Scionic Influence on Root Activity in *Citrus* Using a Radiotracer Technique

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ABSTRACT

The distribution and efficiency of roots in Kinnow mandarin and acid lime (Kagzi Kalan) on Karna Khatta rootstock (*Citrus karna*) was recorded using 32P as a tracer. 32P was injected into soil at fixed geometry and uptake measured in young leaves. The influence of the scion on percentage root activity was limited only to the radial spread and not the depth. However, the specific activity of P measured in leaves was much higher in acid lime as compared to Kinnow at all radial distances, depths and radial distance/depth combinations.

Influence du greffon sur l'activité des racines d'agrumes déterminée par une technique de marqueur radioactif.

RÉSUMÉ

La distribution et l'efficacité des racines de la mandarine Kinnow et de la lime acide greffées sur *Citrus karna* ont été examinées en utilisant le marqueur radioactif P32. Le phosphore radioactif a été injecté dans le sol à des endroits déterminés et la remontée de la radioactivité a été mesurée dans les jeunes feuilles. L'influence du greffon sur le pourcentage d'activité racinaire a été limitée à la diffusion radiale et non pas en profondeur. Cependant, l'activité spécifique du phosphore mesurée dans les feuilles a toujours été plus importante dans la lime acide que dans la mandarine Kinnow, quelles que soient la distance et la profondeur observées.

Influencia del injerto sobre la actividad de las raícese Citrus determinada por la técnica de trazadores radiactivos.

RESUMEN

La distribución y la capacidad radicularia de la mandarina Kinnow y de la lima ácida en el patrón de injerto Karna Khatta (*Citrus karna*) fueron examinados usando el trazador radiactivo 32P. Se inyectó fósforo radiactivo en el suelo, dentro de un espacio determinado y se midió en las hojas nuevas la subida de la radioactividad. Se limitó la influencia del injerto sobre el porcentaje de actividad radicularia a la difusión radial y no en profundidad. Sin embargo, la actividad específica del fósforo medida en las hojas seguía siendo mayor en la lima ácida más que en la mandarina Kinnow, cualesquiera fueren la distancia y la profundidad observadas.

KEYWORDS

Citrus, tracer techniques, soil, rootstocks, scions, leaves, roots.

MOTS CLÉS

Citrus, technique des traceurs, sol, porte-greffe, greffon, feuille, racine.

PALABRAS CLAVES

Citrus, técnicas de trazadores, suelo, portainjertos, injerto de púa, hojas, raices.

introduction

An understanding of the distribution and effectiveness of fruit tree roots is essential for determining optimal fertiliser placement, irrigation and tree spacing (ATKINSON, 1980). Conventional excavation and coring techniques using an auger are cumbersome, labour intensive, costly and give the total distribution of roots including dead, dormant and active roots.

In contrast, radiotracer methods are non-destructive and provide quick and reliable results. Furthermore, root spread as well as the precise areas of active root concentrations, excluding dead and dormant roots, are indicated. Tracer techniques have been used for studying translocation (TANAKA *et al.*, 1960) and root activity.

Attempts have been made to study root activity in grapefruit using 32P (TRIPATHI, 1966; DHANDHAR and SINGH, 1989). Similar studies on root activity have also been reported in sweet orange by NETHSINGHE and BROESCHARDT (1975) under the auspices of IAEA, in acid lime (IYENGAR and MURTHY, 1987), Coorg mandarin (IYENGAR *et al.*, 1988) and Kinnow mandarin (KURIEN *et al.*, 1992). The present study was undertaken to obtain specific information on the impact of scions on root activity and efficiency. This has not yet been attempted in *Citrus*.

materials and methods

The experimental plants included fully bearing Kinnow mandarin on *Citrus karna* and acid lime (Kagzi Kalan) on Karna Khatta rootstock (*Citrus karna*), of uniform age (sixth year of planting), grown with uniform cultural and manurial practices. In both combinations, plants were uniform in growth and vigor and spaced 3.66 m apart. Each combination formed a separate randomized block design, with 3 replications and 12 treatments, *i.e.* combination of 40, 80, 120 and 160 cm radial distance with 8, 16, and 24 cm depth. The soil of the experimental plot was sandy loam (Ustochrept), pH 8.2 (soil to water ratio 1:25), organic C 0.7% and cation exchange capacity 14 meq/100 g soil.

The adopted method was based on the technique described by HALL *et al.* (1953), *i.e.* by placing radioactive phosphorus at fixed geometry and then measuring the amount of activity taken up by the plant through radio chemical analysis of leaves. The applications coincided with the two major flushing seasons in North India. Prior to the start of the experiment and in accordance with the treatment specifications, 12 holes were bored at equidistance, with fixed radial distances and depth around each plant, and PVC pipes (2 cm diameter) of constant length were placed in the soil. Total activity of 434 mCi of 32P of specific activity of 899 mCi/g of P in 1988 and 400 mCi of 32P of specific activity of 1.066 Ci/g of P was procured from Bhaba Atomic Research Center (BARC), Bombay. The activity was standardized to 0.5 mCi/g of P using standard Diammonium phosphate. The first application was in August 1988 and each tree received a dose of 3.86 mCi 32P. The second application was in the March flushing season and 3.55 mCi of 32P was applied per plant. During both seasons, the activity was equally distributed in each of the 12 holes.

Total phosphorus (31P + 32P) in the leaves was estimated colorimetrically by the Vanadomolybdate method (KOENING and JOHNSON, 1942). Radioactive phosphorus was determined at 20, 40, 60 and 80 days after treatment in the first three leaves of the current flush. (IYENGAR and MURTHY, 1987; IYENGAR *et al.*, 1988) by Cerenkov counting in a liquid scintillation counter (Packard Tri Carb liquid scintillation spectrometer model 3220) and observations were recorded as counts per minute (cpm) after deducting the background counts. Subsequently the counts were checked for counter efficiency and converted to cpm per g of dried leaf sample and finally brought uniformly to a common 0 hour.

The percent root activity for each treatment in each replication was calculated by the formula:

$$\frac{\text{Activity of 32P in a location}}{\text{Total activity recovered in the leaves in all treatments in a replication}} \times 100.$$

The efficiency of roots in a zone was calculated by measuring the specific activity which is the ratio of radioactive phosphorus to total phosphorus in the sample.

$$\text{Specific activity} = \frac{32\text{ P}}{31\text{ P} + 32\text{ P}} = \frac{\text{Counts per minute/g dry matter}}{\text{g of total P/g dry matter}}$$

The percent root activity followed a binomial distribution and hence did not meet with the basic assumptions of the analysis of variance technique. Therefore, it was transformed using arc sin transformation so that it would follow a normal distribution. The data range for specific activity was very wide and logarithmic transformation was thus applied to avoid error. The data were then analysed according to a 4 x 3 randomized block design using the analysis of variance technique. Scion effects at each radial distance, depth and distance/depth interaction were compared using a t-test (PANSE and SUKHATME, 1978).

results

mean relative root activity

With regards to root activity patterns, it was found that maximum root activity was limited to a radial distance of 40 cm in both acid lime and Kinnow. However, comparisons between scions at this particular 40 cm distance indicated that root activity was higher in acid lime as compared to Kinnow (Figure 1). It was further observed that the activity pattern in acid lime was gradually reduced from 40 to 80 cm radial distance, followed by a sharp decline up to 160 cm. On the other hand, Kinnow showed considerable activity even up to a radial distance of 120 cm. Concerning depth, both scions gave the highest root activity patterns at 24 cm in 1988 and at 16 cm in 1989. However, there was no notable difference between scions in relation to particular depths of application. For radial distance/depth interactions, the highest root activity was recorded at radial distance/depth combinations of 40 cm x 24 cm in 1988 and 40 x 16 cm in 1989 for both scions (Figure 2). Moreover, it was observed that all depth-distance combinations beyond 120 cm gave relatively higher root activity in Kinnow as compared to acid lime.

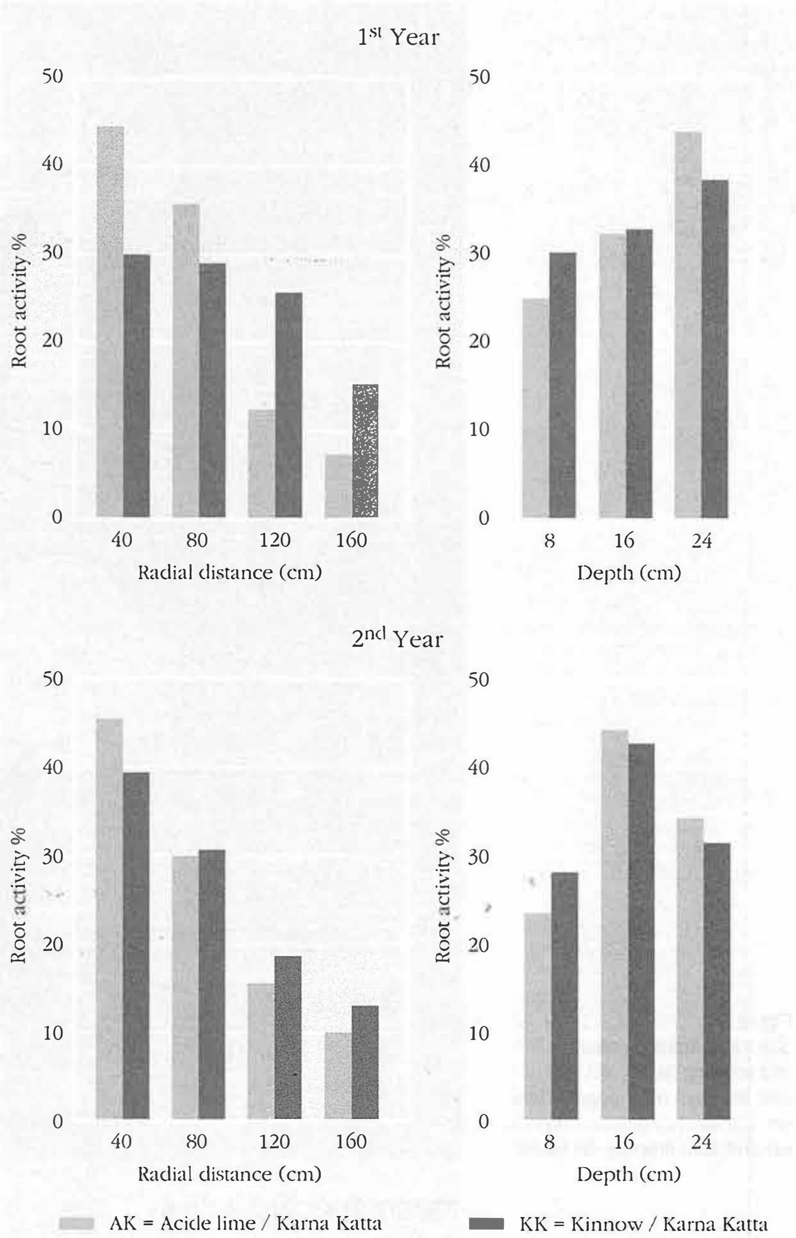

Figure 1
Scionic influence on root activity in Citrus *at different radial distances and depths.*

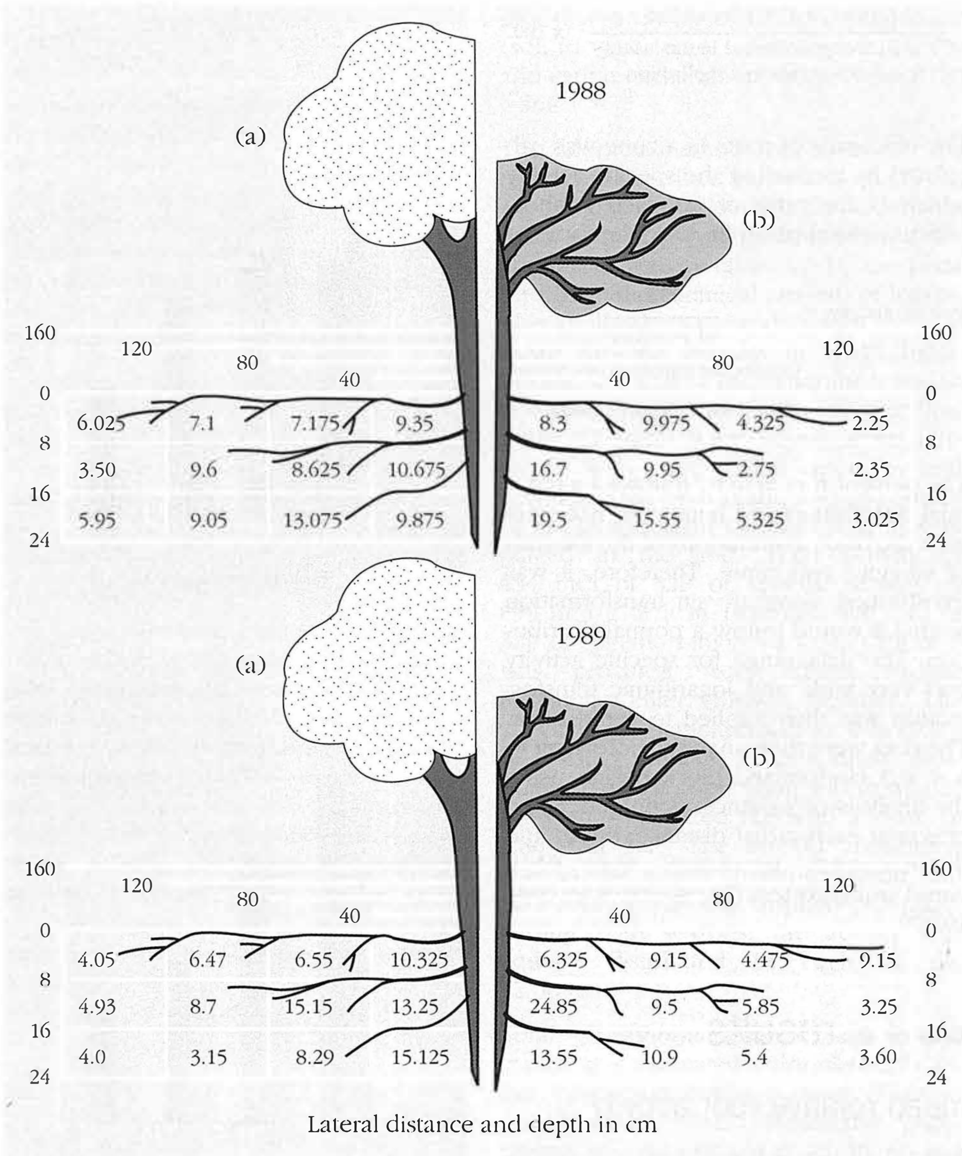

Figure 2
Scionic influence (mean of sampling at 20, 40, 60 and 80 days after application) on root activity pattern: Kinnow (a) and acid lime (b) on Karna.

mean specific activity of P in leaves

Scions also affected the specific activity of P in the leaves at all the radial distances. However, the specific activity was highest at a radial distance of 40 cm in both acid lime and Kinnow. Comparisons between acid lime and Kinnow at 40 cm radial distance indicated that the specific activity was 6- and 3-fold higher in acid lime than in Kinnow in 1988 and 1989, respectively. In both varieties, the mean specific activities in relation to various depths indicated the highest activities in scions at 24 cm in 1988 and at 16 cm in 1989 (Table 1). In general, the specific activity was relatively higher in acid lime as compared to that in Kinnow at all depths. The specific activity of P in leaves in relation to radial distances and depths remained almost identical throughout the sampling period.

The specific activities of P in leaves at all the depth/distance combinations were higher in acid lime than in Kinnow up to a radial distance of 80 cm. In contrast, the reverse occurred beyond a radial distance of 80 cm (Table 2).

Table 1
Scionic influence on specific activity of phosphorus (cpm/µg) in leaves as affected by radial distance (mean of depths), depth of placement (mean of radial distances) and sampling period.

	Days after 32P application									
	20		40		60		80		Mean	
	AK	KK	AK	KK	AK	KK	AK	KK	AK	KK
August flushing season 1988										
Radial distance										
40	0.301	0.287	1.391	0.171	2.662	0.543	10.927	1.423	3.820	0.606
	(- 0.54)	(- 0.57)	(0.09)	(- 0.79)	(0.31)	(- 0.50)	(0.93)	(0.02)	(0.50)	(- 0.26)
80	0.305	0.228	0.572	0.199	2.510	0.529	10.678	1.798	3.516	0.689
	(- 0.52)	(- 0.73)	(- 0.33)	(- 0.75)	(0.34)	(- 0.40)	(1.01)	(0.12)	(0.62)	(- 0.23)
120	0.167	0.195	0.243	0.154	0.781	0.497	2.687	1.807	0.969	0.663
	(- 0.79)	(- 0.73)	(- 0.66)	(- 0.84)	(- 0.23)	(- 0.50)	(0.31)	(- 0.02)	(- 0.10)	(- 0.33)
160	0.097	0.118	0.150	0.079	0.388	0.273	1.889	0.633	0.631	0.276
	(-1.05)	(-1.01)	(-0.85)	(-1.20)	(-0.43)	(-0.75)	(0.16)	(-0.28)	(-0.26)	(-0.59)
Depth (cm)										
8	0.228	0.189	0.428	0.126	0.865	0.442	0.810	0.722	1.333	0.369
	(-0.70)	(-0.77)	(-0.57)	(-0.94)	(-0.14)	(-0.55)	(0.48)	(-0.19)	(0.04)	(-0.48)
16	0.225	0.198	0.563	0.138	1.424	0.521	6.437	1.309	2.162	0.542
	(-0.69)	(-0.82)	(-0.43)	(-0.99)	(-0.09)	(-0.55)	(0.45)	(-0.02)	(0.06)	(-0.39)
24	0.199	0.235	0.776	0.189	2.468	0.419	9.389	2.215	3.208	0.765
	(-0.78)	(-0.70)	(-0.32)	(-0.76)	(-0.22)	(-0.51)	(0.95)	(0.13)	(0.47)	(-0.21)
P (0.05)										
Radial distance	0.15		0.16		0.26		0.28		0.19	
Depth	0.13		0.14		0.23		0.24		0.16	
March flushing season 1989										
Radial distance										
40	0.299	0.243	0.355	0.130	0.886	0.299	1.476	0.308	0.754	0.245
	(- 0.75)	(- 0.75)	(- 0.53)	(- 0.93)	(- 0.12)	(- 0.66)	(0.09)	(- 0.70)	(- 0.19)	(- 0.67)
80	0.141	0.197	0.316	0.162	0.666	0.145	0.759	0.287	0.471	0.198
	(- 0.92)	(- 0.90)	(- 0.57)	(- 0.96)	(- 0.20)	(- 0.88)	(- 0.13)	(- 0.63)	(- 0.33)	(- 0.76)
120	0.147	0.166	0.155	0.067	0.218	0.156	0.475	0.141	0.249	0.133
	(- 0.94)	(-1.13)	(- 0.88)	(-1.27)	(- 0.71)	(- 0.92)	(- 0.40)	(-1.00)	(- 0.65)	(- 0.95)
160	0.059	0.148	0.129	0.035	0.141	0.087	0.254	0.123	0.145	0.098
	(-1.27)	(-1.10)	(- 0.93)	(-1.52)	(- 0.97)	(-1.12)	(- 0.67)	(-1.01)	(- 0.87)	(-1.07)
Depth (cm)										
8	0.097	0.059	0.167	0.079	0.360	0.155	0.514	0.231	0.285	0.131
	(-1.10)	(-1.29)	(- 0.81)	(-1.19)	(- 0.56)	(- 0.88)	(- 0.36)	(- 0.78)	(- 0.60)	(- 0.95)
16	0.227	0.318	0.310	0.116	0.615	0.193	0.947	0.221	0.524	0.212
	(- 0.92)	(- 0.62)	(- 0.65)	(-1.21)	(- 0.40)	(- 0.79)	(- 0.23)	(- 0.84)	(- 0.43)	(- 0.73)
24	0.161	0.189	0.239	0.100	0.459	0.169	0.756	0.193	0.404	0.163
	(- 0.90)	(-1.01)	(- 0.71)	(-1.10)	(- 0.54)	(- 0.97)	(- 0.25)	(- 0.89)	(0.49)	(- 0.92)
P (0.05)										
Radial distance	0.28		0.25		0.24		0.23		0.16	
Depth	0.24		0.21		0.21		0.20		0.14	

AK: Acid lime on Karna KK: Kinnow on Karna
Figures in parenthesis indicate means of log transformed values.

Table 2
Radial distance/depth interaction table showing scionic influence on specific activity of phosphorus (cpm/µg) in leaves (mean of four sampling intervals - 20, 40, 60 and 80 days after application).

	Radial distance (cm)							
	40		80		120		160	
Depth (cm)	AK	KK	AK	KK	AK	KK	AK	KK
				1988				
8	1.259 (0.07)	0.356 (- 0.45)	2.615 (0.41)	0.446 (- 0.38)	0.852 (- 0.08)	0.329 (- 0.52)	0.605 (- 0.24)	0.348 (-0.48)
16	4.859 (0.69)	0.622 (- 0.22)	2.947 (0.47)	0.661 (- 0.28)	0.541 (- 0.39)	0.699 (- 0.30)	0.302 (-0.53)	0.182 (-0.76)
24	5.343 (0.73)	0.839 (- 0.12)	4.988 (0.99)	0.959 (- 0.03)	1.516 (0.18)	0.961 (- 0.17)	0.986 (-0.01)	0.297 (-0.53)
P (0.05)				0.33				
				1989				
8	0.312 (- 0.52)	0.179 (- 0.87)	0.459 (- 0.34)	0.119 (- 0.93)	0.224 (- 0.70)	0.142 (- 0.87)	0.143 (- 0.85)	0.084 (-1.11)
16	1.200 (0.07)	0.212 (- 0.62)	0.479 (- 0.32)	0.315 (- 0.54)	0.276 (- 0.60)	0.198 (- 0.74)	0.143 (- 0.88)	0.122 (- 0.01)
24	0.750 (- 0.13)	0.344 (- 0.53)	0.472 (- 0.33)	0.159 (- 0.81)	0.247 (- 0.64)	0.057 (-1.25)	0.145 (- 0.86)	0.089 (-1.07)
P (0.05)				0.28				

AK : Acid lime on Karna KK : Kinnow on Karna
Figures in parenthesis indicate mean of log transformed values.

discussion

The results indicated that recovery of radioactivity (cpm/g) and specific activity of P in the dry matter were significantly higher in acid lime as compared to Kinnow during both seasons. Maximum root activity (75-80%) was confined within a radial spread of 80 cm in acid lime, whereas in Kinnow it could be observed up to 120 cm radial distance. Concerning depth, no significant differences were observed between scions for relative root activity, indicating that distance/depth interactions were determined by the radial distance. Hence, acid lime had relatively higher activity at all distance-depth combinations up to 80 cm. A similar trend was also observed for specific activity in the leaves, which in turn revealed the inherent efficiencies of roots within the respective zones. Root activity increases have been attributed to feeder root densities in mango (BOJAPPA and SINGH, 1974), grapefruit (TRIPATHI, 1966; DHANDHAR and SINGH, 1989), guava (PUROHIT and MUKHERJEE, 1974) and apple (ATKINSON, 1974; 1977).

The higher root activity in acid lime was due to the fact that root distribution patterns were significantly influenced by the scion variety. Therefore, acid lime might have produced more bushy roots confined within a radial distance of 80 cm, whereas Kinnow might have produced extensive root systems. FORD (1952) compared grapefruit and orange trees on rough lemon rootstock. Grapefruit trees had a high percent of fibrous roots in the top 25 cm surface layer, showing the distinct influence of scions on rooting habits of the rootstock. Scion cultivars have also been shown to affect the root system in plum (GHENA, 1964) and apple (WELLER, 1965; ATKINSON, 1973; ANGELOV, 1975).

conclusion

It may be concluded that each scion, being a distinct genetic entity, has a definite influence on the rootstock with respect to absorption patterns. In the present study, maximum activity in acid lime on Karna was confined to a radial distance of 80 cm and depth of 16-24 cm, whereas in Kinnow on Karna it was confined to a radial distance of 120 cm and depth of 16-24 cm. Hence, fertilizers should be applied within these zones for maximum utilization efficiency of the applied nutrients.

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references

ANGELOV T., 1975.
Root distribution in bearing apple trees and methods of irrigation. *Orashchaestvo*, 55, 33-37.

ATKINSON D., 1973.
Soil management effects on root growth and activity. *Rpt. East Malling Res. Stn.* for 1972, 59.

ATKINSON D., 1974.
Some observations on the distribution of root activity of apple trees. *Plant and Soil*, 40 (2), 333-342.

ATKINSON D., 1977.
Some observations on the root growth of young apple trees and their uptake of materials when grown in herbicided strips in grassed orchards. *Plant and Soil*, 49, 459-471.

ATKINSON D., 1980.
The distribution and effectiveness of roots of tree crops. *Hort. Rev.*, 2, 425-490.

BOJAPPA K. M., SINGH R.N., 1974.
Root activity of mango by radiotracer techniques using 32P. *Indian J. Agric. Sci.*, 44, 175-180.

DHANDHAR A.G., SINGH R.N., 1989.
Root studies in grapefruit (*Citrus paradisi* Macf.) using a radiotracer technique. *Scientia Hortic.*, 40, 113-118.

FORD H.W., 1952.
The distribution of feeder roots of orange and grapefruit trees on rough lemon rootstock. *Citrus Mag.*, 14 (11), 22-23.

GHENA N., 1964.
Studies on the structure of the root systems of apple, apricot and sweet cherry trees grown on a degraded chernozem soil at Istnta. *Leur. Stiint. Inst. Agron. N. Bolcescu Hort. Ser.*, 137, 37-45.

HALL N.S., CHANDLER W.F., VANBAVEL C.H.M., REID P.H., ANDERSON J.H., 1953.
A tracer technique to measure growth and activity of plant root systems. *N.C. Agric. Exp. Stn. Tech. Bull.*, 101, 1-40.

IYENGAR B.R.V., MURTHY S.V.K., 1987.
Spatial distribution of root activity in Kagzi lime (*Citrus aurantifolia* Swingle). *Indian J. Hort.*, 44, 41-44.

IYENGAR B.R.V., MURTHY S.V.K., SHIVANANDA T.N., 1988.
Seasonal variations in root activity in mandarin (*Citrus reticulata* Blanco.). *J. Nuclear agri. Biol.*, 17, 67-71.

KOENING R. A., JOHNSON C.R., 1942.
Calorimetric determination of phosphorus in biological materials. *Ind. Eng. Chem. Anal.*, Ed. 14, 155-156.

KURIEN S., GOSWAMI A.M., DEB D.L., 1992.
Root activity of two *Citrus* rootstocks assessed using radiotracer techniques. *J. Hort. Sci.*, 67 (1), 87-94.

NETHSINGHE D.A., BROESCHARDT H., 1975.
Root activity patterns of some tree crops. IAEA. *Tech. Rep. Series*, 170, 1-135.

PANSE V.G., SUKHATME P.V., 1978.
Statistical methods for agricultural workers, 343 p. New Delhi (India): ICAR Publication, 3rd edition, 166-185.

PUROHIT A.G., MUKHERJEE S.K., 1974.
Characterising root activity of guava trees by radiotracer technique. *Indian J. Agric. Sci.*, 44, 575-581.

TANAKA Y., NAKANAA K., KOIKE A., ISHIDA T., NISHIGAKI S., SHIBUYA M., KOYAMMA T., 1960.
A study on translocation and distribution of phosphorus applied to the soil or injected into the trunk of *Citrus* trees using 32P as tracer. *J. Hort. Assoc. Jpn.*, 29, 63-69.

TRIPATHI R.D., 1966.
To determine root activity of Citrus by 32P injection and auger techniques, 94 p. New Delhi (India): Indian Agricultural Research Institute, Ph.D. thesis submitted to Post Graduate School, 51-54.

WELLER F., 1965.
Some observations on root distribution in the soil in relation to rootstock and scion variety. *Erwokstbsobstban*, 8, 181-184.