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Impact of Drip-Fertigation on Changes in Rhizosphere of Oil Palm

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A field study was taken up to determine the physical, chemical and biochemical and microbial changes in the rhizosphere of oil palm trees cultivated under two systems of fertilizer applications namely drip fertigation and surface irrigation with fertilizer application. Soil samples were drawn at different depths (0-60cm) to assess the horizontal and vertical changes occur in rhizosphere of palm. Physical, chemical and biochemical characteristics of the soil were studied in both systems of fertilizer application. The data have shown physical and chemical properties were similar between two systems of fertilizer application. The microbial activities inclusive of mycorrhizal population were distributed uniformly in the entire root zone (up to 45 cm) in fertigation system while such distribution confined to a narrow zone in conventional system of fertilizer application. The data suggest that fertigation has direct role to play in improving rhizosphere activities (microbial population and biochemical changes) in the entire root zone of oil palm vis-a-vis nutrient availability.

Key words: Drip fertigation, surface irrigation, rhizosphere, soil properties, oil palm.

Drip-fertigation is a localized application of water and nutrients at desirable proportions to meet the requirement of crop on a replace basis. Since, drought occurrence is on the rise and water availability is diminished, drip fertigation is gaining popular particularly in commercial crops. The method ensures that applied soluble plant nutrients become available to a substantial fraction of the plant root system; this is particularly important in sandy soils (Bar-Yosef, 1977; Bucks and Nakayama, 1980; Clothier, 1984). When using low quality water, drip irrigation has several advantages over other irrigation methods because it does not wet the foliage, and because of its high application frequency, concentrations of salts in the rooting zone remain manageable (Mantell *et al.,* 1985).

One of the major constraints in oil palm cultivation is nutrient and irrigation management. In comparison to coconut, oil palm requires fertilizers twice as that of coconut besides copious water. This necessitates introducing drip-fertigation to be able to reduce nutrient and water requirements while conserving the productive potential of Oil palm. The term rhizosphere is now defined more generally as the volume of soil, which is influenced by root activity (Hinsinger, 1998). Transport of nutrients in soils and root uptake is generally restricted to the soil solution phase. Thus, mineral nutrient availability in the rhizosphere largely depends on (1) soil-chemical and soil-physical properties determining the delivery of nutrients from the solid phase to the soil solution; (2) on the activity of soil microorganisms involved in the mineralisation of soil organic matter, and (3) on the plant requirements and root uptake rates for a given nutrient. This implicates the formation of gradients for nutrient availability in the rhizosphere: In Tamil Nadu Rice Research Institute (TRRI), Aduthurai, an Oil palm experiment was undertaken in an area of 15 acres wherein part of the palms were maintained under drip-fertigation and the remaining half is under conventional system of cultivation. In order to gain insights into the moisture and nutrient dynamics in the rhizosphere, the present investigation was taken up during 2008-09 cropping season. This is a pioneering attempt to look at the rhizospheric changes as a result of fertigation in oil palm.

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Materials and Methods

Soil samples were collected from rhizosphere of oilpalm (cultivar:dura) planted at experimental plots of TRRI, Aduthurai where two systems of nutrient management practices namely drip fertigation and surface irrigation with fertilizer application were adopted for the past seven years. The experimental soil belongs to Madukkur series, Inceptisol, very deep soil, neutral pH (7.3), low electrical conductivity (0.08 dSm^{-1}) and organic carbon (0.48 %) and low in available N (145 kg ha^{-1}), medium in available P (10.6 kg ha^{-1}) and high in available K (256 kg ha^{-1}) and deficient in available micronutrients. Oil palms were planted in the year

2002 and being fertilized @ 1200: 600: 1200 g NPK per palm per year in two splits during June-July and November-December for conventional system. For drip-fertigation, nutrients were applied through drips once in 10 days (100: 18: 117 g NPK per palm) dissolved in 210 litres of water delivered through 7 drippers in 4 h. Soil samples were dawn from two distinct treatments namely drip fertigation (I1) and conventional system (I2). Soil samples were drawn at different depths {(0-15 cm (D_1), 16-30 cm (D_2), 31-45cm (D_3), 46-60cm (D_4)}. Sampling was done in five palms per system of cultivation. The soil samples were analysed for pH, EC, CEC, soil available nutrients by following standard procedures (Stanford and English, 1949; Subbiah and Asija, 1956; Olsen *et al*. 1954; Jackson, 1973). The physical properties such as bulk density, particle density, pore space and water holding capacity were analysed (Piper, 1966; Gupta and Dhakshinamurthi, 1981). Different forms of soil organic carbon such as biomass carbon, biomass nitrogen, water soluble carbohydrate and organic carbon were analyzed (McGill *et al.* 1975; Jenkinson and Powlson, 1976; Brink *et al.* 1960; Jenkinson, 1988). Microbiological parameters like fungi, bacteria and actionomycetes and mychorrizal colonization percentage were also estimated (Dalpe, 1993).

Results

Soil physical properties

The results of physical properties such as bulk density, particle density, pore space and water holding capacity are given in Table 1.The result showed that in both drip and surface irrigation the bulk density and particle density increases with depth. The highest bulk density (1.58 gcc^{-1}) was observed in the depth of 45-60 cm. But when compared to both the irrigations, both the densities are lower in drip fertigation. When compared to drip irrigation, surface irrigation treatment recorded higher percentage of pore space. It varied from 41.56 to 45.20%.In surface irrigation, pore space percentage increased with depth. There was a significant difference between drip and surface irrigation with regard to water holding capacity (WHC). Highest water holding capacity (39.36%) was observed in drip irrigation of 45-60 cm. In surface irrigation, WHC of 37.65 % was increased in 15-30 cm depth

Table 1. Physical properties of rhizosphere soil of oil palm under drip-fertigation (I_1) and surface irrigation (I_2) measured at varying depths

Treatment	Bulk Density (g cc^{-1})	Particle Density (g cc^{-1})	Pore Space (%)	Water Holding Capacity (%)
I_1				
0-15 cm	1.25	2.66	43.59	35.59
16-30 cm	1.33	2.78	41.97	36.41
31-45 cm	1.26	2.7	42.67	37.32
46-60 cm	1.45	2.83	45.69	36.22
I_2				
0 -15 cm	1.25	2.33	44.51	39.31
16 - 30 cm	1.35	2.55	44.62	35.3
31 - 45 cm	1.43	2.53	45.45	37.44
46 - 60 cm	1.44	2.65	46.75	36.24
CD (p =0.05)				
I	0.023	0.023	0.331	0.264
D	0.028	0.034	0.24	0.215
I at D	0.040	0.047	0.441	0.369
D at I	0.039	0.048	0.345	0.304

Soil chemical properties

The chemical properties (pH, EC and CEC) were determined and given in Fig.1. Drip-fertigation leachates had recoded higher pH, EC and CEC than surface irrigation regardless of depth or distance. The results of available nutrients like N, P and K are given in table 2. The results showed that, all the available nutrients were higher under drip fertigation

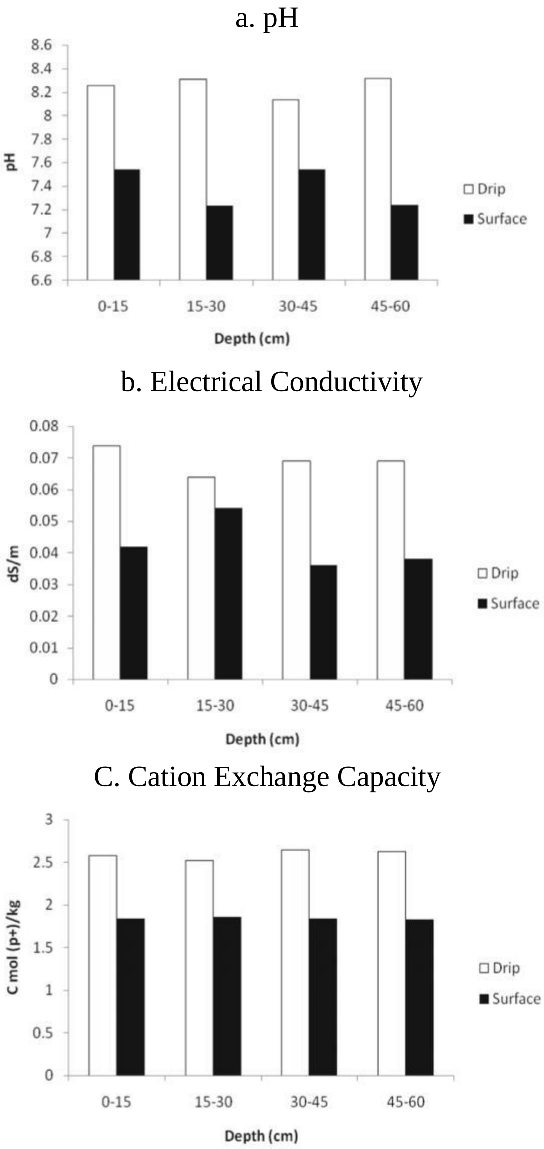

Fig.1.Chemical properties of rhizosphere soil of oil palm under drip-fertigation (I1) and surface irrigation (I2) measured at varying depths

Table 2. Available nutrient status of rhizosphere soil of oil palm at different depths influenced by drip fertigation (I_1) and surface irrigation (I_2)

Treatment	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
I_1			
0 -15 cm	189.3	2.66	43.59
16 -30 cm	184.9	2.78	41.97
31- 45 cm	183.3	2.7	42.67
46 - 60 cm	163.9	2.83	45.69
I_2			
0 -15 cm	165.8	2.33	44.51
16 - 30 cm	156.1	2.55	44.62
31 - 45 cm	155.8	2.53	45.45
46 - 60 cm	163.3	2.65	46.75
CD (p =0.05)			
I	24.478	2.105	35.587
D	28.482	1.900	37.735
I at D	NS	NS	NS
D at I	NS	NS	NS

than surface irrigation. In drip fertigation, the available N content ranged from 159 to190 kgha^{-1}and the available P status ranged from 10.6 to 12.9 kg ha^{-1} while, the available K content ranged from 256 to 279 kg ha^{-1}.

Soil biochemical properties

Soil biochemical properties such as biomass carbon, biomass nitrogen, water soluble carbon, water soluble carbohydrate and organic carbon are given in Table 3. Water soluble organic carbon content in drip fertigation treatment was higher than surface irrigation treatment. It ranged from 0.18 to 0.65 %. In surface irrigation, the values ranged from
0.12 to 0.60 %. There was no significant difference between the irrigation systems with regard to biomass carbon and biomass nitrogen. The

Table 3. Soil organic carbon status of rhizosphere of oilpalm soil at different depths influenced by drip fertigation (I_1) and surface irrigation (I_2)

Treatment	Biomass C (mg kg^{-1})	Biomass N (mg kg^{-1})	WSC (mg kg^{-1})	WS-CHO (mg kg^{-1})	Organic carbon (%)
I_1					
0 -15 cm	0.0025	35.59	0.368	342	0.17
16 - 30 cm	0.0026	36.41	0.602	322	0.21
31 - 45 cm	0.0033	37.32	0.136	183	0.24
46 - 60 cm	0.0016	36.22	0.186	122	0.18
I_2					
0 -15 cm	0.0026	39.31	44.51	341	0.22
16 - 30 cm	0.0028	35.3	44.62	311	0.20
31 - 45 cm	0.0024	37.44	45.45	310	0.24
46 - 60 cm	0.0026	36.24	46.75	306	0.23
CD (p =0.05)					
I	NS	4.598	NS	47.370	NS
D	NS	4.729	0.018	50.087	0.028
I at D	0.067	NS	0.027	76.785	0.055
D at I	0.061	NS	0.025	70.834	0.040

biomass carbon content was more in drip fertigation than conventional method of irrigation. The water soluble carbohydrate content was more or less similar in both the irrigation systems. It ranged from 110 to 342 mg kg^{-1} drip ferigation and in surface irrigation 280 to 340 mg kg^{-1}.

Microbial properties

Among the two method of irrigation systems, drip fertigation recorded higher number of microbes than surface irrigation. Among the microbes the fungal population was more in roots than bacteria and actionomycetes. The microbial population decreased with depth. Regarding mychorrizal colonization, it was higher in surface irrigation than drip fertigation. In drip fertigation colonization ranged from 41 to 45 % while it was 52 to 57 %. Under surface irrigation, as the depth increases, the mycorrhizal colonization percentage decreased in both the irrigation systems (Table 4).

Table 4. Microbial population in rhizosphere of oil palm under drip-fertigation (I_1) and surface irrigation (I_2) measured at varying depths

Treatment	Fungi (x10^{4}cfu/g soil^{-1})	Bacteria (x10^{6}cfu/g soil^{-1})	Actinomycetes (x10^{3}cfu/g soil^{-1})	Mycorrhizal colonization (%)
I_1				
0 -15 cm	41	22	11	42
16 - 30 cm	38	19	9	43.8
31 - 45 cm	37	17	10	41.8
46 - 60 cm	32	15	8	40.8
I_2				
0 -15 cm	35	17	11	54
16 - 30 cm	31	17	9	51
31 - 45 cm	29	14	10	52.2
46 - 60 cm	22	13	8	54.6
CD (p =0.05)				
I	NS	NS	NS	5.45
D	6.005	3.294	NS	NS
I at D	NS	NS	NS	NS
D at I	NS	NS	NS	NS

Discussion

Drip- fertigated soils recorded lower bulk density than conventional irrigation. This may be due to the partial saturation in drip fertigation. A slight difference in bulk density and porosity were detected between the irrigation methods, being higher in the soils under drip irrigation. The data suggested inadequate gas exchange and associated negative effects including increasing mechanical resistance to root penetration. There was a significant difference between drip fertigation and surface irrigation for water holding capacity (WHC). In surface irrigation, WHC of 37.65 % was increased in 15-30 cm depth. As dripping of water done at very low rates, the wetting front moves by capillarity action and only a portion of soil volume around the emitters maintained saturation. The volume and shape of the soil wetting zone mainly depend on the soil hydraulic properties and the amount and rate of irrigation. Increasing the quantity of water increased horizontal and vertical infiltration and consequently the volume of wetted soil. However, a moisture gradient is always produced in the wetted area, from the emitter (higher than field capacity) to the wetting front (lower than field capacity), independent of the amount of water applied .Therefore, it increases water filled pore spaces. The effect of Water Filled Pore Spaces (WFPS) in these processes has been very well documented by Davidson (1991), Granli and Bockman (1994) and Laura (2008).

The drip irrigation treatments recorded higher EC than surface irrigation regardless of depth and distance. It may be due to the salt accumulation near the root zone. In drip irrigation system moisture distribution pattern restricted around the emitter, they may result in a build up of salts at the fringes of the wetted soil volume. This phenomenon has often led to a salt build up in drip irrigated fields and usually requires off-season leaching, especially if the irrigation water used contains considerable amounts of salts.

The drip irrigation treatments recorded higher pH than surface irrigation. The use of non-acid forming fertilizers and the quality of irrigation water may have contributed to the increase in soil pH irrespective of treatments. The irrigation water used had a pH of 6.9-7.0 and naturally occurring calcium and magnesium ions, resulting in accumulation of these nutrients. The increase in soil pH within the wetted soil zone in drip-irrigated plum was attributed to irrigation water containing high amounts of calcium and magnesium. The pH strongly influenced the availability of residual nutrients in the soil fertigation. The balance between the uptake of cations and anions by the plants affect the pH in the rhizosphere. Nitrate and ammonium are the main forms of N available for the plant uptake. When a plant takes up more nutrient cations than anions, as occurs when NH_4^+ is the main N source, protons are exuded by the roots and acidify the rhizosphere. If the anion uptake predominant, as when NO_3^- is the main source of N, the root exudes OH- or HCO_3, which results in a pH rise in the rhizosphere. The rhizosphere pH varies with the form and concentration of the N fertilizer, but the extent of the pH change in the zone around the root depends on the buffer capacity of soil. Application of nutrients by fertigation with complete fertilizer decreased soil pH directly under the drippers, whereas traditional application by broadcasting followed by irrigation with alkaline water increased soil pH.

All the available nutrients were higher under drip fertigation than surface irrigation. It may be due to the application of fertilizers through drip that caused accumulation of nutrient ions around the root zone. Theses data indicated that the nutrient ions get concentrated around the wetting with the flux of the water in the soil. On the other hand in conventional method, distribution of nutrient ions was higher in the soil. A significant percentage of the gases emitted from soils treated with $(NH_4)_2SO_4$ under drip irrigation was produced by nitrification, while under furrow irrigation, denitrification was more important than nitrification (Li, *et al.,* 2003 and 2004). The fertigation process might improve distribution of NO_3^-N in the root zone as also reported by who found that NO_3^-N ion is very mobile in the soil and fertigation treatments maintained high concentration of NO_3^-N at shallow depth.

Greater mobility of P beyond 30 cm depth was recorded in drip fertigation. Bhat *et al.* (2007) revealed that drip fertigation retains nutrients in active root zone besides maintaining favorable soil moisture content resulting in much greater movement of phosphorus and potassium in arecanut root zone. Our data confirm the findings of others who attributed to greater mobility and availability of P in high frequency drip fertigation. This may be due to the accumulation of nutrients in the sampling area as delivery of nutrients confined to wetting zone around the drippers.. Fertigation enables higher availability of P to plants while reducing the loss to the environmental pollution. In contrast, the nutrient distribution may spread over in all the places in the surface irrigation that caused dilution of nutrients. The P status decreased with depth. The present findings suggested that continuous application of P fertilizers is needed to satisfy the P fixing needs of the soil and plant requirement. Phosphate transport in soil applied treatments was too slow for the average rate of root growth into the soil, due to the fact that phosphorus is prone to fixation at the point of application. Most of the applied P may be turned to in soluble form in a short time after its application, and the observed concentrations build up in the upper soil layer could affect root growth and create unfavorable conditions for P uptake. The results suggest higher response to P fertigation than soil application of fertilizers. The data are in conformity with the findings of other fertigation studies (Vasane *et al.,* 1996; Badr and Shafei, 2002). This may be due to the concentration of nutrients in and around the sampling area. It can be presumed that the drip fertigation has the potential to minimize leaching loss while improving the available K status in the root zone. But in surface irrigation, K+ ions may be spread out over in all the places, and thus less K content in the surface irrigation. Similarly to P, K also decreased with depth. In soils with low CEC and K fixation, potassium ions move along with the water when injected through drip irrigation. It is prudent to apply K fertilizers through drip irrigation in frequent splits in order to achieve the maximum nutrient use efficiency. Further, it was observed that drip fertigation places nutrients in active root zone besides maintaining favourable soil moisture level resulting in much greater movement of phosphorus and potassium in the rhizosphere of arecanut (Bhat *et al.,* 2007). This suggests that split application of K fertilizers through drip system would be a better option for tomato than soil application. Despite the fact that the experimental soil was sandy and deficient in available K status, the drip fertigation assisted in improving the availability of nutrients within the effective root zone and thereby alleviated K deficiency and sanctioned the productivity of palms. Similar observation was reported in tomato. (Hanson *et al.,* 2006; Rivera *et al.,* 2006).

Biochemical changes in the rhizosphere of drip-fertigation and surface irrigation was examined. There was no significant difference between the irrigation systems with regard to biomass carbon and biomass nitrogen. This may be attributed mainly to higher root biomass production with fine root biomass besides in situ root decay in the soil. The higher root activity in drip fertigation which was associated with higher soil air CO_2 concentration (Martinez, *et al.* 2004).

The microbial population decreased with depth under drip-fertigation system. This may be due to under drip irrigation conditions, the application of water at localized points at a low water flow probably favours more aerobic than anaerobic microsites. As the depth increases, the mycorrhizal colonization percentage decreased in both the irrigation systems. Drip fertigation resulted in higher root biomass, fine roots and extensive horizontal root spread along with dripping plane (Sujatha and Haris, 2000).

Conclusion

Fertigation technology has many advantages due to increasing scarcity of water and cultivated land, and escalating fertilizer prices. Further, this technology provides gives scope for reducing environmental pollution by lesser use of fertilizers and fuel. Microbial activities inclusive of mycorrhizal population were distributed uniformly in the entire root zone (up to 45 cm) in fertigation system while such distribution confined to a small narrow zone in conventional system of fertilizer application. The data suggest that fertigation has a direct role to play in improving rhizosphere activities (microbial population and biochemical changes) in the entire root zone of Oil palm vis-a-vis nutrient availability.

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