fractions of stem wood and differentially isolated stem bark segment of apple trees supplied with ^{32}P solution.

Time \ Tissue	Wood		Bark			
			below ring		above ring	
	below ring	above ring	isolated	intact	isolated	intact
4 hr	0.53	0.59	0.16	0.21	0.17	0.40
20 hr	8.88	7.75	7.31	18.38	5.43	25.39

Radioactivity, cpm$\times 10^{-3}$/g dry wt.

^{32}P was rapidly absorbed by roots, and translocated and accumulated in the tissues. Root tissue always contained a higher percentage of ^{32}P than did either shoot or leaf tissue. ^{32}P was found in all stem tissues in four hours after treatment, where more radioactivity was found in wood tissue than in bark tissue (table 2). By 20 hrs at least a 10-fold increase in radioactivity had occurred in all stem tissues.

The amount of ^{32}P found in intact bark tissue, both below and above the ring, was approximately 50% of that found in wood tissue at two hrs and 20% of that found at 20 hrs. The amount of ^{32}P found intact bark tissue was not greatly affected by the presence of the ring, since the difference in amount of ^{32}P in wood tissues above and below the ring was similar to the differences in amount of ^{32}P in bark tissue above and below the ring.

Isolated bark tissue contained less ^{32}P than intact bark tissue. This difference was greater above the ring than below the ring, and was greater after 20 hrs than after four hrs. Isolated bark tissue below the ring had 70% as much ^{32}P as intact bark tissue below the ring after two hrs. By 20 hrs, however, this isolated bark below the ring contained 40% as much ^{32}P as the intact bark below the ring. Above the ring, bark tissue, both intact and isolated, had more ^{32}P than bark tissue below the ring 4 hourse after treatment. ^{32}P between isolated and intact bark above the ring followed a similar pattern as was found for bark tissue below the ring.

B. Citrus trees

^{32}P was rapidly absorbed by roots and slowly translocated to shoot and leaf tissues (table 3). Root tissue always contained a high percentage of ^{32}P than did either shoot or leaf tissue. By four hrs, ^{32}P was found in all stem tissues, but more radioactivity was found in wood tissue than in bark tissue (table 4). By 20 hrs at least a 2-fold increase in radioactivity had occurred in all stem tissues, but at both times less ^{32}P was found in tissues above the ring than tissues below the ring.

The amount of ^{32}P found in intact bark tissue, both below and above the ring, was appoximately 20% of that found in wood

Table 3. Distribution of ^{32}P among fractions of leaf, shoot, stem and root tissues of citrus supplied with ^{32}P solution.

Time \ Tissue	4 hr	20 hr
Root	10.04	45.24
Stem wood	0.71	1.19
Stem bark	0.43	1.11
Shoot	0.84	1.39
Leaf	0.70	0.64

Radioactivity, cpm$\times 10^{-3}$/g dry wt.

Table 4. *Distribution of ^{32}P among fraction of stem wood and differentially isolated stem bark segment of citrus trees supplied with ^{32}P solution.*

Time \ Tissue	Wood		Bark			
			below ring		above ring	
	below ring A	above ring B	isolated B	intact D	isolated A	intact C
4 hr	0.67	0.76	0.15	0.25	0.15	0.39
20 hr	1.82	1.56	0.59	0.40	0.50	1.40

Radioactivity, cpm$\times 10^{-3}$/g dry wt.

tissue at four hrs, and 40% of that found at 20 hrs. However, there was no difference in the amount of ^{32}P found in intact bark tissue above the ring at 20 hrs.

Isolated bark tissue above the ring had 40% as much ^{32}P as intact bark tissue above the ring after 20hrs. By 20hrs, however, the isolated bark above the ring contained 35% as much ^{32}P as the intact bark above the ring.

Discussion

The absorption and translocation of ^{32}P occurred readily in young apple and citrus trees from which a ring of bark had been removed, this result agrees with previous research on urea ^{14}C[9, 11]. Biddulph[1, 2, 3] has demonstrated that phosphorous is highly mobile in a plant has suggested the possibility of a continuous circulation of phosphorous. A given phosphorous atom, for example, may make several complete circuits in a plant in a single day[1, 2].

Although evidence exists for the transport of N compound and other inorganic matters through the phloem[5, 10, 12, 13, 14], the xylem is considered the primary pathway through which N and other salts moves from roots to aerial portions of the plant[1, 6, 8]. In previous experiments[9, 11], the increase in the amount of urea and metabolic products derived from urea-^{14}C in the isolated bark segments strongly indicated that direct radial movement of urea and probably amino acids occurs from xylem to phloem tissue. Movement from xylem to phloem tissue could occur through a pathway involving incompletely differenciated shoot tissues, where interchange of translocated substances between xylem and phloem tissues would take place in the absence of secondary tissues: thence substances could move back down the phloem to the distal side of the ring (above), or upwards to the proximal side of the ring (below). Any exchange between xylem and phloem would have to occur through ray cells or cambium. This pathway of radial translocation is not well understood[7] and clarification is needed before a complete model of the translocation pattern of woody plants can be visualized[9].

Conclusion

^{32}P was translocated to shoots and leaves although considerable translocation occurred especially in wood and bark tissues. The accumulation ^{32}P in isolated bark segments indicates that the occurrence of these material in this tissue was via radial translocation from xylem tissue, and that the main upward translocation pathway of ^{32}P supplied to roots is through the xylem.

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