Intermat and intramat competition in banana studied using ^{32}P

Sajan KURIEN[a*], Paickattumana Suresh KUMAR[b], Nerukavil Varieth KAMALAM[b], Pallacken Abdul WAHID[b]

[a] RARS, Kerala Agricultural University, Kumarakom, PO 686 566, Kottayam, Kerala State, India, rarskum@sancharnet.in

[b] College of Horticulture, Kerala Agricultural University, PO 680 656, India

* Correspondence and reprints

Received 13 April 2005
Accepted 28 April 2006

Fruits, 2006, vol. 61, p. 225–235

DOI: 10.1051/fruits:2006020
www.edpsciences.org/fruits

RESUMEN ESPAÑOL, p. 235

Intermat and intramat competition in banana studied using ^{32}P.

Abstract — **Introduction**. Competition between plants on a mat (intramat) and between plants on different clumps (intermat) is quite common in crops such as banana. A study was therefore undertaken to know the extent of intramat and intermat competition using isotopic techniques. **Materials and methods**. The competition between plants in a mat and between mats were recorded in a combination of three spacings and five physiological phases of sucker retention by giving ^{32}P to an experimental plant using soil injection techniques and monitoring the levels of recovery. The recovery of the isotope was recorded in the applied plant and its daughter (intramat) and in the neighboring border plant and its sucker (intermat). **Results**. The study revealed that, when ^{32}P was given by soil injection techniques to one plant, it could be recovered in the border plant and its sucker during both years of study. In the first year, activity in initial samplings in border clumps were the highest, with the widest spacing in the experimental plant showing the highest recovery, but a differential pattern of recovery was observed at different samplings in the border clumps. In the irrigated crop of the second year, the highest recovery was observed at the closest spacing in both the experimental and border clumps. With respect to sucker retention at definite physiological phases, the recovery was the highest at the late vegetative phase, the flower bud initiation and the shooting phase. The recovery in the mother plant and its sucker and the border plant and its sucker studied separately gave a measurement of the intramat competition. **Conclusion**. The differential nature seen with retention phases confirms the requirement and intensity of activity with defined physiological phases and the overall need to evaluate and redefine recommendations, taking into consideration the critical physiological phases.

India / *Musa* / nutrition physiology / tracer techniques / radioisotopes / developmental stages / plant competition

Compétitions entre plant et rejet et entre plants voisins chez le bananier, étudiées à l'aide de ^{32}P.

Résumé — **Introduction**. La compétition entre plants issus d'un même rejet (intraplants) et entre plants de différentes touffes (interplants) est tout à fait commune dans des cultures comme la banane. Une étude a été donc entreprise pour évaluer l'ampleur de la compétition intraplants et interplants chez le bananier en utilisant un isotope. **Matériel et méthodes**. La compétition entre les plants d'une même touffe et entre ceux de différentes touffes a été étudiée, sur trois densités de plantation différentes et cinq stades physiologiques de développement des rejets, en apportant du ^{32}P à un plant expérimental par injection dans le sol, puis en suivant la récupération de la radioactivité dans les feuilles. La récupération de l'isotope a été mesurée sur le plant traité et son rejet fils (intraplants) et sur les plants voisins et leurs rejets (interplants). **Résultats**. L'étude a indiqué que, quand le ^{32}P était apporté à un plant par injection dans le sol, l'élément pouvait être récupéré dans le plant voisin et son rejet pendant les deux années de l'étude. Lors de la première année, l'activité récupérée a été la plus forte lors des premiers prélèvements effectués dans les touffes voisines du plant traité, la plus faible densité de plantation des plants expérimentaux ayant montré la meilleure récupération mais différents comportements ont été observés lors des différents prélèvements effectués dans les touffes voisines. Lors de la culture irriguée de la deuxième année, la récupération a été la plus élevée avec la densité la plus forte à la fois pour les plants expérimentaux et pour leurs voisins. Pour les rejets étudiés à des phases physiologiques définis, la récupération a été la plus forte pour ceux aux stades de végétation avancée, de l'initiation florale et de sortie du rejet. La récupération de ^{32}P dans le plant mère et son rejet et dans les plants voisins et leurs rejets, étudiée séparément, a permis de mesurer la compétition intraplants. **Conclusion**. Les différences observées selon les phases de développement considérées confirment que les besoins et l'activité des plants sont liés à des stades physiologiques définis et qu'il est nécessaire d'évaluer et de redéfinir des recommandations en tenant compte des phases physiologiques critiques.

Inde / *Musa* / physiologie de la nutrition / technique des traceurs / isotope radioactif / stade de développement / compétition végétale

1. Introduction

Bananas and plantains figure as the third most important fruit [1] and, in India, they rank first in production among all fruit crops.

In this country, the group of plantains and bananas is more concentrated in the southern states and the maximum intra- and interclonal variation is observed in the state of Kerala. There, the cultivation of these clones is also very distinct and very different from the cultivation of clones in other parts of the subcontinent. Except for the 'Nendran' clone, all other cultivars find a place either as an intercrop in coconut gardens or as a component of home gardens.

The home garden of Kerala is a crop mixture with no definite crop geometry but accommodating all crops for food, timber and fodder purposes such that each household is almost an independent self-sufficient unit with a strong food security system. With arable land declining due to high population and urbanization, the extent of the area of home gardens is gradually shrinking, leading to high intra- and interspecific competition between plants.

Productivity in the plant community is not only determined by environment, soil and the plant's inherent productive capacity, but also by the synergism and antagonism between individual crops often reflected in the form of competition, which could be manifested in different forms. The common competition observed is at canopy level in the case of light harvest and root level for water and nutrients.

The competition for light can easily be observed at the level of shoot growth, whereas that for water and nutrients depends on the efficiency of the root system, and root activity of competition from other plants, and it is manifested at the level of growth but is seldom, if not normally realized.

Another typical feature of banana in home gardens is the ratooning system practiced. Though it has been confirmed that the first ratoon gives the best yield in 'Mysore', what is being observed in home gardens is an indiscriminate ratooning, thus increasing the plant density, which again makes the intra- and intermat competition more severe.

Different methods of studying root systems exist and they have been reviewed [2–4]. Physical methods of studying the root distribution give a gross idea of the root system and include the dead, dormant and live roots but cannot account for the root activity, which depends both on root physiological aspects and soil status. On the other hand, studies involving radiotracers give a quantitative picture of root activity. Various radiotracers have been used for root studies. The successful use of stable strontium [5] and lithium [6] has been reported. However, ^{32}P is most widely in use, as this ion is immobile in the soil and highly mobile in plant systems [2, 3, 7].

From these data, our study on the major banana clone of south India was taken up with the main objective of studying the intra- and intermat level of competition; also, we assessed the extent or intensity of competition level with respect to plant spacing and the physiological stage of sucker retention.

2. Materials and methods

The experimental site was located at 12° 32' N, 74° 2' E and 22.52 m above mean sea level. The experiment was conducted over 2 years with 'Mysore' (syn. Palayankodan), the most important clone of banana present in home gardens. The soil of the area belongs to the group Eutrorthox, order Oxisol, Vellanikkara (India) series with a pH of 5.3, organic carbon content of 0.47%, CEC of 10.4 $cmol \cdot kg^{-1}$ and bulk density of 1.34 $mg \cdot m^{-3}$.

Suckers of uniform size and shape were selected from a large population. The planting was done such that each block consisted of nine plants with the central plant being considered as the experimental plant receiving the radioactivity. All the plants received uniform cultural techniques and manure applications which followed the package of practices recommendation [8].

The treatments consisted of 15 treatments:

– a combination of three spacings: 1.5 m × 1.5 m, 1.8 m × 1.8 m (the two spacings used in high-density planting) and 2.0 m × 2.0 m (the commonly adopted spacing),

– five stages of sucker retention: early vegetative phase, vegetative phase, flower bud initiation phase, shooting phase and fruit maturity phase. The stages of sucker retention, meaning the stage of the mother plant at which the sucker was allowed to develop, were based on a previous study [9] in the same variety and reviewed by the Indian Council of Agricultural Research (ICAR) technical committee.

For each of the 15 treatment plots, another similar plot was maintained without suckers. The two common major seasons of planting in the Kerala state formed two separate experiments.

In the first experiment, planting was done on 15 April; that planting date coincided with the rainfed banana crop of the state, which is nourished by the south-west monsoon from June to August and by the north-east monsoon from September to November.

The second experiment, done on 1 September, coincided with the most important planting time of banana in the state, which is the normal irrigated crop of the state; the crop received irrigation once every three days as per the package of practices recommendation.

Ten PVC tubes (3/4" in diameter) 30 cm in length (depth) were laid out in a radial manner in the soil, 20 cm from the pseudostem, as this was found to be the zone of maximum root activity in banana [10]. After all the retention phases were achieved, ^{32}P was procured from the Bhaba Atomic Research Centre, Bombay; a dose of 1.91 mCi and 1.49 mCi per plant was given during the first year (rainfed crop) and second year (irrigated crop), respectively, using soil injection techniques. The radioactivity was applied to the root zone using a field dispenser [11] such that each pipe and every experimental plant received an identical dose of activity. Both the experiments were replicated in a randomized block design.

Sampling was done four times at 10-day intervals beginning from the fifth day after application of the isotope. The mid-portion of the second full opened leaf was used for analysis [12]. The leaf samples from the suckers of the experimental plants and border plants on all the four sides were collected in the first experiment.

The recovery of the radioactivity was measured using Cerenkov counting techniques in a liquid Rack Beta scintillation counter (LKB Wallac model, Finland) following a diacid digestion [13]. The activity was corrected for background radiation and radiation decay by giving it a common zero hour and it was expressed as counts per minute per gram of the dried leaf sample ($cpm \cdot g^{-1}$). To facilitate comparison between years, the recovery of activity was multiplied by a common factor. The data in each experiment was logarithmically transformed and analyzed using the analysis of variance technique [14].

3. Results

The results of the study on the intermat and intramat competition in bananas using radiotracer techniques were evaluated at three levels:

– the intermat competition at the clump level,

– the intermat competition at the individual experimental plant and its border plant level (only plant crops with no suckers),

– the intramat level, i.e., between the main plant and its sucker and border plant and its sucker.

3.1. Intermat competition at clump level

The data on the mean radioactivity recovery in the experimental mother plant (R_{Moth}) and its sucker ($R_{Moth\text{-}Suck}$) and the border mother plant (R_{Bord}) and its sucker ($R_{Bord\text{-}Suck}$) show that there were no significant differences between the different treatments (three spacings and five sucker retention stages) in the first year (rainfed).

A perusal of the mean data [(R_{Moth} + $R_{Moth\text{-}Suck}$) / 2] and [(R_{Bord} + $R_{Bord\text{-}Suck}$) / 2] reveals that, in the first year, the activity

Table I.
Intermat competition between mother clump and border clump as evidenced by retrieval of ^{32}P activity ($cpm \cdot g^{-1}$ of dry matter) in *Musa*, in an irrigated experiment, after injection into soil of a dose of 1.49 mCi ^{32}P (spacing 1: 2.0 m × 2.0 m; spacing 2: 1.8 m × 1.8 m; spacing 3: 1.5 m × 1.5 m).

(A) Mean mother clump data: data of [experimental mother plant (R_{Moth}) + its sucker ($R_{Moth\text{-}Suck}$)] / 2.

Stage of ^{32}P injection	5 d after injection			15 d after injection			25 d after injection			35 d after injection		
	Spacing 1	Spacing 2	Spacing 3	Spacing 1	Spacing 2	Spacing 3	Spacing 1	Spacing 2	Spacing 3	Spacing 1	Spacing 2	Spacing 3
Early vegetative	347.00 (2.54)[1]	245.35 (2.93)	646.95 (2.77)	774.86 (2.89)	381.92 (2.58)	710.22 (2.85)	480.34 (2.68)	398.17 (2.19)	795.47 (2.90)	342.98 (2.54)	310.960 (2.47)	465.58 (2.40)
Vegetative	176.77 (2.25)	199.55 (2.94)	1094.54 (2.94)	328.38 (2.52)	420.72 (2.63)	3193.64 (3.50)	378.56 (2.58)	580.67 (2.77)	1812.50 (3.23)	211.35 (2.33)	404.41 (2.61)	757.62 (2.86)
Flower bud initiation	228.76 (2.36)	187.42 (1.94)	1215.62 (3.02)	567.12 (2.75)	160.47 (2.21)	1552.42 (3.19)	496.63 (2.69)	86.79 (1.85)	1210.50 (3.07)	211.71 (2.33)	12.13 (0.70)	735.56 (2.86)
Shooting phase	317.22 (2.50)	127.31 (1.11)	296.40 (2.35)	645.91 (2.81)	273.99 (2.44)	186.90 (2.27)	814.06 (2.91)	223.30 (2.35)	143.30 (2.16)	654.05 (2.81)	47.77 (1.69)	45.01 (1.61)
Fruit maturity	208.46 (2.32)	466.39 (2.67)	130.58 (2.12)	440.73 (2.60)	1014.62 (3.01)	273.14 (2.42)	504.13 (2.70)	1221.88 (3.09)	314.99 (2.50)	224.48 (2.30)	598.94 (2.78)	153.37 (2.19)

Critical difference (p = 5%) for comparison of mean mother clump data is equal to 0.115; for comparison of spacing is equal to 0.182; for comparison of sucker stage is equal to 0.180; for comparison of (spacing × sucker stage) is equal to 0.227.

(B) Mean border clump data: data of [experimental border mother plant (R_{Bord}) + its sucker ($R_{Bord\text{-}Suck}$)] / 2.

Stage of ^{32}P injection	5 d after injection			15 d after injection			25 d after injection			35 d after injection		
	Spacing 1	Spacing 2	Spacing 3	Spacing 1	Spacing 2	Spacing 3	Spacing 1	Spacing 2	Spacing 3	Spacing 1	Spacing 2	Spacing 3
Early vegetative	230.33 (2.36)[1]	270.38 (2.43)	359.61 (2.56)	458.73 (2.66)	548.79 (2.74)	3189.38 (3.50)	507.72 92.71)	788.08 (2.90)	2299.75 (3.36)	355.880 (2.55)	472.155 (2.67)	692.90 (2.83)
Vegetative	86.79 (1.94)	80.89 (1.91)	77.86 (1.90)	200.89 (2.31)	195.52 (2.30)	188.40 (2.14)	142.97 (2.36)	257.265 (2.30)	230.28 (2.09)	125.78 (2.12)	149.75 (2.14)	92.04 (1.96)
Flower bud initiation	182.36 (2.26)	27.00 (1.45)	334.15 (2.53)	361.45 (2.56)	98.18 (3.00)	2868.19 (3.46)	424.96 (2.63)	91.13 (1.96)	2567.61 (3.41)	328.52 (2.51)	63.23 (1.80)	894.11 (2.85)
Shooting phase	115.40 (2.07)	75.96 (1.88)	87.33 (1.82)	240.41 (2.38)	289.93 (2.46)	349.07 (2.54)	221.42 (2.35)	375.96 (2.58)	230.27 (2.36)	123.67 (2.08)	265.165 (2.39)	97.55 (1.98)
Fruit maturity	210.06 (2.31)	269.31 (2.43)	65.98 (1.83)	1940.94 (3.29)	613.88 (2.79)	171.44 (2.34)	1878.99 (3.27)	832.45 (2.92)	123.26 (2.09)	197.68 (2.16)	384.10 (2.59)	43.03 (1.64)

[1] Figures in parenthesis show mean of log-transformed values.

Critical difference (p = 5%) for comparison of mean border clump data is equal to 0.98; for comparison of spacing is equal to 0.90; for comparison of sucker stage is equal to 0.89; for comparison of (spacing × sucker stage) is equal to 0.176.

observed in the border plants was much higher than that observed in the experimental plant, except in the third and fourth sampling; nevertheless, in the second year (*table I*), the activity in the border plants was less in the first sampling but, as sampling advanced, the retrieval of activity in border plants began to increase and in the final sampling showed almost comparable counts to the activity observed in the experimental plants.

Comparison of absorption at different spacings revealed an interesting trend, though the results were not significant. In the first year, the relative rate of absorption in the widest spacing was the highest in the first three samplings but, in the last sampling, the intermediate spacing revealed the highest recovery of activity. In all the samplings, the closest spacing showed the least absorption. In the case of the border plants, the intermediate spacing showed the highest absorption in the first sampling; in the second sampling, the wider spacing recorded the highest; in the last two samplings, the closest spacing revealed the maximum retrieval. During the second year, the highest retrieval levels were observed in the closest spacing followed by the widest spacing in the treated clumps (*table I*). An identical trend was also observed in the border plants.

In the second year (irrigated), the results were statistically significant (*table I*). The retention at flower bud initiation in the first sampling, retention at the vegetative and flower bud initiation phases in the second sampling and retention at the vegetative phase in the later samplings recorded maximum uptake of ^{32}P whereas, in the border plants, the earliest phase of retention revealed the highest recovery.

A careful analysis of the mean activity retrieval values reveals that, both in the rainfed and irrigated crops, the border clumps competed with the main plant. In the rainfed crop, they showed more recovery than main plants up to the second sampling but the activity retrieval was reduced thereafter whereas, in the irrigated crop, the main plant showed more recovery up to the second sampling but declined thereafter (*figure 1*).

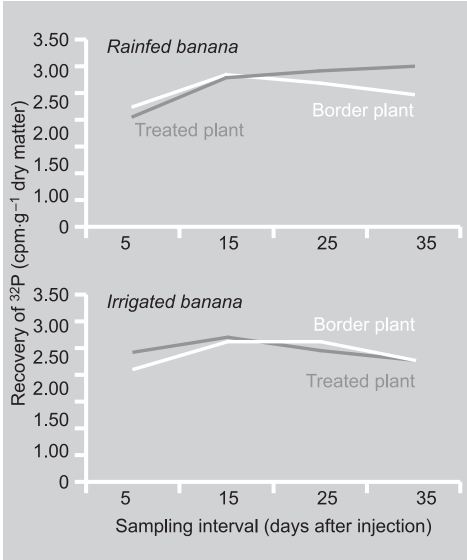

Figure 1.
Mean recovery of ^{32}P radioactivity in treated and border plants in rainfed and irrigated bananas according to different time of sampling from injection day of the radiotracer in soil around banana plants.

3.2. Intermat competition at mother plant vs. border plant level (with no sucker retention)

A critical analysis of the data on the competition between the experimental mother plant and the border mother plant under both conditions, i.e., with and without sucker retention, revealed that spacings were not significant in the first year.

The plants with sucker retention actually indicated a condition where competition can arise from the physiological phase of the mother plant and sucker, whereas the plants with no sucker retention indicated the actual requirement with the physiological phase of the crop.

In the first year, though the results were not significant, the mean recovery was highest in the closest spacing followed by that in the widest spacing; when there was no sucker retention, the activity recovery ranked from the widest spacing to the closest one. The competition pattern for the border plants was less intensive in the wider spacing but, in the highest spacing, it was more, as revealed by a comparison of activity recovery in the experimental plant and the border plants both with and without sucker retention. At the closest spacing, a perusal of the data on mean activity in the border rows show that the border rows accounted for more activity than the experimental or treated plants. In the case of sucker retention, the closest spacing accounted for maximum recovery, whereas the intermediate spacing gave maximum recovery in the case of no sucker retention.

In the second year, for the mother plant, the closest spacing recorded the highest activity recovery in the case of sucker retention or no sucker retention (*table II*). In the border plants, the trend was just the same in the case of no sucker retention whereas, in the case of sucker retention, the trend was just the reverse with the widest spacing showing maximum recovery of activity.

Table II.
Intermat competition as affected by with and without sucker retention at different spacings and retention phase, using retrieval of ^{32}P activity ($cpm \cdot g^{-1}$ of dry matter) in *Musa*, in an irrigated experiment, after injection into soil of a dose of 1.49 mCi ^{32}P (spacing 1: 2.0 m × 2.0 m; spacing 2: 1.8 m × 1.8 m; spacing 3: 1.5 m × 1.5 m).

Stage of ^{32}P injection	With sucker						Without sucker					
	Mother plant			Border mother plant			Mother plant			Border mother plant		
	Spacing 1	Spacing 2	Spacing 3	Spacing 1	Spacing 2	Spacing 3	Spacing 1	Spacing 2	Spacing 3	Spacing 1	Spacing 2	Spacing 3
Early vegetative	821.59 (2.891)[1]	504.21 (2.68)	1091.03 (2.942)	705.02 (2.56)	382.45 (2.83)	654.96 (2.79)	1155.29 (3.03)	767.55 (2.85)	1591.65 (3.16)	453.26 (2.69)	558.40 (2.72)	727.40 (2.83)
Vegetative	427.39 (2.609)	424.89 (2.59)	573.19 (2.74)	228.50 (2.31)	181.85 (2.21)	264.31 (2.38)	476.08 (2.66)	833.71 (2.88)	710.77 (2.82)	305.67 (2.46)	538.60 (2.71)	518.05 (2.66)
Flower bud initiation	727.34 (2.81)	57.01 (0.97)	1066.42 (2.99)	558.74 (2.73)	29.58 (0.81)	416.31 (2.58)	909.59 (2.93)	218.76 (2.28)	1497.72 (3.13)	381.33 (2.54)	189.37 (2.26)	647.46 (2.77)
Shooting phase	404.31 (2.69)	135.53 (1.66)	85.72 (2.49)	220.09 (2.31)	97.16 (1.96)	28.76 (1.17)	530.32 (2.69)	354.95 (2.52)	183.24 (1.53)	328.71 (2.48)	199.02 (2.08)	135.81 (1.87)
Fruit maturity	63.08 (1.43)	1454.93 (3.12)	329.66 (2.49)	36.05 (1.21)	756.02 (2.85)	161.89 (2.17)	266.54 (1.90)	2297.82 (3.32)	362.26 (2.53)	271.86 (2.41)	1322.77 (3.10)	229.90 (2.30)

[1] Figures in parenthesis show mean of log-transformed values.

Critical difference (p = 5%) for comparison of with and without sucker is equal to 0.202; for comparison of spacing is equal to 0.175; for comparison of sucker stage is equal to 0.216; for comparison of (spacing × sucker stage) is equal to 0.306.

In the case of sucker retention phases, in the first year, the retention of suckers at the late vegetative phase followed by that at the shooting and fruit maturation phases showed maximum activity recovery. The same trend was also observed in the case of border rows with sucker retention. In the case of no sucker retention, the crop in the shooting phase showed maximum recovery in the case of treated plants whereas, in the border rows, the stage of flower bud initiation showed maximum ^{32}P recovery. In the second year, the retention at the early vegetative phase followed by that at the flower bud initiation phase showed maximum recovery both in the main experimental plants and in border plants (*table II*). When no sucker was retained, application at these physiological stages accounted for maximum recovery.

Among the interaction effects, in the first year, the combination of late vegetative phase and widest spacing followed by the late phases and closest spacing were the best treatments in the case of experimental plants and border plants when suckers were retained. In the case of no sucker retention, the experimental plants at the closer two spacings in combination with those at the shooting phase and intermediate spacing with those at the shooting phase were the best treatments in terms of recovery of activity.

In the second year, the highest recovery was observed in the combination of intermediate spacing and last stage of retention followed by the closest spacing at the earliest stage of retention; this was significantly superior to other combination treatments (*table II*).

In the second year, the gradation in the level of ^{32}P absorption between that observed in the mother plant and that in border plants was almost identical in the case of blocks with and without sucker retention.

3.3. Intramat competition or competition between the mother plant vs. its sucker

In the first year, in both the experimental mother plant and border mother plant, the closest spacing recorded the maximum ^{32}P

Table III.
Intramat competition as evidenced by recovery of ^{32}P activity (cpm·g⁻¹ of dry matter) in *Musa*, in an irrigated experiment, after injection into soil of a dose of 1.49 mCi ^{32}P, in mother plant and its sucker and in border mother plant and its sucker.

Stage of ^{32}P injection	Mother plant			Sucker of the mother plant			Border mother plant			Sucker of the border mother plant		
	Spacing 1	Spacing 2	Spacing 3	Spacing 1	Spacing 2	Spacing 3	Spacing 1	Spacing 2	Spacing 3	Spacing 1	Spacing 2	Spacing 3
Early vegetative	821.585 (2.891)[1]	504.21 (2.68)	1091.03 (2.94)	151.50 (2.13)	164.50 (2.19)	218.07 (1.21)	705.02 (2.83)	382.45 (2.56)	654.96 (2.79)	71.80 (1.76)	649.74 (2.78)	2656.08 (2.46)
Vegetative	427.39 (2.61)	424.90 (2.50)	573.19 (2.74)	120.02 (2.04)	377.65 (2.50)	2885.98 (3.30)	228.50 (2.42)	181.85 (2.21)	264.31 (2.56)	49.71 (1.45)	159.86 (2.17)	29.98 (0.99)
Flower bud initiation	727.34 (2.82)	51.54 (1.18)	1066.42 (3.00)	24.76 (1.11)	121.86 (1.83)	1290.63 (2.93)	558.74 (2.73)	29.58 (1.15)	416.31 (2.58)	89.92 (1.72)	110.18 (1.983)	2916.71 (3.25)
Shooting phase	404.31 (2.59)	135.33 (1.85)	85.72 (1.88)	811.30 (2.88)	200.65 (2.24)	250.07 (2.22)	220.10 (2.31)	97.14 (1.96)	28.75 (1.16)	130.35 (2.09)	405.31 (2.51)	353.35 (2.43)
Fruit maturity	63.08 (1.43)	1454.93 (3.12)	329.74 (2.49)	605.81 (2.74)	195.97 (2.22)	101.29 (1.71)	36.05 (1.40)	756.03 (2.85)	161.89 (2.40)	1407.90 (3.15)	293.84 (2.24)	39.95 (1.05)

[1] Figures in parenthesis show mean of log-transformed values.

Critical difference (p = 5%) for comparison of the mother plant vs. its sucker and border mother plant vs. its sucker is equal to 0.23; for comparison of spacing is equal to 0.17; for comparison of sucker stage is equal to 0.22; for comparison of (spacing × sucker stage) is equal to 0.35.

recovery followed by the widest spacing. In the case of their suckers, the pattern was different. The intermediate spacing in the case of experimental plant suckers and closest spacing in the case of border suckers accounted for maximum retrieval of activity.

In the second year, the means of spacing showed that, at all spacings, the absorption was higher in the mother plant than the sucker, though the differences were statistically significant only in the widest and closest spacings (*table III*).

Comparison of the sucker retention phases showed that, in the first year, the retrieval of ^{32}P activity was maximum in the mother plants (both experimental and border) when the suckers were retained in the late vegetative phase. In the case of suckers, the pattern was different: for suckers of the experimental plant, the sucker retained at the flower bud initiation phase of the mother plant showed maximum activity whereas, for the suckers of the border plant, maximum activity was in the sucker retained at the earliest vegetative phase.

During the second year, the earliest retention phase followed by that at the flower bud initiation phase showed the highest absorption, which was significantly superior to that of other treatments in the case of the mother plants. For the suckers of the treated mother plants, it was those at the flower bud initiation phase followed by those at the late vegetative phase which were superior (*table III*).

4. Discussion

In our study, the mother and border plants at the widest spacing showed maximum economy, as the level of competition was comparatively less.

Firstly, in the case of the suckers, the competition was less at the intermediate and closer spacings. Plants at closer spacings tend to became taller: in the first year and second year, the mean heights in the closest spacing were 2.53 m and 2.75 m, respectively; in the widest spacing, they were

2.46 m and 2.60 m and, in the intermediate spacing, they were 2.49 m and 2.75 m. The result observed in the case of suckers can only be interpreted in terms of the sucker development. Identical results for taller plants with closer spacing were observed in banana [15, 16].

Secondly, in banana, it has already been reported that there is a preferential allotment of nutrients to the sucker. Initially, it is the earliest sucker which receives the major allocation. Once this sucker reaches independence, the following one gets the lion's share; or the gradual production of suckers, which are separated by some time, is a mechanism for nurturing the young suckers to independence [17].

With regard to sucker retention at various physiological phases of the mother plant, retention of suckers at the late vegetative phase in the rainfed crop and at the flower bud initiation phase in the irrigated crop showed maximum ^{32}P recovery. This result can be argued with only changes in the physiological stages of the mother plant and its inherent basic requirements. This concept gains more acceptance as the suckers retained at the flower bud initiation phase during both seasons showed maximum activity recovery. Almost the same trend was observed with respect to sucker retention in mother plants and border rows; a similar trend in ^{32}P recovery to phasic requirements reveals the intensity or efficiency of root activity in relation to the physiological state or the inherent need of the plant. Though identical studies are not available in this regard, it has been reported in Kinnow mandarin that the season of flush influences the activity and efficiency of roots [18].

The recovery of ^{32}P activity observed at the clump level is interesting too. In the rainfed crop of the first year, the border plants accounted for more activity in the initial two samplings but later ones showed a decreasing trend whereas, in the irrigated crop (second year), the activity in border plants was initially less but gradually rose with intervals of sampling. This can be explained only at the level of competition. The rainfed crop, being more stressed, should have exhibited more competition initially and, naturally, the level of competition reduced with time. On the other hand, in the irrigated crop, the initial level of competition was less and only increased with the passage of time. The reason could be only that water was not a limiting factor and the only difference between the two experiments.

The clump level in the rainfed crop with respect to spacing gives a better picture of the process of competition. In the case of experimental plants, the ^{32}P recovery was highest in the widest spacing in the first two samplings and, in the last two samplings, the intermediate sampling showed the highest recovery. The closest spacing recorded the lowest activity recovery. For the border clumps, the activity was highest in the closest spacing, clearly establishing the fact that competition level is more explicit when plants have grown as clumps, and this level is intense with reduction in spacing. On the contrary, in the rainfed crop, the highest ^{32}P recovery was observed at the closest spacing in mother plants and border plants whatever the intervals.

An analysis of the sucker retention phases gave the best answers regarding the requirement pattern of the crop. In the first year (rainfed), the retention phase at flower bud initiation in the first sampling, retention at the shooting phase in the second and third samplings and retention at the fruit maturity phase followed by that at the flower bud initiation stage in the last sampling recorded the highest activity. For the border rows, again retention at the shooting phase in the first sampling, and at the early and late vegetative phases in the second, third and fourth samplings revealed the highest recovery. Though underground competition for plant nutrients in cultivation has been well documented [19] and in natural communities [20], the requirement at different physiological phases requires detailed examination.

With regard to sucker retention the picture is very clear. In the rainfed crop the stages of retention at flower bud initiation, shooting and maturity demanded more nutrients and hence showed more recovery of activity. Whereas, in the case of the irrigated crop, it was the retention at bud initiation that accounted for a comparatively higher recovery of radioactivity, revealing that the requirement of the plant for the later stages of shooting and maturity is satisfied earlier under better management conditions.

Comparison of the intramat competition between the mother plant and its sucker revealed an interesting trend contrary to normal expectations. In the first year (rainfed), sucker retention at the earliest two phases showed less competition whereas, in the second year (irrigated), competition was less only in the earliest phase of retention. Thereafter, there was more intense competition between the mother and daughter suckers, as revealed by the equal activity retrieval registered by both the mother and daughter plants in a clump.

Interaction effects were not significant in the first year. In the treated mother plants, a combination of vegetative retention phase and widest spacing registered maximum activity retrieval, whereas, for the suckers, it was a combination of the same phase but with intermediate spacing which yielded maximum ^{32}P activity. For border mother plants, it was the same as in the experimental plants but, in the suckers of the border plants, it was the earliest retention in the intermediate phase that yielded maximum retrieval activity.

Another major factor that requires detailed verification is the modifications of the root system with sucker retention and different spacings due to manifold reasons. Primarily, variation in root activity could have been a reason, as reported in the case of cereals and peas when grown in pure stands and mixtures [21]. Secondly, various root characters could have been another reason. Characters such as the apex diameter as a good indicator of the root growth potential and the actual lateral growth have recently been established [22]. Similarly, the twin effects of root origin, position and diameter on root length and branching habits have been reported [23]. Thirdly, the better foraging capacity of thick roots has also been reported recently [24]. All the characters such as diameter of root apices or origin and position could change with the type of cultivation. However, in our study, observations on root characters were not made, as it involved radiotracer placement at a specific distance and depth, and the inherent risk involved with radiotracer application. Hence, this could form a line for future investigation.

A critical scrutiny of the results of with and without sucker retention with regard to spacing revealed the differential patterns of activity recovery or absorption by the border rows. In the case of no sucker retention, the trends observed in the border rows were the same with sampling whereas, in the case of sucker retention, the trends observed in the border rows were just the opposite. When sucker retention was affected, the plant density almost doubled, providing a situation where competition was more intense and the applied radiolabel should have been taken up by the experimental mother plant. On the other hand, when no suckers were retained, the recovery trend in border plants with respect to spacing was the same as in the case of experimental plants, as the border plants were not as stressed. The plants of the border rows of the treated experimental plants should have led to more recovery due to the intermingling of roots, as the roots of border plants should have reached the zone of application and, hence, more absorption by the border rows at the closest spacing were observed.

5. Conclusion

Finally, the study has generated results of great practical relevance; firstly, it has brought out the differential nature of the absorption pattern in experimental mother plants and border rows with respect to spacing and the differential nature of isotope recovery of border plants with spacing. Secondly, it has revealed the competition at clump level. Thirdly, it has brought out the allocatory pattern of mother plants and daughter suckers in a mat and, most importantly, the intensity of root activity with respect to sucker retention at critical phases of the mother plant. Our study also revealed the imperative need that, though recommendations can be made at an individual plant level, the block requirements should be taken into consideration. All the existing split applications also have to be tuned not only to the critical physiological phases of plants but, more importantly, the input quantity should match critical physiological phases and requirements. Only future studies on this subject could offer confirmatory requirements at each identified phase.

Acknowledgements

The authors acknowledge the ICAR for the full funding of the work, the director of research, the head, department of pomology and all members of the radiotracer lab of the Kerala Agricultural University for the help rendered during the stages of this work.

References

[1] Anon., Bulletin of statistics, 9 (3/4), FAO, Rome, Italy, 1996, pp. 114–115.

[2] Abbot M.L., Fraley L.J., A review: radiotracer methods to determine root distribution, Env. Exp. Bot. 31 (1991) 1–10.

[3] Atkinson D., The distribution and effectiveness of roots of tree crops, Hortic. Rev. 2 (1980) 425–470.

[4] Bohm W., Methods of studying root systems, Springer-Verlag, Berlin, Germany, 1979.

[5] Pinkerton H., Simpson J.R., The use of stable strontium as a chemical tracer for root penetration, Aust. J. Agric. Res. 30 (1979) 239–249.

[6] Martin M.P.L.D., Snaydon R.W., Drenman D.S.H., Lithium as a non-radioactive tracer for roots in inter cropped species, Plant Soil 64 (2) (1982) 203–208.

[7] Anon., Root activity pattern of some tree crops, IAEA, Techn. Ser., Vienna, Austria, 170, 1975, 154 p.

[8] Anon., Package of practices recommendation, Kerala Agric. Univ., Trichur, India, 1995.

[9] Koshy M., Flower bud differentiation in banana, Coll. Agric., Kerala Agric. Univ., Thesis, Vellayani, India, 1989, 87 p.

[10] Sobhana A., Aravindakshan M., Wahid P.A., Root activity patterns of Banana (var. Nendran) under irrigated and rainfed conditions, J. Nucl. Agric. Biol. 18 (2) (1989) 117–123.

[11] Wahid P.A., Kamalam N.V., Sankar S.J., Determination of phosphorus-32 in wet-digested plant leaves by Cerenkov counting, Int. J. Appl. Radiat. Isot. (1985) 323–324.

[12] Rajeevan P.K., Intra clonal variations and nutritional studies in banana cv. Palayankodan, Kerala Agric. Univ., Thesis, Trichur, India, 1985, 96 p.

[13] Wahid P.A., Kamalam N.V., Sankar S.J., A device for soil injection of ^{32}P solution in root activity studies of tree crops, J. Plant. Crop. 16 (1) (1988) 62–64.

[14] Panse V.G., Sukhatme P.V., Statistical methods for agricultural workers, Indian Counc. Agric. Res. (ICAR), New Delhi, India, 1978.

[15] Ahmed K., Mannam A., Effect of size of pit and spacing on performance of Amritsagar banana, Punjab Fruit J. 32 (1970) 7–13.

[16] Chattopadhyay P.K., Chattopadhyay S., Mait S.C., Bose T.K., Effect of plant density on growth, yield and quality of banana, in: Mathukrishan E., Abdul Khader J.B.M. Md (Eds.), Natl. Symp. Ban. Prod. Technol., TNAU, Coimbatore, India, 1980, 88 p.

[17] Kurien S., Anil B.K., Kumar S.P., Wahid P.A., Kamalam N.V., Nutrient studies in banana using ^{32}P, *Musa* news, Infomusa 8 (1) (1999) 35–36.

[18] Kurien S., Goswami A.M., Deb D.L., Studies on influence of flush on root activity in citrus using ^{32}P, Trop. Agric. 69 (4) (1992) 306–314.

[19] Casper B.B., Jackson R.B., Plant competitions underground, Ann. Rev. Ecol. Syst. 28 (1997) 545–570.

[20] Aerts R., Interspecific competition in natural plant communities: mechanisms, trade off and plant soil feed backs, J. Exp. Bot. 50 (1999) 29–37.

[21] Tofinga M.P., Snaydon R.W., The root activity of cereals and peas when grown in pure stands and mixtures, Plant Soil 142 (1992) 281–285.

[22] Lecompte F., Ozier-Lafontaine H., Pages L., The relationship between static and dynamic variables in the description of root growth. Consequences for field interpretation of rooting variability, Plant Soil 236 (1) (2001) 19–31.

[23] Lecompte F., Vacuelle A., Pages L., Number, position, diameter and initial direction of growth of primary roots in *Musa*, Ann. Bot. 90 (1) (2002) 43–51.

[24] Araya M., Blanco F., Changes in the stratification and spatial distribution of the banana (*Musa* AAA cv. Grand Nain), J. Plant Nutr. 24 (11) (2001)1679–1693.

Competencia entre plántula y vástago al igual que entre plántulas vecinas en el platanero mediante uso de un radiotrazador.

Resumen — Introducción. La competencia entre plántulas provenientes de un mismo vástago (intraplántulas) y entre plántulas de diferentes matas (interplántulas) es completamente común en las culturas como la del plátano. Por ello se llevó a cabo un estudio con el fin de evaluar la amplitud de la competencia intraplántulas e interplántulas en el platanero mediante el uso de un isótopo. **Material y métodos**. Se estudió la competencia tanto entre plántulas de una misma mata como entre plántulas de matas diferentes, aplicando tres densidades de plantación diferentes y cinco estados fisiológicos del desarrollo de los vástagos, añadiendo ^{32}P a una plántula experimental mediante inyección en el suelo y analizando la recogida de la radioactividad en las hojas. La recogida del isótopo fue medida por un lado en la plántula tratada y en su vástago (intraplántulas) y, por otro, en las plántulas vecinas y en sus vástagos (interplántulas). **Resultados**. El estudio indicó que, cuando se aportaba ^{32}P a una plántula mediante inyección en el suelo, el elemento podía recuperarse en la plántula vecina y en su vástago durante los dos años de estudio. Durante el primer año, la mayor actividad recogida ocurrió durante las primeras extracciones efectuadas en las matas vecinas de las plántulas tratadas; la densidad más débil de plantación de las plántulas experimentales con muestras de la mejor extracción pero se observaron comportamientos diferentes en las diferentes recogidas llevadas a cabo en las matas vecinas. Durante el cultivo de regadío del segundo año, la recogida fue más elevada con la densidad más fuerte a la vez para las plántulas experimentales y para sus vecinos. Para los vástagos estudiados en fases fisiológicas definidas, la mayor recogida fue para aquellos en estados de vegetación avanzados, de iniciación floral y de salida del vástago. La recogida de ^{32}P en la plántula madre y en su vástago, y en las plántulas vecinas y en sus vástagos, estudiada por separado, permitió medir la competencia intraplántulas. **Conclusión**. Las diferencias observadas según las fases de desarrollo consideradas confirman las necesidades y la actividad de plántulas ligadas a estados fisiológicos definidos y la necesidad global de evaluar y de redefinir recomendaciones teniendo en cuenta las fases fisiológicas críticas.

India / *Musa* / fisiología de la nutrición / técnicas de trazadores / radioisotopos / etapas de desarrollo / competición vegetal