academicJournals

Vol. 9(12), pp. 872-879, 25 March, 2015
DOI: 10.5897/AJMR2015.7378
Article Number: 499F5E751856
ISSN 1996-0808

http://www.academicjournals.org/AJMR

African Journal of Microbiology Research

Full Length Research Paper

Trickle and micro sprinkler fertigation on soil microbial population in cocoa (*Theobroma cacao* L.)

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Received 12 January, 2015; Accepted 13 March, 2015

Cocoa, the 'Food of Gods' is one of the important plantation crops consumed worldwide and around 40 - 50 million people depend on cocoa for their livelihood. An experiment was conducted during 2010 and 2011 to investigate the impact of N, P and K fertilizers through fertigation on soil microbial population of cocoa at Tamil Nadu Agricultural University, India. The study was laid out in randomized block design with 13 treatment combinations. The study shows that, fertigation with 125% recommended fertilizer dose as water soluble fertilizer through fertigation by micro sprinkler irrigation (T_{10}) had the highest soil bacterial population (60.10×10^{-6} CFU g^{-1}), fungal population (16.61×10^{-4} CFU g^{-1}) and actinomycetes population (8.07×10^{-3} CFU g^{-1}). The same treatment recorded higher yield characters viz., beans per pod (47.81), bean length (2.47 cm), bean girth (3.57 cm), single bean wet weight (3.15 g), single bean dry weight (1.31 g), dry bean weight per pod (62.23 g), dry bean yield per tree (3273.63 g).

Key words: Fertigation, drip irrigation, micro sprinkler irrigation, bacteria, fungi, actinomycetes.

INTRODUCTION

Cocoa is cultivated mainly in Africa, Asia, Central America and South America and major cocoa producing countries are Ivory Coast, Ghana, Indonesia, Nigeria, Cameroon, Brazil, Ecuador and Malaysia. The annual production is around 4.8 million tonnes with an estimated value of $ 8.3 billion (World Cocoa Foundation, 2012). Ivory Coast leads in production occupying 38% of total world cocoa production followed by Ghana (21%), Indonesia (13%), Nigeria (5%), Cameroon (5%), Brazil (4%), Ecuador (3%), Malaysia (1%) and others (10%). West Africa alone contributes nearly 70% of the world cocoa production (World Cocoa Foundation, 2011).

India offers considerable scope for cocoa cultivation, production and further development. Though cocoa has been known as the beverage crop even before tea and coffee, it is a relatively new crop to India. Cocoa is inter-cropped in coconut and arecanut and is a good companion to these crops. Cocoa readily responds to applied fertilizers to meet its nutrient requirements (Armando et al., 2001; Owusu et al., 2010).

Fertigation ensures 40% higher fertilizer use efficiency than the surface irrigation, besides providing scope for making soil amendments and even biological methods of plant protection. In the fertigation method, fertilizers can be applied throughout the crop growing season in a phased manner, in various split doses, in any desired

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concentration. This is in contrast to the conventional practice where larger amounts of fertilizers are placed on the soil at the beginning of the season in one or very few split doses (Dangler and Locascio, 1990; Kadam and Karthikeyan, 2006). Many countries have recognized fertigation to usher a second Green Revolution for enhancing productivity (Beard, 2000).

Through fertigation, nutrients are added to the soil in adequate doses and intervals through which a qualitative improvement of produce can also be attained. Production of quality beans in cocoa (single bean weight of more than 2 g) will enable the farmers to earn more income. Being relatively demanding in terms of soil fertility, cocoa requires frequent doses of fertilizers coupled with soil moisture to utilize the nutrients more effectively (Noordiana et al., 2007; Soumya et al., 2012). Drip and micro sprinkler irrigation are innovative approaches to precisely meet the water requirements of many crops (Selvaraj et al., 1997; Salo et al., 2000; Gupta et al., 2012).

In Tamil Nadu, a dose of 100:40:140 g NPK tree^{-1} year^{-1} is generally recommended for cocoa (Anonymous, 2004). The tap roots (1.2 m deep) in cocoa act as physical support and only lateral roots (20 - 30 cm) absorb the nutrients. As cocoa is very sensitive to moisture stress and water logging, irrigation should be at its optimum level for better growth.

The fertility of soil depends not only on its chemical composition but also on the qualitative and quantitative nature of microorganisms inhabiting it. Soil microorganisms in the rhizosphere influence the plant growth in many ways. Most of them play a role in the carbon, nitrogen, phosphorus and sulphur cycles and availability of certain trace elements like manganese, copper and iron in the soil. Some soil microbes act as antagonists for soil borne pathogens, thus aiding normal growth of plants. Besides, the soil microbes influence the permeability, water holding capacity and tilth of the soil (Balasubramanian, 2007; Govindan and Nair, 2011).

The present study was aimed to evaluate the fertigation system involving drip and sprinkler irrigation methods; various levels of fertilizers with a comparison of the farmers practice (surface irrigation + soil application of RDF) on soil microbial population in the rhizosphere of a cocoa plantation.

MATERIALS AND METHODS

Six year old cocoa trees were selected for the study. In a coconut plantation of 30 years old, the cocoa plants were intercropped with a spacing of 3 x 3 m. In case of drip irrigation, two emitters were installed with a discharging rate of 8 lph (litres per hour). Two micro sprinklers transmitting @ 60 lph micro sprinkler^{-1} were installed to cover the entire basin. The micro sprinkler type is half sub circle with a height of 30 cm and it has sprinkling capacity of 60 cm area (Figure 1). The venturi was used for mixing of fertilizer with water. The study was laid out in randomized block design with 13 treatment combinations replicated thrice (Table 1).

An annual application of 100 g N, 40 g P_2O_5 and 140 g K_2O through the mode of surface irrigation (T_1) is recommended for annual basis per tree in two splits (1st dose in 1st week of April and 2nd dose in 1st week of September). Surface irrigation was carried out once in seven day's interval. The fertilizers were applied through drip and micro sprinkler irrigation system (fertigation) at weekly intervals for drip and micro sprinkler treatments (T_2 to T_{13}) and the irrigation was carried out once in a day (20 L tree^{-1} day^{-1}). The rhizosphere soil sample from cocoa was analysed for bacteria, fungi and actinomycetes.

Serial dilution of soil sample

Ten grams of rhizosphere soil sample was transferred to 90 ml of sterile distilled water to get 10^{-1} dilution. After thoroughly mixing it, 1 ml of this dilution was transferred to 9 ml water blank to get 10^{-2} dilution. Likewise, sample was diluted serially with 9 ml water blanks till appropriate dilution was obtained (Srinivas et al., 2011).

Bacteria

The total bacterial population was enumerated by planting 1 ml of 10^{-6} dilution in sterile Petri plates using soil extract medium. The bacterial colonies appearing on the plates after 48 h of incubation at 30°C were counted and expressed per g of dry weight of the soil.

Fungi

For the enumeration of fungal population, 1 ml of 10^{-4} dilution of the soil sample was plated in sterile plate with potato dextrose agar medium. After 72 h of incubation, the fungal colonies were counted and expressed per g of dry weight of soil.

Actinomycetes

The total actinomycetes population was enumerated by plating 1 ml of 10^{-3} dilution with starch casein nitrate agar medium. The powdery colonies of actinomycetes appearing after 5 days were counted and expressed per gram of dry weight of soil.

RESULTS AND DISCUSSION

Data recorded on the soil bacterial populations during first and second season in 2010 and 2011 showed significant effect of the treatments applied. The highest bacterial population was registered by fertigation with 100% RDF as WSF using micro sprinkler (T_9) of 63.06 x 10^{-6} cfu g^{-1} soil and T_{11} (62.28 x 10^{-6} cfu g^{-1} soil) during first season in 2010 and 2011. The treatment T_{10} recorded highest bacterial population (66.76 and 62.40 x 10^{-6} cfu g^{-1} soil) during second season in 2010 and 2011. The lowest bacterial population was recorded in control (45.30 and 41.58 x 10^{-6} cfu g^{-1} soil, 34.38 and 39.08 x 10^{-6} cfu g^{-1} soil) during first and second season in 2010 and 2011 respectively (Table 2). Data on pooled mean (2010 and 2011) showed that, the highest soil bacterial population of 60.10 × 10^{-6} CFU g^{-1} was registered by T_{10} (125 % RDF as WSF through fertigation by drip irrigation) which was on par with T_9 (59.90 × 10^{-6} CFU g^{-1}). The

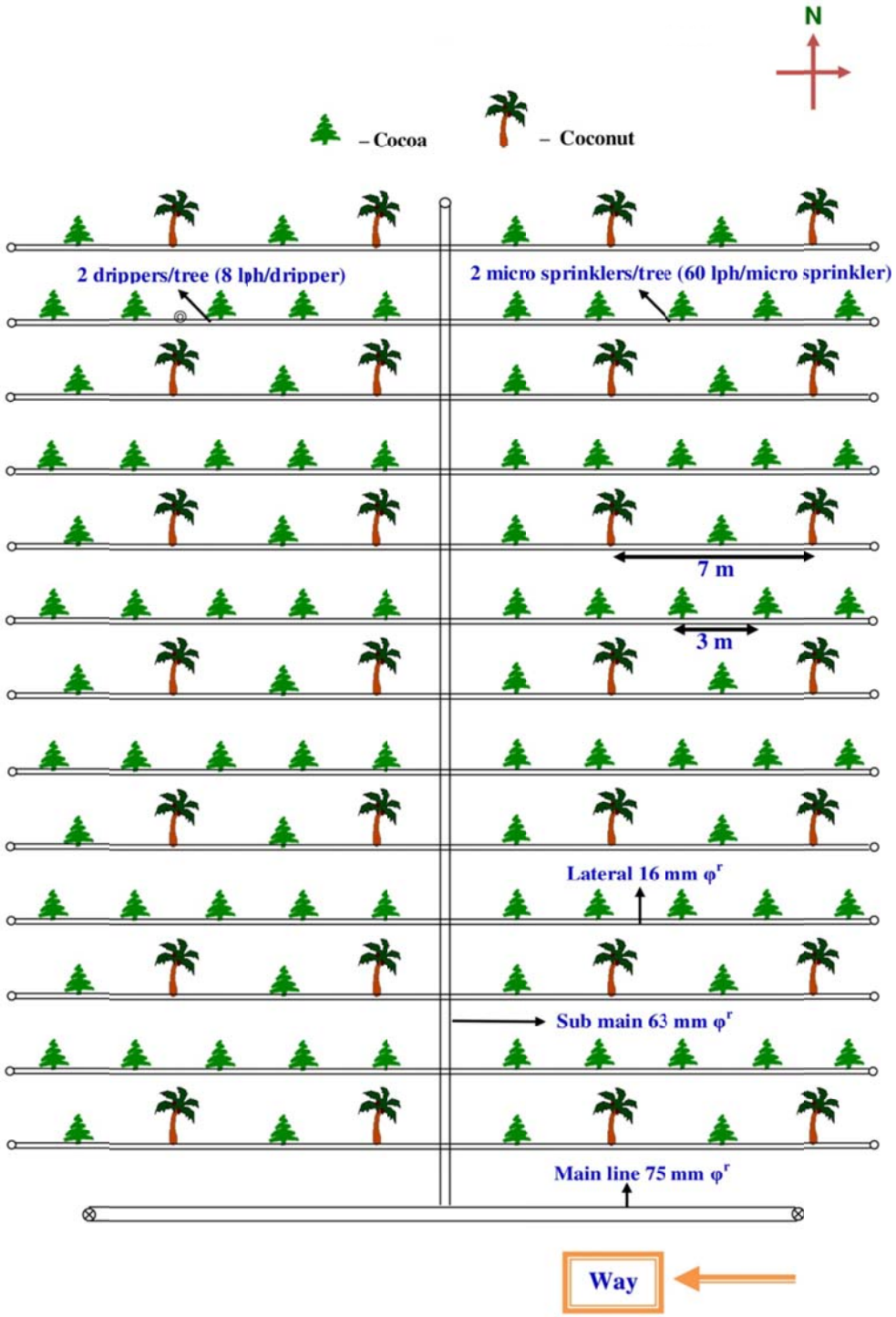

Figure 1. Lay out of drip and micro springer in cocoa.

lowest bacterial population was recorded in control (40.09 × 10^{-6} CFU g^{-1}) (Figure 2).

Significant difference was noticed among the treatments in relation to soil fungal population. The highest soil fungi population of 18.64 and 16.67 x 10^{-4} cfu g^{-1} soil was registered by T_{10} (125 % RDF as WSF through fertigation by micro sprinkler irrigation) during first season in 2010 and 2011 respectively. During second season in 2010 and 2011, the treatment T_9 registered highest soil fungi population of 18.72 and 17.08 x 10^{-4} cfu g^{-1} soil. The lowest fungal population was recorded in control (11.61 and 12.23 x 10^{-4} cfu g^{-1} soil, 10.52 and 11.76 x 10^{-4} cfu g^{-1}

Table 1. Treatment details of the experiment.

Treatment number	Dosage	Method of application / irrigation
T_1	100% RDF	Surface application + flood irrigation (control)
T_2	75% RDF as WSF	Drip
T_3	100% RDF as WSF	Drip
T_4	125% RDF as WSF	Drip
T_5	75% RDF as straight fertilizers	Drip
T_6	100% RDF as straight fertilizers	Drip
T_7	125% RDF as straight fertilizers	Drip
T_8	75% RDF as WSF	Micro sprinkler
T_9	100% RDF as WSF	Micro sprinkler
T_{10}	125% RDF as WSF	Micro sprinkler
T_{11}	75% RDF as straight fertilizers	Micro sprinkler
T_{12}	100% RDF as straight fertilizers	Micro sprinkler
T_{13}	125% RDF as straight fertilizers	Micro sprinkler

RDF, Recommended dose of fertilizer; WSF, water soluble fertilizer.

Table 2. Effect of drip and micro sprinkler fertigation on soil bacterial population ($\times 10^{-6}$ CFU g^{-1}) at various seasons.

Treatments	2010			2011			(Pooled analysis for the year 2010 and 2011)
	1st season	2nd season	Mean	1st season	2nd season	Mean	
T_1	45.30	41.58	43.44	34.38	39.08	36.73	40.09
T_2	49.48	45.31	47.40	45.91	40.31	43.11	45.26
T_3	47.92	49.69	48.81	45.64	44.94	45.29	47.05
T_4	54.37	51.27	52.82	43.07	48.62	45.85	49.34
T_5	48.11	40.38	44.25	40.68	39.19	39.94	42.10
T_6	56.68	49.14	52.91	47.17	42.74	44.96	48.94
T_7	45.76	55.02	50.39	49.35	41.68	45.52	47.96
T_8	57.43	52.19	54.81	55.29	52.27	53.78	54.30
T_9	63.06	56.00	59.53	61.00	59.53	60.27	59.90
T_{10}	52.45	66.76	59.61	58.76	62.40	60.58	60.10
T_{11}	56.28	52.13	54.21	62.28	56.96	59.62	56.92
T_{12}	50.16	56.94	53.55	59.46	50.72	55.09	54.32
T_{13}	55.12	52.55	53.84	60.11	49.85	54.98	54.41
SEd	0.976	1.029		1.140	1.041		0.998
CD (0.05)	2.014	2.123		2.353	2.148		2.059
CD (0.01)	2.745	2.893		3.206	2.927		2.806

soil) during first and second season in 2010 and 2011 respectively. Pooled mean data showed that the highest fungal population (Table 3) was registered by T_{13} (16.61× 10^{-4} CFU g^{-1}), followed by T_9 (16.38 × 10^{-4} CFU g^{-1}). The lowest population was recorded in T_1 (11.53× 10^{-4} CFU g^{-1}) (Figure 3).

Soil actinomycetes were significantly influenced by the different treatments during both the years. During first and second season in 2010, the actinomycetes colonies were found to be at a higher level (8.42 and 8.13 x 10^{-3} cfu g^{-1} soil) when the plants were fertigated with micro sprinklers with 100 % RDF as WSF (T_9). The treatment T_{10} recorded the highest actinomycetes population of 9.10 and 8.65 x 10^{-3} cfu g^{-1} soil during first and second season in 2011. The lowest population (3.07 and 3.98 x 10^{-3} cfu g^{-1} soil, 4.04 and 3.16 x 10^{-3} cfu g^{-1} soil) was recorded in control during first and second season in 2010 and 2011 respectively (Table 4). Pooled mean values showed that T_{10} recorded the highest soil actinomycetes population (8.07 × 10^{-3} CFU g^{-1}). The trees which received 100 % RDF as soil application recorded lowest soil actinomycetes population (3.57 × 10^{-3} CFU g^{-1})

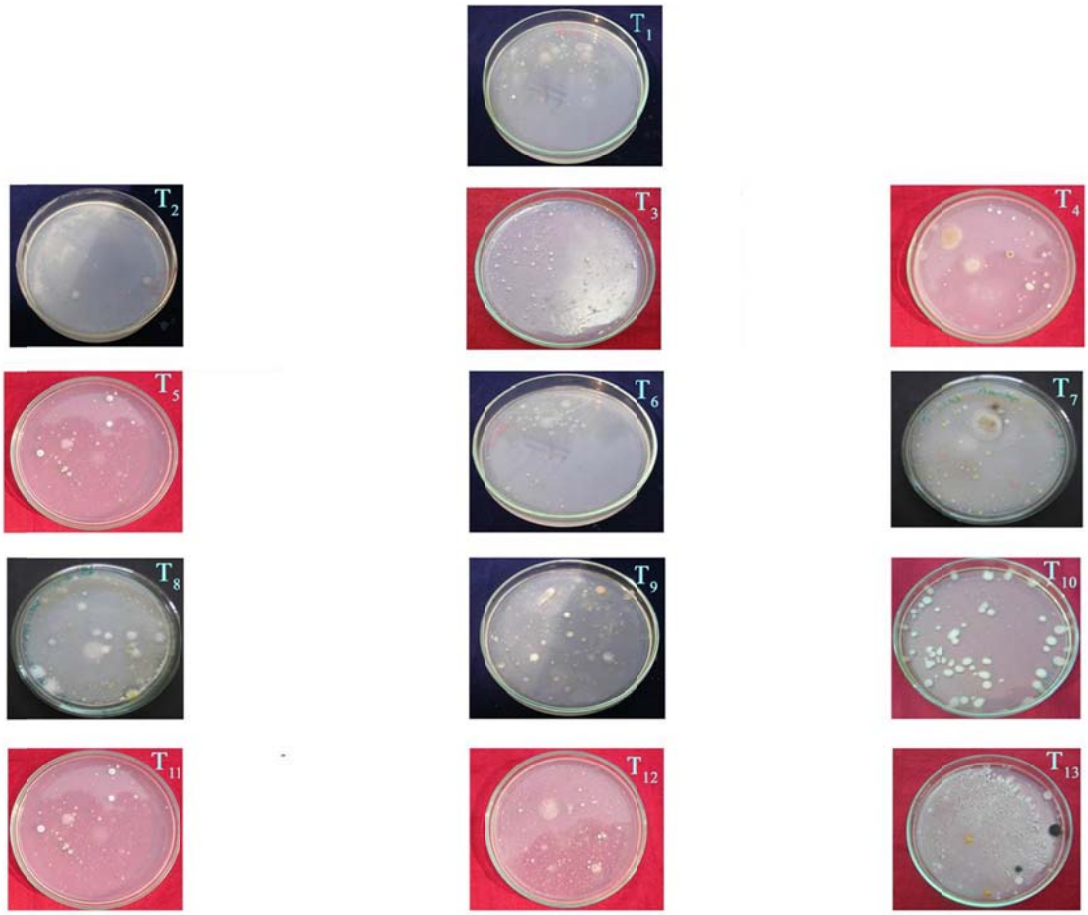

Figure 2. Effect of drip and micro sprinkler fertigation on bacterial population.

Table 3. Effect of drip and micro sprinkler fertigation on soil fungal population (× 10^{-4} CFU g^{-1}) at various seasons.

Treatments	2010			2011			(Pooled analysis for the year 2010 and 2011)
	1st season	2nd season	Mean	1st season	2nd season	Mean	
T_1	11.61	12.23	11.92	10.52	11.76	11.14	11.53
T_2	15.05	14.81	14.93	15.66	14.28	14.97	14.95
T_3	12.32	15.39	13.86	12.79	13.37	13.08	13.47
T_4	16.84	15.74	16.29	14.31	12.51	13.41	14.85
T_5	12.19	13.52	12.86	11.76	13.00	12.38	12.62
T_6	14.00	16.36	15.18	10.93	13.68	12.31	13.75
T_7	15.63	14.03	14.83	14.07	11.78	12.93	13.88
T_8	16.86	17.68	17.27	13.39	14.33	13.86	15.57
T_9	15.27	18.72	17.00	14.44	17.08	15.76	16.38
T_{10}	17.28	16.96	17.12	15.30	16.89	16.10	16.61
T_{11}	16.53	14.22	15.38	15.29	14.32	14.81	15.10
T_{12}	16.06	16.41	16.24	14.52	15.14	14.83	15.54
T_{13}	18.64	12.39	15.52	16.67	14.46	15.57	15.55
SEd	0.311	0.319		0.277	0.271		0.269
CD (0.05)	0.642	0.659		0.571	0.559		0.554
CD (0.01)	0.875	0.898		0.779	0.762		0.756

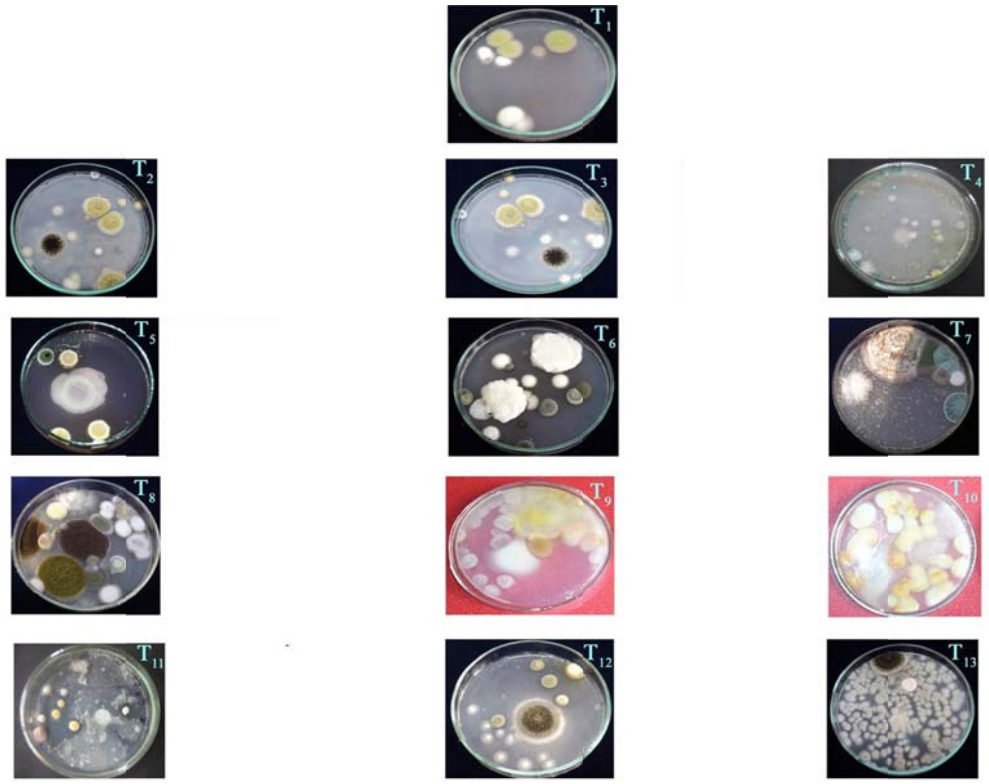

Figure 3. Effect of drip and micro sprinkler fertigation on fungal population.

Table 4. Effect of drip and micro sprinkler fertigation on soil actinomycetes population (× 10^{-3} CFU g^{-1}) at various seasons.

Treatments	2010			2011			(Pooled analysis for the year 2010 and 2011)
	1st season	2nd season	Mean	1st season	2nd season	Mean	
T_1	3.07	3.98	3.53	4.04	3.16	3.60	3.57
T_2	3.51	4.82	4.17	6.28	7.02	6.65	5.41
T_3	5.50	3.99	4.75	6.49	5.38	5.94	5.35
T_4	4.50	6.12	5.31	8.16	6.14	7.15	6.23
T_5	6.34	4.50	5.42	5.51	4.82	5.17	5.30
T_6	6.89	4.65	5.77	6.69	5.93	6.31	6.04
T_7	4.97	6.44	5.71	8.34	7.50	7.92	6.82
T_8	7.18	4.77	5.98	7.85	5.47	6.66	6.32
T_9	8.42	8.13	8.28	7.09	8.22	7.66	7.97
T_{10}	7.58	6.92	7.25	9.10	8.65	8.88	8.07
T_{11}	6.84	6.38	6.61	8.56	6.07	7.32	6.97
T_{12}	6.06	7.15	6.61	6.16	5.94	6.05	6.33
T_{13}	7.10	7.67	7.39	7.49	6.00	6.75	7.07
SEd	0.166	0.155		0.167	0.160		0.146
CD (0.05)	0.343	0.321		0.344	0.330		0.301
CD (0.01)	0.468	0.437		0.469	0.450		0.409

(Figure 4).

In the present study, micro sprinkler irrigation had more significant influence on soil microbial population than drip irrigation. In micro sprinkler irrigation, the leaf litter was decomposed quickly by water sprinkled on leaf litter along the tree basin. The decomposed plant residue in

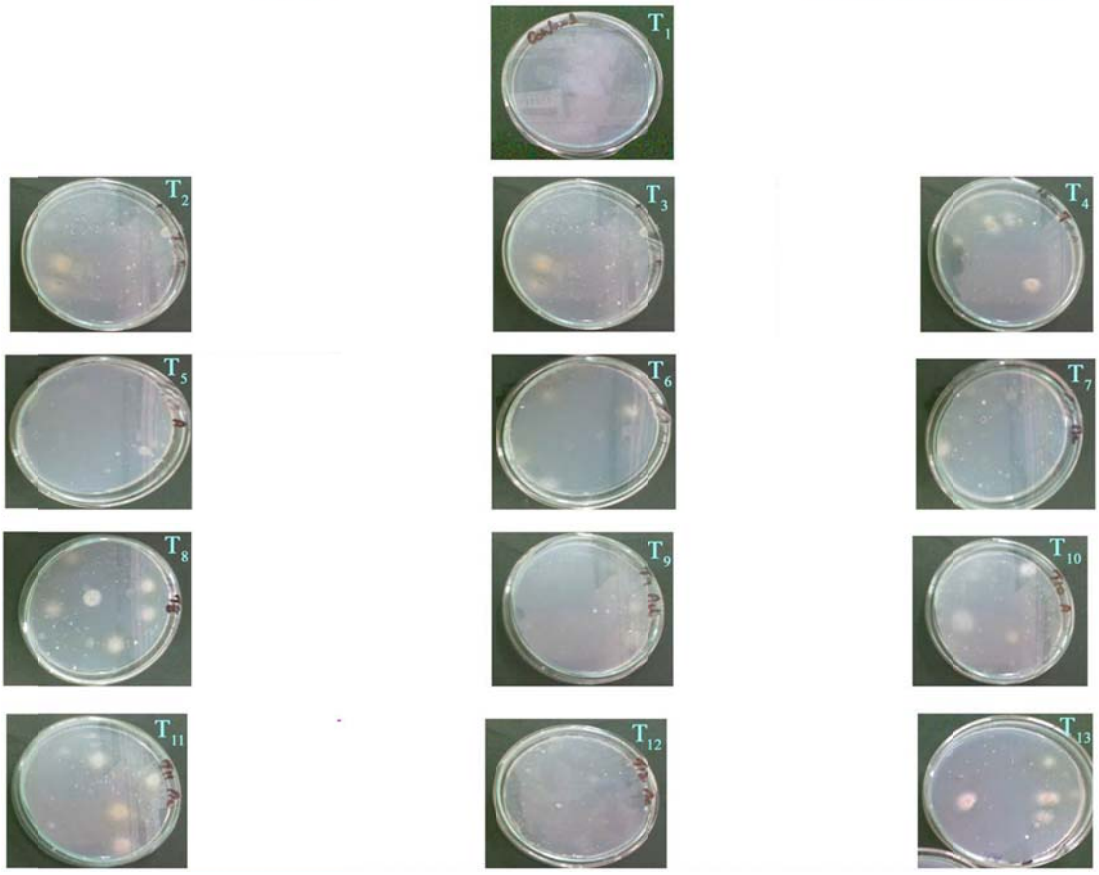

Figure 4. Effect of drip and micro sprinkler fertigation on actinomycetes population.

the tree basin would have been helpful for microbial growth (Hebbar et al., 2010; Shobana et al., 2012). In contrast, in the drip irrigated plots, water applied slowly directly to the soil rather not sprayed in the tree basin. These findings are supported by Shivanand (2003) in tomato and Nguyen (2003) who reported that high above ground biomass yield are obviously accompanied by an active root system, which releases an array of organic compounds into the rhizosphere. Plant roots release about 17% of the photosynthate captured, most of which is available to soil organisms. These compounds support the growth of the microbial community and result in dense population in micro sprinkler fertigation plot over the other systems of fertilization.

Conclusions

Fertigation studies on cocoa through micro sprinkler irrigation with a dose of 100 or 125% RDF as water soluble fertilizer (WSF) has shown to increase the soil bacterial population (60.10×10^{-6} CFU g^{-1}), fungal population (16.61×10^{-4} CFU g^{-1}) and actinomycetes population (8.07×10^{-3} CFU g^{-1}) respectively. It can be concluded that, application of 100 or 125% RDF as water soluble fertilizer (WSF) through micro sprinklers increases microbial growth, nutrient transformations inside the roots, degrade biomass and destroy xenobiotic contaminants (such as residual herbicides).

Conflict of interests

The authors did not declare any conflict of interest.

ACKNOWLEDGEMENTS

We acknowledged the Cadbury India *Ltd*. for affording financial support and Jain Irrigation System *Ltd*. for providing drip and micro sprinkler irrigation system for this study.

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