



P-ISSN: 2349-8528

E-ISSN: 2321-4902

www.chemijournal.com

IJCS 2020; 8(5): 1902-1906

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Received: 13-07-2020

Accepted: 15-08-2020

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Physicochemical properties of banana soils as influenced by drip-fertigation system

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DOI: <https://doi.org/10.22271/chemi.2020.v8.i5z.10580>

Abstract

Field experiments were conducted on banana during 2008-2010 at the Mondouri Research Farm of AICRP on Tropical Fruits, Bidhan Chandra Krishi Viswavidyalaya, West Bengal encompassing Genetic plains of India with three levels of drip irrigation at 50, 60 and 70% of CPE and three levels of drip fertigation at 50, 60 and 80% of recommended NPK fertilizers with one conventional surface irrigation at IW/CPE 1.0 laid in an augmented factorial complete block design having three replications to assess the changes of physicochemical properties of soil. The results of the study showed that irrespective of irrigation methods and levels of drip fertigation soil fertilization, the physicochemical parameters of soil such as pH, EC, organic carbon, water holding capacity, permeability, porosity and saturated hydraulic conductivity are consistently increasing with the increase depth of soil profile. However, drip fertigation system is found to be the best option in improving these soil health indices in comparison with the conventional surface irrigation and direct soil fertilization which is likely to increase the fruit yield, water and nutrient productivity of banana crop.

Keywords: Banana, drip irrigation, fertigation, physical and chemical properties of soils

Introduction

Banana is an important and leading fruit crop in India contributing 37% of the total fruit production due to wide adaptability to varying soils and climatic conditions (Pawar and Dingre, 2013) [11]. In the lower Gangetic plains of West Bengal, the farmers generally follow the traditional surface method of irrigation in banana cultivation which produces moderate yield and renders excessive wastage of water and nutrients in deep percolation below the root zone, besides contributing to water logging, poor soil aeration and weed infestation (Veeraputhiram *et al.*, 2005) [19]. Drip fertigation, on the other hand, is an efficient and economically viable irrigation technology in India and has proved its superiority over other methods of irrigation due to judicious application of water and nutrients in right time directly to the vicinity of crop root zone (Hebbar *et al.*, 2004; Patel and Rajput, 2000) [3, 10]. It also helps to increase the water and nutrient use efficiency by way of reducing the leaching and conveyance losses exclusively associated with conventional application (Solaimalai *et al.*, 2005; Kumar *et al.*, 2005; Gardenas *et al.*, 2005; Raina *et al.*, 2011) [15, 6, 1, 12]. The mobility of water and nutrients to crop influences the fruit yield of banana which primarily depends on physicochemical properties of the soil. Very little work has been progressed on these aspects. Therefore, the present study was undertaken to assess the impacts of drip fertigation vis-à-vis conventional surface irrigation on the physicochemical properties of banana soils in the Gangetic plains of West Bengal, India.

Materials and Methods

Field experiments were conducted on banana cv. Martaman (AAB, Silk) during 2008-2010 at the Mondouri Research Farm of AICRP on Tropical Fruits, Bidhan Chandra Krishi Viswavidyalaya, West Bengal lying at 23.5° N latitude and 80° E longitudes with an elevation of 9.75 m above mean sea level. Soil is Genetic alluvium having salty clay in texture (Typic Haplaquept) with well drainage facility. The trial was laid out in an augmented factorial complete block design having three replications with ten treatments consisting of three drip irrigation schedules at 50 (I₁), 60 (I₂) and 70 (I₃) % of cumulative pan evaporation (CPE) and

three fertigation schedules at 50 (F₁), 60 (F₂) and 80 (F₃) % of recommended NPK fertilizers through drip irrigation with one surface irrigation at IW/CPE 1.0 as standard check. A separate lateral line (12 mm) was laid for each treatment. Two drippers in each plant with a discharge rate of 1.8 lph were provided on either side of plant at a distance of 30 cm. The operating pressure of drip system was 1.2 kgcm⁻². Water requirement (WR) was computed based on pan evaporation, pan factor and crop co-efficient. The irrigation frequency by drip system was once in every 3 days in summer and 5 days in winter based on 50, 60 and 70% of evaporation replenishment. In surface method, irrigation water was applied at 100% of IW/CPE in 30 splits scheduled at 7-10 day interval with 50 mm depth per irrigation in check basin. The recommended dose of N, P and K fertilizer was 250, 50 and 300 g plant⁻¹ year⁻¹ applied through urea (46% N), phosphoric acid (31.68% P) and muriate of potash (60% K₂O), respectively. Solid and liquid fertilizers as per schedules dissolved in an overhead tank connected to a bore well delivering good quality irrigation water controlled through a valve. This fertilizer-water mixture was injected into the drip system through a fertilizer injector at 3-5 day interval starting from 45 days after planting to 210 days. The concentration of nutrient solution passing through irrigation water was around 1.1 to 1.7%. Drip fertigation was scheduled in 30 splits each commencing from 9th to 38th week for plant and ratoon crop. In surface method of irrigation, 100% recommended dose of NPK fertilizers were applied in soil in 4 splits at 2, 5, 7 and 9 months after planting of plant and ratoon crop. The initial physicochemical characteristics of the soil are presented in Table 1. The treatment-wise soil samples were collected separately at a depth of 0-15, 15-30, 30-45 and 45-60 cm layer before planting and harvesting of both plant and ratoon crop under surface irrigation plus soil fertilization and drip fertigation and analyzed for pH, EC, organic carbon, water holding capacity, porosity, permeability and saturated hydraulic conductivity of soils using the standard methods (Jackson, 1973) [4]. The data were subjected to statistical analysis such as analysis of variance using software like MS excel and SPSS 12.0 version. Statistical significance between means of individual treatments was assessed using Fisher's least significant difference (LSD) at $P < 0.05$ level.

Results and discussion

pH

Soil pH, irrespective of methods of irrigation and levels of fertilizer application, progressively decreased in varying magnitudes with increase in soil depth in drip as well as surface irrigated plots in both years (Table 2). The decrease in soil pH at the bottom layers is presumed that some amounts of nitrogenous and phosphatic fertilizers applied through drip or surface irrigation are leached from surface layer and accumulated in the layers underneath (Teixeira *et al.*, 2007) [18], which in effect causes acidification due to phosphoric acid (Mohammad *et al.*, 2004) [8] and nitrogenous fertilizer on microbial decomposition (Hauter and Mengel, 1988; Parchomchuck *et al.*, 1993) [2, 9]. However, drip irrigation at 60% of CPE or drip fertigation at 60% of recommended NPK fertilizers, on an average, recorded the higher pH values as compared to other drip irrigation and fertigation schedules (Table 4). The interaction between drip irrigation and fertigation on soil pH was significant which indicates that both irrigation and fertigation have a positive impact in changing the soil pH. Drip irrigation as a whole was found to

show relatively a higher pH value than in conventional surface irrigation (Tables 2 and 4).

Electrical conductivity

The electrical conductivity of soil regardless of methods of irrigation and fertilization significantly and consistently decreased with increase in soil depth in drip and surface irrigated plots in both years (Table 2). There was an improvement of EC values in surface layer when compared with initial soil value, possibly due to the addition of soluble materials through fertilizers. Drip irrigation at 60% of CPE recorded a relatively higher value than the initial soil value, while the levels of drip fertigation did not show a conspicuous change in EC values, rather it virtually remained unchanged (Table 4). It is postulated that application of higher amount of K accounted for more cation in solution resulting in higher electrical conductivity (Parchomchuck *et al.*, 1993) [9]. The interaction between drip irrigation and fertigation on EC was significant, thereby indicating the role of drip fertigation in promoting the EC values. Relatively a higher value of EC was observed in drip irrigation than in surface irrigation (Tables 2 and 4).

Organic carbon

Irrespective of methods of irrigation and fertilization, soil organic carbon content decreased progressively and significantly with concomitant increase in soil depth in drip and surface irrigated plots in both years similar to that of soil pH and EC (Table 2). A little improvement of soil organic carbon was observed in all soil layers as compared with initial value, the more so in surface layer than in subsurface layers. On the contrary, application of drip irrigation or drip fertigation at incremental levels significantly increased the soil organic carbon, although in varying magnitudes (Table 4). The higher level of drip irrigation at 70% of CPE or of drip fertigation at 80% of recommended NPK fertilizers recorded the higher value of organic carbon. The increasing availability of N, P and K in soil with congenial soil moisture regime as a result of drip fertigation might have increased the soil microbial activity leading to increased soil organic carbon (Salvin, 1999; Kavino *et al.*, 2004) [14, 5]. The interaction between drip irrigation and drip fertigation on soil organic carbon content was non-significant in both years. However, the drip irrigation as a whole showed a marginally higher value of soil organic carbon than in surface irrigation (Tables 2 and 4).

Water holding capacity

The stepwise significant decrease of water holding capacity down the layers of the soil profile, irrespective of methods of irrigation and fertilization, followed more or less the same trend as in soil pH, EC and organic C (Table 3). The effects of incremental levels of drip irrigation or fertigation in increasing the WHC of soil were significant similar to that of other soil parameters (Table 5). This may be attributable to profuse root biomass production owing to drip irrigation cum drip-fertilizer application as compared to conventional method of irrigation and direct fertilizer application in soil (Srinivas, 1997; Reddy *et al.*, 2002) [16, 13] and their subsequent accumulation indifferent soil layers after decomposition. These results are in agreement with the findings of Swarup and Wanjari (2000) [17]. The interaction between drip irrigation and drip fertigation on soil water holding capacity was non-significant in both years. In comparison to conventional surface irrigation, soil water

holding capacity was slightly higher in drip irrigation, although the difference was non-significant (Tables 3 and 5).

Soil permeability

The progressive decrease of soil permeability down the layers of the soil profile, irrespective of methods of irrigation and fertilization, closely followed the same trend as in other soil parameters (Table 3). The administration of incremental drip irrigation or fertigation significantly increased the soil permeability (Table 5) and the values were slightly higher than the initial soil value with some deviations. Higher production of soil organic carbon down the soil layers owing to drip irrigation as well as drip fertigation resulted in higher soil porosity in the layers underneath as was observed in the study leading to the increased soil permeability (Reddy *et al.*, 2002) [13]. The interaction between drip irrigation and drip fertigation on soil permeability was significant in both years. The soil permeability was significantly higher in drip irrigation than in conventional surface irrigation (Tables 3 and 5).

Saturated hydraulic conductivity

The saturated hydraulic conductivity of soil, in general, consistently and significantly decreased with increasing depth of soil profile in drip and surface irrigated plots during first and second year (Table 3). The same finding has been reported by Mahendran and Mathan (1994) [7]. The increasing level of drip irrigation from 50 to 60% of CPE recorded the significant increase in saturated hydraulic conductivity of soil; thereafter it remained unchanged with further increase in the level of drip irrigation at 70% of CPE (Table 5). Similarly, the drip fertigation at 60% of recommended NPK fertilizers documented maximum saturated hydraulic conductivity, which was declined significantly with increase in fertigation level at 80% of recommended NPK fertilizers. The increased saturated hydraulic conductivity with increasing doses of NPK was observed by Swarup and Wanjari (2000) [17]. The interaction between irrigation and drip fertigation on saturated hydraulic conductivity of soil was significant in both the years. It was observed that drip irrigation as a whole performed better in promoting saturated hydraulic conductivity of soil than that of surface irrigation.

Table 1: Physical and chemical characteristics of the experimental soil.

Soil depth (cm)	Sand (%)	Silt (%)	Clay (%)	Bulk density (Mg/m ³)	Water holding capacity (%)	Soil permeability (10 ⁻⁶ MS ⁻¹)	Saturated hydraulic conductivity (10 ⁻⁶ MS ⁻¹)	p ^H (1:2)	EC (dSm ⁻¹)	Organic carbon (%)
0-15	10.1	40.0	49.9	1.27	50.25	2.74	1.76	6.46	0.10	0.45
15-30	10.5	41.3	48.2	1.31	49.06	2.18	1.35	6.38	0.08	0.39
30-45	12.2	42.1	45.7	1.42	48.21	1.72	0.97	6.28	0.09	0.36
45-60	14.3	40.8	44.9	1.46	46.83	1.32	0.64	6.30	0.07	0.31

Table 2: Effect of different levels of drip and surface irrigation on pH, electrical conductivity and organic carbon content of soils under banana plantation.

Depth (cm)	pH			EC (dSm ⁻¹)			Organic carbon (%)		
	Plant	Ratoon	Mean	Plant	Ratoon	Mean	Plant	Ratoon	Mean
Drip irrigation									
0-15	6.57	6.41	6.49	0.15	0.18	0.17	0.49	0.48	0.49
15-30	6.50	6.36	6.43	0.12	0.15	0.14	0.42	0.44	0.43
30-45	6.44	6.34	6.39	0.09	0.12	0.11	0.36	0.37	0.37
45-60	6.39	6.18	6.28	0.08	0.08	0.08	0.29	0.33	0.31
CD (0.05)	0.04	NS	0.11	0.01	0.01	0.01	0.02	0.02	0.01
Surface irrigation									
0-15	6.51	6.35	6.43	0.12	0.14	0.13	0.48	0.46	0.47
15-30	6.46	6.32	6.39	0.10	0.13	0.12	0.40	0.42	0.41
30-45	6.38	6.24	6.31	0.11	0.10	0.11	0.35	0.39	0.37
45-60	6.34	6.31	6.32	0.10	0.09	0.10	0.28	0.32	0.30
CD (0.05)	0.03	NS	0.09	0.01	0.01	0.01	0.03	0.02	0.01
Drip	6.48	6.32	6.40	0.11	0.14	0.13	0.39	0.40	0.40
Surface	6.42	6.31	6.36	0.10	0.11	0.11	0.37	0.39	0.38
CD (0.05)	0.05	NS	0.13	0.01	0.01	0.01	NS	0.02	0.02

NS: Not significant

Table 3: Effect of different levels of drip and surface irrigation on soil water holding capacity, permeability and saturated hydraulic conductivity of soil under banana plantation.

Depth (cm)	Water holding capacity (%)			Soil permeability (10 ⁻⁶ MS ⁻¹)			Porosity (%)			Saturated hydraulic conductivity (10 ⁻⁶ MS ⁻¹)		
	Plant	Ratoon	Mean	Plant	Ratoon	Mean	Plant	Ratoon	Mean	Plant	Ratoon	Mean
Drip irrigation												
0-15	51.26	50.22	50.74	3.20	3.34	3.27	50.70	50.38	50.54	2.13	2.18	2.15
15-30	50.63	48.78	49.70	2.53	2.58	2.56	48.54	48.74	48.64	1.40	1.45	1.43
30-45	49.30	47.90	48.60	1.96	2.03	1.99	46.91	46.87	46.89	1.03	1.07	1.05
45-60	48.18	46.50	47.34	1.57	1.62	1.59	45.28	45.26	45.27	0.81	0.85	0.83
CD(0.05)	0.04	0.09	0.11	0.03	0.03	0.03	0.47	0.48	0.31	0.03	0.03	0.02
Surface irrigation												
0-15	49.21	50.78	50.00	2.85	3.02	2.94	49.00	48.18	48.59	1.88	2.00	1.94
15-30	48.09	47.98	48.03	2.31	2.41	2.36	48.05	47.58	47.81	1.34	1.35	1.34
30-45	48.00	46.87	47.44	1.74	1.85	1.80	46.51	46.51	46.52	0.96	0.98	0.97
45-60	46.79	45.61	46.20	1.43	1.47	1.45	44.34	45.38	44.86	0.67	0.73	0.70

CD(0.05)	0.12	0.14	0.08	0.04	0.05	0.02	0.32	0.35	0.22	0.04	0.02	0.02
Drip	49.84	48.35	49.10	2.31	2.39	2.35	47.85	47.81	47.83	1.34	1.39	1.36
Surface	48.02	47.81	47.92	2.09	2.19	2.14	46.97	46.86	46.94	1.21	1.26	1.24
CD(0.05)	0.64	NS	0.63	0.04	0.04	0.03	0.56	NS	0.37	0.03	0.03	0.03

NS: Not significant

Table 4: Effect of different levels of drip fertigation on pH, electrical conductivity and organic carbon content of soil under banana plantation.

Treatment	pH			EC (dSm ⁻¹)			Organic carbon (%)		
	Plant	Ratoon	Mean	Plant	Ratoon	Mean	Plant	Ratoon	Mean
Irrigation									
I ₁	6.46	6.28	6.37	0.08	0.10	0.09	0.37	0.35	0.36
I ₂	6.47	6.38	6.43	0.11	0.11	0.11	0.40	0.38	0.39
I ₃	6.50	6.31	6.40	0.11	0.12	0.12	0.42	0.39	0.41
CD(0.05)	NS	NS	NS	0.01	0.01	0.01	0.01	0.02	0.01
Fertilizer									
F ₁	6.39	6.28	6.33	0.10	0.11	0.11	0.36	0.34	0.35
F ₂	6.54	6.43	6.49	0.11	0.11	0.11	0.40	0.38	0.39
F ₃	6.50	6.26	6.38	0.11	0.12	0.12	0.43	0.40	0.42
CD(0.05)	0.04	NS	0.10	0.01	0.01	0.01	0.01	0.02	0.01
Irrigation x Fertilizer									
I ₁ F ₁	6.29	6.08	6.19	0.08	0.10	0.09	0.34	0.31	0.33
I ₁ F ₂	6.53	6.42	6.47	0.10	0.11	0.11	0.37	0.35	0.36
I ₁ F ₃	6.55	6.34	6.45	0.11	0.12	0.12	0.39	0.40	0.40
I ₂ F ₁	6.43	6.28	6.36	0.09	0.11	0.10	0.36	0.34	0.35
I ₂ F ₂	6.56	6.43	6.50	0.11	0.11	0.11	0.40	0.40	0.40
I ₂ F ₃	6.42	6.42	6.42	0.12	0.13	0.13	0.43	0.39	0.41
I ₃ F ₁	6.43	6.48	6.46	0.11	0.11	0.11	0.36	0.37	0.37
I ₃ F ₂	6.53	6.43	6.48	0.11	0.12	0.12	0.43	0.40	0.41
I ₃ F ₃	6.53	6.01	6.27	0.13	0.14	0.14	0.46	0.42	0.44
CD(0.05)	0.07	0.34	0.17	0.01	0.01	0.01	NS	NS	NS
Drip	6.48	6.32	6.40	0.11	0.14	0.13	0.39	0.40	0.39
Surface	6.42	6.31	6.36	0.10	0.11	0.11	0.37	0.39	0.38
CD(0.05)	0.05	NS	0.13	0.01	0.01	0.01	NS	0.02	0.01

NS: Not significant

Table 5.Effect of different levels of drip fertigation on soil water holding capacity, permeability and saturated hydraulic conductivity of soil under banana plantation.

Treatment	Water holding capacity (%)			Soil permeability (10 ⁻⁶ MS ⁻¹)			Porosity (%)			Saturated hydraulic conductivity (10 ⁻⁶ MS ⁻¹)		
	Plant	Ratoon	Mean	Plant	Ratoon	Mean	Plant	Ratoon	Mean	Plant	Ratoon	Mean
Irrigation												
I ₁	49.19	47.82	48.50	2.22	2.25	2.24	47.02	47.89	47.45	1.24	1.28	1.26
I ₂	49.67	48.02	48.84	2.23	2.38	2.31	46.91	47.28	47.09	1.39	1.44	1.42
I ₃	50.67	49.22	49.94	2.49	2.54	2.52	47.49	47.81	47.65	1.39	1.44	1.42
CD(0.05)	0.49	0.76	0.49	0.03	0.03	0.03	0.43	0.44	0.29	0.02	0.02	0.02
Fertilizer												
F ₁	49.37	47.69	48.53	2.26	2.33	2.30	47.82	47.09	47.46	1.30	1.34	1.32
F ₂	50.24	48.34	49.29	2.28	2.45	2.37	48.07	47.75	47.91	1.39	1.43	1.41
F ₃	49.91	49.02	49.47	2.39	2.40	2.40	47.52	48.37	47.95	1.33	1.39	1.36
CD(0.05)	0.49	0.76	0.49	0.03	0.03	0.03	0.43	0.44	0.29	0.02	0.02	0.02
Irrigation x Fertilizer												
I ₁ F ₁	48.87	46.98	47.92	2.12	2.19	2.15	47.81	46.49	47.15	1.10	1.16	1.13
I ₁ F ₂	49.27	48.16	48.71	2.16	2.28	2.22	47.97	48.47	48.22	1.34	1.33	1.34
I ₁ F ₃	49.42	48.31	48.87	2.38	2.30	2.34	47.90	48.73	48.31	1.29	1.35	1.32
I ₂ F ₁	48.96	47.00	47.98	2.18	2.24	2.21	48.07	47.17	47.62	1.33	1.36	1.34
I ₂ F ₂	50.20	48.45	49.33	2.25	2.50	2.38	48.09	47.90	48.00	1.45	1.50	1.47
I ₂ F ₃	49.85	48.60	49.22	2.26	2.41	2.33	47.57	48.28	47.92	1.41	1.45	1.43
I ₃ F ₁	50.29	49.10	49.69	2.49	2.56	2.52	47.59	47.62	47.61	1.48	1.50	1.49
I ₃ F ₂	51.24	48.40	49.82	2.45	2.56	2.50	48.14	47.33	47.74	1.40	1.45	1.42
I ₃ F ₃	50.47	50.16	50.31	2.54	2.50	2.52	47.10	48.11	47.61	1.29	1.38	1.33
CD(0.05)	NS	NS	NS	0.05	0.05	0.05	NS	0.76	0.50	0.04	0.04	0.04
Drip	49.84	48.35	49.10	2.31	2.39	2.35	47.85	47.81	47.83	1.34	1.39	1.36
Surface	48.02	47.81	47.92	2.09	2.19	2.14	46.97	46.91	46.94	1.21	1.26	1.24
CD(0.05)	0.64	NS	0.63	0.04	0.04	0.03	0.56	NS	0.37	0.03	0.03	0.03

NS: Not significant

Conclusions

Drip fertigation is found to be the best option in sustaining the physicochemical properties of soil by improving the pH, EC, organic carbon, water holding capacity, permeability, porosity and saturated hydraulic conductivity of soil in comparison with conventional surface irrigation and soil fertilization. The environment generated by drip fertigation is conducive for maintaining the optimum level of water and nutrients in soil which is likely to increase the fruit yield, water and nutrient productivity of banana crop.

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