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Short communication

Root activity distribution and inter-plant root competition in 'Robusta' banana (*Musa* sp., 'AAA') under high-density planting determined by tracer technique

S.C. Kotur and V. Ramachandran[1]
Isotope Laboratory
ICAR-Indian Institute of Horticultural Research
Hessaraghatta Lake Post, Bengaluru-560089, India
Email: sckotur@gmail.com

ABSTRACT

By applying soil injection technique using carrier-free ^{32}P as a tracer in 'Robusta' banana (*Musa* sp. 'AAA') planted at 1.5m x 1.5m spacing, during the 8th leaf stage of growth, 52.04 and 62.96% of active roots were present at 25cm across and 15cm depth, respectively. At the 16th leaf stage, only 40.5% of active roots were traced at 25cm across, and root activity increased at wider distances and deeper layers. At flower-initiation stage, a significant gain in root activity was seen at 45cm depth. Distance-wise distribution, however, did not change appreciably. At the shooting stage, 46.89% and 43.98% of the active roots were present closest to the pseudostem (25cm distance) and soil surface (15cm), respectively. However, the greatest depth (45cm) gained active roots (38.51%) at shooting-stage, creating an hour-glass pattern of root distribution, mainly owing to migration of roots from the surface (15cm deep) soil. However, a strong presence of active roots persisted close to the base of the plant, and in the surface-soil. A small proportion (<1%) of phosphorus applied to the main plant was absorbed by the orthogonal neighbour located at 1.5m distance, indicating practically insignificant competition with its closest neighbour. None of the diagonal neighbours located farthest (at 2.1m distance from the main plant) showed any activity of the tracer indicating that the root competition with the main plant was absent. Results indicate that a spacing of 1.5m × 1.5m in high-density planting of 'Robusta' banana raised in sandy-loam is optimum, with practically no untoward competition from the root for nutrients applied to each plant.

Key words: Banana, high-density planting, inter-plant root competition, tracer technique, ^{32}P

Tracer technique has been successfully employed to determine spatial and temporal root-activity distribution in a variety of fruit crops like citrus, grape, mango and guava (Kotur and Keshava Murthy, 1998), papaya (Kotur and Keshava Murthy, 2001), pomegranate (Kotur and Keshava Murthy, 2003) and annona (Kotur, 2009). This information is useful for refining nutrient and water application, and planting density, to optimize input use efficiency (Bojappa and Singh, 1973). Severe plant-to-plant competition and increased variability was observed under high-density planting in banana beyond 2,222 plants ha^{-1} (Robinson and Nel, 1989). A definite recovery of ^{32}P applied in neighbouring banana plants was observed by Kurien *et al* (2002) due to inter-plant root competition. Therefore, root-activity distribution was studied under high-density planting (1.5m × 1.5m, at 4,444 plants/ ha) in 'Robusta' banana (*Musa* sp., 'AAA') from the early vegetative to the fruiting stage, with emphasis on inter-plant competition for root-activity among neighbouring plants.

Soil injection technique was applied, using carrier-free ^{32}P as a tracer. The crop was raised on red sandy-loam soil (Typic Haplustalf), with pH 5.9, organic carbon 0.3% and cation exchange capacity 8.4cmol (p+)/kg. The crop was planted using apparently uniform suckers, during November 2007. Observations were made at four stages of growth: 8-leaf (50 days after planting, Feb. 2008); 16-leaf (100 days, May 2008); flower initiation (150 days, August 2008) and at shooting (210 days, November 2008). The treatment included all the combinations of three depths (15, 30 and 45cm from the surface) and three lateral distances (25, 50 and 75cm from the base of pseudostem). The isotope (1.01 to 2.07 mCi/ plant, depending upon the age of plant) was injected equally into pre-installed PVC pipes placed concentrically around the plant (8 holes at 25cm, 16 holes at 50cm and 24 holes at 75cm radial distance). Root-activity distribution (%) was calculated from the activity of ^{32}P in leaf (dpm/g dry matter) as a ratio of the activity of ^{32}P at any given location and the activity of ^{32}P at all the locations

[1]Division of Nuclear Agriculture and Biotechnology, Bhabha Atomic Research Centre, Trombay, Mumbai-400 085, India

was expressed as percentage. To arrive at a quantitative measure of inter-plant root competition for nutrient supplied to each plant by its neighbouring plants, the same tracer was tagged with specific activity of 0.5014, 0.8333, 0.7667 and 1.3364µCi/mg of P in the solution, using potassium dihydrogen orthophosphate as a carrier in the injection given from the 1st to the 4th stage, respectively. Phosphorus (the tracer) derived (Pdft, %) by the orthogonal or diagonal neighbour from the phosphorus applied was calculated as a ratio of the specific activity of phosphorus at a given location, and the specific activity of phosphorus at all locations, and was expressed as percentage. Activity of ^{32}P in the lamina of the 3rd open leaf was monitored at 20 - day interval upon injection of the isotope. The leaf sample was dried in an oven at 70°C, powdered and digested in a diacid mixture (9:4 nitric acid: perchloric acid). Radioactivity of ^{32}P was determined by Cerenkov counting in a liquid scintillation analyzer (LSA). Root activity was calculated as a ratio of radioactivity at a given location to that of the total of all the locations, and was expressed as percentage. Results of the sample taken at 40 days after injecting the tracer are presented.

Table 1. Root activity distribution (%) in 'Robusta' banana plant (40 dai) during various stages of plant growth

Depth (cm)	Distance (cm)			
	25	50	75	Total
8th leaf stage				
15	36.26	13.78	12.92	62.96
30	10.69	11.73	3.46	25.88
45	5.09	3.31	2.76	11.16
Total	52.04	28.82	19.14	100.00
SEm (±)	0.595			
C.D. *(P=0.05)*	1.768			
16th leaf stage				
15	21.94	19.59	20.14	61.67
30	13.27	7.54	4.20	25.01
45	5.32	5.24	2.76	13.32
Total	40.53	32.37	27.10	100.00
SEm (±)	0.410			
C.D. (*P=0.05)*	1.226			
Flower initiation stage				
15	30.28	20.37	12.21	62.86
30	12.49	4.31	1.40	18.20
45	11.51	2.07	5.36	18.94
Total	54.28	26.75	18.97	100.00
SEm (±)	0.555			
C.D. (*P=0.05)*	1.650			
Shooting stage				
15	17.61	13.79	12.58	43.98
30	8.57	3.38	5.56	17.51
45	20.71	8.56	9.24	38.51
Total	46.89	25.73	27.38	100.00
SEm (±)	0.709			
C.D. (*P=0.05)*	2.108			

Root-activity distribution

Results showed that at the 8th leaf stage, active roots were predominated to an extent of 52.04 and 62.96% at 25cm lateral distance and 15cm depth, respectively (Table 1). As the lateral distance and depth increased, percentage of active roots declined sharply, as, the plant was still in its early vegetative growth. There appeared to be three phases of root activity at the 8th leaf stage. High (36.26%) root activity was present closest to the base of the plant, at a lateral distance of 25cm and a surface depth of 15cm. Moderate distribution of 10.69-13.78% was evident at 50cm and 75cm distances at 15cm depth, as well as at 25 and 50cm lateral distance at 30cm depth. In the rest of the locations at a farther distance/depth from the base of the plant during early stage of root growth, presence of active roots was low (2.76-5.09%). At the 16th leaf stage (which represents a vigorous stage of growth), distribution of active roots was similar to that at the 8th leaf stage, in terms of depth-wise distribution. Distance-wise, however, active roots showed a definite lateral expansion. This was highly pronounced at 15cm depth, which showed a fairly uniform presence of 19.59-21.94% active roots at different distances. There was a slight gain in root-activity at 25cm distance and at 30cm depth, while, the rest of the locations at 45cm depth continued to show lower root-activity. At the flower initiation stage, root activity showed a pronounced presence at both 15cm depth (62.86%) and 25cm lateral distance (54.28%), favouring 25cm and 50cm distances at 15cm depth. A substantial gain of active roots was seen at 25cm distance and 45cm depth, but, root activity decreased concomitantly at 75cm distance and 15cm depth. Remainder of the locations showed low root-activity. At the shooting stage, a change was observed in the pattern of root activity, especially in terms of soil depth. The greatest soil depth (45cm) at all the lateral distances studied, gained active roots which led to an hour-glass pattern of root activity distribution, depth-wise. This may reflect a tendency of banana roots to explore deeper layers of the soil in a quest for nutrients which may be needed at this critical stage of growth. Laterally, a total of over half of the active roots were found at 50cm and 75cm distances.

From the presence of over 1/3rd of the active roots closest to the trunk (25cm distance and 15cm depth) at the early vegetative stages, roots were observed to extend continuously (both sideways and deep) into the soil.

However, over 50% of the active roots were concentrated close to the base of the plant (25cm distance) and to the soil surface (15cm depth), right upto the flower initiation stage of growth. At the shooting stage, however, active roots extended upto 75cm laterally and at a depth of 45cm, leading to fairly uniform root-activity distribution in the entire rooting volume. At the shooting stage, a change in the pattern was observed, especially, in terms of soil depth. The greatest depth of 45cm at all the distances gained active roots at the expense of the surface layer, at 25 and 50cm lateral distances.

Phosphorus uptake by neighbouring plants

Absorption of the tracer element was evident in the orthogonal nieghbour located closest to the main plant, at 1.5m distance (although, the tracer was not discernible in some of the replicates indicating, that, the plants did not compete for phosphorus applied to the main plant on a definite basis). Similar recovery of the tracer by the neighbouring plants was reported by Kurien *et al* (2002), although it was not quantified. However, in this study, Pdft was very small (<1%), indicating that inter-plant competition for root activity was of a very small order. At all the growth stages, Pdft was highest at 15cm depth, compared to that in deeper layers (Table 2). At the 8th leaf stage, total Pdft at different growth stages showed a decline, with increasing depth. In the rest of the growth stages, Pdft at 30cm depth was lowest among the three depths studied. Distance-wise, maximum Pdft was observed midway at 50cm across (except at the 16th leaf stage), while, at the closest distance (25cm), least Pdft was evident. None of the diagonal neighbours located the farthest (at 2.1m distance from the main plant) showed any activity of the tracer indicating that the root competition with the main plant was absent. This may be due to the reduced length of large roots under high density planting due to inter-plant competition (Mohan and Rao, 1984).

Table 2. Phosphorus derived from isotope (Pdft, %) applied to the main plant of the orthogonal neighbour during various stages of plant growth in 'Robusta' banana (40 dai)

Depth (cm)	Distance (cm)			
	25	50	75	Total
8th leaf stage				
15	0.073	0.191	0.109	0.373
30	0.000	0.173	0.128	0.301
45	0.043	0.021	0.052	0.116
Total	0.116	0.385	0.289	0.790
SEm (±)	0.0049			
C.D. (*P=0.05)*	0.0147			
16th leaf stage				
15	0.052	0.116	0.162	0.330
30	0.016	0.031	0.073	0.120
45	0.080	0.033	0.043	0.156
Total	0.148	0.180	0.278	0.606
SEm (±)	0.0041			
C.D. (*P=0.05)*	0.0123			
Flower initiation stage				
15	0.100	0.140	0.127	0.367
30	0.015	0.019	0.037	0.071
45	0.000	0.021	0.126	0.147
Total	0.062	0.096	0.067	0.585
SEm (±)	0.0056			
C.D. (*P=0.05)*	0.0165			
Shooting stage				
15	0.030	0.034	0.077	0.141
30	0.024	0.000	0.003	0.027
45	0.016	8.56	0.000	0.113
Total	0.070	0.117	0.080	0.287
SEm (±)	0.0071			
C.D. (*P=0.05)*	0.0211			

In conclusion, it may be surmised 'Robusta' banana under high-density planting attained fairly uniform root-activity distribution in the soil volume studied, though a strong presence of active roots persisted close to the base of the plant and in the surface-soil. A small proportion (<1%) of phosphorus applied to the main plant was absorbed by the orthogonal neighbour, indicating practically no competition from its closet neighbour. Root competition from diagonal neighbours located the farthest (at 2.1m distance from the main plant) was not evident. Results indicated that a spacing of 1.5m × 1.5m in high-density planting of 'Robusta' banana raised in sandy-loam was optimal, with no untoward root competition for nutrients applied to the plant. However, this needs to be verified in other soil types and banana cultivars where high-density planting is practiced.

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