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Root distribution of arecanut (*Areca catechu*) as influenced by drip fertigation in a laterite soil*

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Rooting pattern of a crop influences the growth and yield by enhancing the uptake of water and nutrients. Efficient irrigation and fertilizer application requires an understanding of the distribution of roots, water and soil nutrients in the soil profile. This is more important in crops like arecanut (*Areca catechu* L.) due to shallow root system of palms and its cultivation in highly porous laterite soils with poor nutrient and moisture retention capacity. Several workers emphasized that the root system is not only central to the acquisition of water and nutrients by plants but also a major pathway for the input of carbon and nutrients to soil (Coleman 2007).

Casper and Jackson (1997) reported that the configuration of the root system is largely determined in response to selective pressures from below ground interactions and the spatial distribution of nutrient and water resources. In arecanut, 61–67% of the roots were found concentrated within 50 cm radius in an 8-year-old palm. Better root growth and biomass production were reported in young arecanut palms due to ferti-drip irrigation compared to drip or basin irrigation methods (Sujatha and Haris 2000). Information on fine root biomass production is critical for quantifying the productivity as fine roots control the uptake of water and nutrients from the soil. Thus, the present study was conducted to evaluate the distribution pattern of both fine and thick roots in arecanut as influenced by drip fertigation, basin and sprinkler irrigation methods.

A long-term experiment was initiated at Regional Station, Central Plantation Crops Research Institute, Vittal, Karnataka, India (12° 15′N latitude and 75° 25′E longitude, 91 m above MSL) in December 1996. The average annual rainfall over last 30 years was 3670 mm distributed over 120 days. Mean temperature ranges from 21 (minimum) to 36°C (maximum). The soil is well drained deep laterite comprising 54.6% sand, 14.4% silt and 36% clay at 0–60 cm soil depth. The bulk density of soil was 1.61 g/cm^3 and field capacity varied between 18 and 22% at different soil depths (0–75 cm). Pre-experimental soil analysis indicated acidic *p*H (5.6), medium organic carbon status (1.5%), 10.1 ppm P and 53 ppm K at 0–30 cm soil depth.

The experiment was laid out in randomised block design with 3 replications incorporating factorial combinations of 4 levels of fertilizers, viz 25, 50, 75 and 100% of recommended fertilizer dose (100 : 40 : 140 g N : P_2O_5 : K_2O /palm/year) and 3 frequencies of fertigation, viz 10, 20 and 30 days. Two controls, viz control 1 (drip irrigation without fertilizer application) and control 2 (drip with 100% NPK soil application) were included for better appraisal of the results. The root distribution was studied in April–May 2005 after imposition of treatments for 10 years in selected treatments such as 50% NPK, 75% NPK and 100% NPK fertigation at 10 days interval and 100% NPK soil application. In addition, root distribution in other methods of irrigation, like basin and sprinkler was also studied for comparison. The crop was drip irrigated at 100% E_0 during post monsoon season and the fertilizer was applied from December to May. Three emitters of 8 litres/hr discharge rate were placed 60 cm away from the base of the palm on 3 sides. The sources of fertilizers used were urea, diammonium phosphate and muriate of potash. A ventury was used to inject the fertilizer solution into the main line of drip system after allowing the solution to pass through screen filter. In case of 100% NPK soil application, fertilizers were applied in 2 splits, i e 1/3 in May–June and 2/3 in September–October. In basin method, irrigation was given as per recommendation, i e 200 litre/palm once in 4–6 days interval during December to May. In sprinkler irrigation, the water was given @ 40–60 litre/palm with an irrigation interval of 3–4 days.

Root distribution was measured using the monolith method (Bohm 1979). Trenches of 1m depth and 0.5 m width were dug at 1.5 m from the base of the palm and the edges of root system of the palm were delineated. The root system was divided into dripping plane and non-dripping plane. Monoliths were collected at distances of 0–0.5, 0.5–1.0 and above 1.0 m from base of the palm. The roots were separated from the marked areas, i e 0–50 cm, 50–100 cm and > 100

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cm distance and depth. In field, the roots of monoliths were carefully separated from the soil and washed under a jet of water using a 4 mm mesh sieve. Subsequently, fresh roots were washed in the laboratory, classified into two, 2 mm and > 2 mm diameter, and oven-dried at 65°C. Root weight density (g/0.5 m^3) was obtained from the estimated dry weight divided by the monolith volume. For estimation soil moisture, soil samples were collected 24 hr after irrigation in drip fertigation and 48 hr after irrigation in basin and sprinkler methods. Soil moisture content was estimated by gravimetric method and expressed as per cent on dry weight basis.

Horizontal spread of root system was more in case of drip fertigation (135–144 cm), while it was only 127 cm in case of sprinkler and 121 in cm basin methods (Table 1). Rooting depth was also more in drip fertigation (101–136 cm) than in basin and sprinkler method (77–78 cm). Basin irrigation, ie flooding the surface caused roots to grow near the ground surface rather than to grow in the deeper layers. Similar observation was made under sprinkler irrigation also. The results of root studies revealed that arecanut roots were not uniformly distributed throughout the soil profile and the root system was not limited to a small zone that surrounded the dripping plane. Roots declined with depth and their horizontal distribution was strongly affected by the wetting pattern of the irrigation system. This might have increased the root biomass. Similar observations were made by Klepper (1991).

Drip fertigation resulted in production of higher fine root biomass (34–43%) than drip + 100% NPK soil application (33%), basin (22%) and sprinkler (21%). The drip fertigation has contributed to fine root proliferation, while natural precipitation of more than 3000 mm received during monsoon season from June to September wetting the entire profile would have resulted in better root distribution. Further the root: shoot ratio was found better with drip fertigation as compared to other irrigation methods. This agrees with a previous report on root distribution of young arecanut palm in the same experiment that drip fertigation in arecanut resulted in higher root mass and more horizontal root spread along dripping plane (Sujatha and Haris 2000).

Weight density of both fine and thick roots at varied soil depths and distances from the base of the palm was significantly influenced by the different irrigation methods (Table 2). The density of fine roots (g/0.5 m^3) in basin (0.6) and sprinkler (17.5) irrigation methods was negligible beyond 50 cm horizontal distance from the base of the palm when compared to drip fertigation (553–771) and drip + 100% NPK soil application (445). Similarly root density (g/0.5 m^3) at 0–50 cm soil depth was higher in drip fertigation (2664–3871) and drip + 100% NPK soil application (2126) over sprinkler (1604) and basin irrigation (901). At 50–100 cm soil depth reduction in fine root production was maximum with sprinkler irrigation. However the reduction under basin irrigation was negligible. Under drip fertigation and drip + 100% NPK soil application, even though reduction was observed, the density was still higher compared to other method of irrigation. Shivakumar *et al.* (2002) also noticed increased dry weight of feeder roots under drip and fertigation compared to furrow irrigation method in mulberry (*Morus alba* L.).

Drip fertigation at 100% NPK resulted in significantly higher root production than drip fertigation, drip + 100% NPK soil application and basin and sprinkler irrigation methods. Maximum distribution of roots, both fine and thick, was noticed with in 50 cm radius from the base of the palm and decreased at 50–100 cm distance and depth in all the treatments. In drip fertigation with different fertilizer levels, weight density of fine roots was maximum with 100% NPK (13 833 g/0.5 m^3), followed by 75% NPK level. With increase in distance from the base of the palm, the root weight density decreased. The extent of decrease was more with basin irrigation, followed by sprinkler irrigation compared to drip fertigation. This can be attributed to direct and efficient supply, especially phosphorus to the root system throughout the post monsoon season in drip fertigation. Application of phosphorus to small surface area through drip increases the phosphorus concentration in soil preferably more than P-fixing capacity of soil thus enhancing root development (Bar-Tal *et al.* 1990, Levinson and Adato 1991). Previous studies in the same experiment showed that adoption of fertigation places nutrients in active root zone, besides maintaining favourable soil moisture level resulting in much greater movement of phosphorus and potassium (Bhat *et al.*

Table 1 Root characteristics of arecanut palms as influenced by drip fertigation, basin and sprinkler irrigation methods

Parameter	100% NPK fertigation	75% NPK fertigation	50% NPK fertigation	100% NPK soil application+ drip	Basin irrigation	Sprinkler irrigation
Maximum rooting length (cm)	135	144.5	128	115	121	127
Maximum rooting depth (cm)	136	116	101	117	78	77
Total root weight (kg/palm)	8.23	7.99	4.84	5.28	3.25	3.94
Total shoot weight (kg/palm)	21.11	20.81	19.99	16.88	13.74	18.63
Root: shoot ratio	0.39	0.38	0.24	0.31	0.24	0.21
Fine roots (%)	34	37	43	33	22	21

Table 2 Root weight density (g/0.5 m^3) of arecanut at different soil depths and distances from the base of the palm in different irrigation methods

Irrigation method	Soil depth (cm)	Distance (cm) from the base of the palm								
		0–50			50–100			Mean		
		Fine	Thick	Total	Fine	Thick	Total	Fine	Thick	Total
Ferti-drip 50%NPK	0–50	2 094	3 200	5 294	570	544	1 114	2 664	3 744	6 408
	50–100	547	1 042	1 589	201	214	415	748	1 256	2 004
	Mean	2 641	4 242	6 883	771	758	1 529	3 412	5 000	8 412
Ferti-drip 75%NPK	0–50	3 531	5 126	8 657	340	959	1 300	3 871	6 085	9 956
	50–100	1 816	3 183	4 999	245	471	716	2 061	3 654	5 715
	Mean	5 347	8 359	13 656	585	1 430	2 016	5 932	9 739	15 671
Ferti-drip 100%NPK	0–50	3 503	5 289	8 792	318	980	1 298	3 821	6 269	10 090
	50–100	1 886	3 155	5 041	235	575	810	2 121	3 740	5 851
	Mean	5 389	8 444	13 833	553	1 555	2 108	5 942	10 009	15 941
Drip +100% NPK soil application	0–50	1 824	3 157	4 981	302	739	1 041	2 126	3 896	6 022
	50–100	1 157	2 341	3 498	142	313	455	1 299	2 654	3 953
	Mean	2 981	5 498	8 479	444	1 052	1 496	3 425	6 550	9 975
Sprinkler	0–50	1 587	4 557	6 144	17	194	211	1 604	4 751	6 355
	50–100	270	2 588	2 858	0.5	2.5	3	270.5	2 590.5	2 861
	Mean	1 857	7 145	9 002	17.5	1 96.5	214	1 874.5	7 341.5	9 216
Basin irrigation	0–50	901	3 596	4 497	0.4	2.1	2.5	901.4	3 598	4 499.5
	50–100	934	2 855	3 789	0.2	1.5	1.7	934	2 856.5	3 790.5
	Mean	1 835	6 451	8 286	0.6	3.6	4.2	1 835.4	6 454.5	8 290

	Fine roots		*Thick roots*		*Total*	
	SEm±	CD (*P*=0.01)	SEm±	CD (*P*=0.01)	SEm±	CD (*P*=0.01)
Depth/distance	4.19	16.02	5.07	19.41	5.66	21.64
Irrigation method	7.26	27.75	8.79	33.61	9.80	37.49
Irrigation vs depth/distance	10.26	39.24	12.43	47.53	13.86	53.02
Depth vs distance	5.92	22.62	7.18	27.44	8.00	30.59
Irrigation vs distance vs depth	14.51	55.49	17.58	67.22	19.61	74.98

2007). Significant correlation between root weight density of fine roots and soil depth (R^2 = 0.816)/distance from the base of the palm (R^2 = 0.607 and 0.924) further substantiates these results. Previous reports also show a positive response of RLD or root biomass to fertilization (Hebbar *et al.* 2004, Coleman 2007). The weight density of both fine and thick roots was more along dripping plane than along non dripping plane at 0–50 cm soil depth irrespective of drip fertigation treatments. While at 50–100 cm soil depth considerable reduction in root weight density was noticed in both dripping and non dripping planes.

Soil moisture (Fig 1) and root distribution data indicated that the root distribution was strongly influenced by the irrigation method followed. In drip fertigation method, the moisture availability along the horizontal plane up to 90 cm distance and up to 60 cm depth (22–27%) was higher than field capacity (18–22%) level of the soil. In basin and sprinkler irrigation methods, soil moisture availability reduced considerably compared to drip fertigation. Favourable soil moisture levels and uniform water

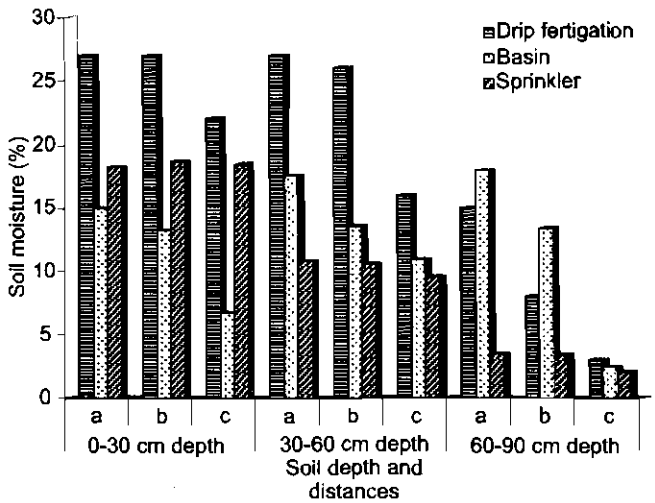

Fig 1 Soil moisture content (%) in arecanut basin as influenced by different irrigation methods (a, b and c – 0–30, 30–60 and 60–90 cm distance respectively)

distribution in the areca rhizospheres would have contributed to more production of root biomass.

The results revealed that there was a change in rooting pattern of arecanut with different irrigation methods and root distribution is strongly influenced by moisture and nutrient availability. Drip fertigation was found to improve the root distribution and fine root production as compared to basin and sprinkler irrigation.

SUMMARY

As part of a long-term study on drip fertigation initiated in 1996, the root distribution of arecanut was examined in April–May 2005 in 50% NPK, 75% NPK and 100% NPK fertigation at 10 days interval, 100% NPK soil application with drip irrigation, basin and sprinkler irrigation methods. Horizontal spread of root system was more in drip fertigation (135–144 cm), while it was only 121 cm in case of sprinkler and basin methods. Rooting depth was also more in drip fertigation (101–136 cm) than in basin and sprinkler method (77–78 cm). Drip fertigation resulted in production of higher fine root biomass (34–43%) than drip + 100% NPK soil application (33%), basin (22%) and sprinkler irrigation (21%). Maximum distribution of roots both fine and thick was noticed with in 50 cm radius from the base of the palm and decreased at 50–100 cm distance and depth in all the treatments. The weight density of both fine and thick roots was more along dripping plane than along non-dripping plane at 0–50 cm soil depth. With increase in distance from the base of the palm, the root weight density decreased. The extent of decrease was more with basin irrigation, followed by sprinkler irrigation compared to drip fertigation.

REFERENCES

Bar-Tal A, Bar-Yosef B and Kafkafi V. 1990. Pepper seedling response to steady and transient nitrogen and phosphorus supply. *Agronomy Journal* **82**: 600–3.

Bhat Ravi, Sujatha S, Upadhyay A K and Ashalatha B V. 2007. Phosphorus and potassium distribution as influenced by fertigation in arecanut rhizosphere. *Journal of Plantation Crops* **35** (2): 68–72.

Bohm W. 1979. *Methods of Studying Root Systems*. 194 pp. New York: Springer-Verlag.

Casper B B and Jackson R B. 1997. Plant competition underground. *Annual Review of Ecology and Sysytematics* **28**: 545–70.

Coleman M. 2007. Spatial and temporal patterns of root distribution in developing stands of four woody crop species grown with drip irrigation and fertilization. *Plant and Soil* **299**: 195–213.

Hebbar S S, Ramachandrappa B K, Nanjappa H V and Prabhakar M. 2004. Studies on NPK drip fertigation in field grown tomato (*Lycopersicon esculentum* Mill.). *European Journal of Agronomy* **21**: 117–27.

Klepper B. 1991. Crop root system response to irrigation. *Irrigation Science* **12**: 105–08.

Levinson B and Adato I. 1991. Influence of reduced rates of water and fertilizers application using daily intermittent drip irrigation on the water requirement, root development and response of Avocado trees. *Journal of Horticultural Science* **66** (4): 449–63.

Shivkumar H R, Shankar M A, Muniswamappa, Janarjuna S and Shanthala J. 2002. Relative efficiency of furrow, drip and fertigation on distribution pattern of roots in mulberry (*Morus alba*). (*in*) *Extended Summaries, 2nd International Agronomy Congress*, pp 1356–58. held during 26–30 November 2002 at New Delhi.

Sujatha S and Abdul Haris A. 2000. Root distribution pattern as influenced by different irrigation methods in young arecanut (*Areca catechu* L.) palms. *Journal of Plantation Crops* **28** (2): 117–22.