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Effect of Fertigation through Drip and Micro Sprinkler on Plant Biometric Characters in Cocoa (*Theobroma cacao* L.)

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Abstract: A field experiment to study the influence of fertigation of N, P and K fertilizers on biometric characters of cocoa (*Theobroma cacao* L.) was conducted at the Department of Spices and Plantation Crops, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore during January 2010 to December 2011. The experiment was laid out with thirteen treatments replicated three times in a randomized block design. A phenomenal increase in growth parameters such as trunk girth, canopy spread and weight of the pruned branches removed, leaf fresh weight and leaf dry weight was observed with increasing levels of NPK as well as methods of fertilizer application in this study. Among the various treatments, fertigation with 125% 'Recommended Dose of Fertilizers' (125:50:175 g NPK plant year^{-1}) as Water Soluble Fertilizers (WSF) through drip irrigation increased all vegetative growth parameters like trunk girth increment (1.62 cm), canopy spread increment (66.79 cm), leaf fresh weight (3.949 g), leaf dry weight (2.039 g), weight of the pruned branches removed (fresh weight 7.628 kg plant^{-1}) and dry weight (4.650 kg plant^{-1}).

Key words: Fertigation, drip irrigation, microsprinkler irrigation, water soluble fertilizers, straight fertilizers

INTRODUCTION

Cocoa (*Theobroma cacao* L.) the 'Food of Gods' is one of the most important plantation crops consumed worldwide and around 40-50 million people depend on cocoa for their livelihood. 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 3 million tonnes with an estimated value of $ 5.1 billion. 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.

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 relatively a new crop to India. Cocoa is intercropped in coconut and arecanut and is a good companion to these crops. Four states viz., Kerala Andhra Pradesh, Tamil Nadu and Karnataka share the major cocoa production in India. The current area is estimated to be 46, 318 ha with production of 12, 954 MT. The national productivity is 550 kg dry beans per ha. Kerala leads in production with an area of 11, 044 hectares contributing 6344 MT of cocoa beans w ith a productivity of 592 kg per hectare. Tamil Nadu occupies third in cocoa cultivation and the area reported under this crop is 15,000 ha with an annual production of 350 MT (Elain Apshara *et al*., 2009).

More than 80% of active roots in cocoa are located within the radius of 30-60 cm, surface application of the required fertilizers are to be applied between 30-60 cm distance from the main trunk under conventional system of irrigation. Such spot application of fertilizers often leads to mismatch in meeting the nutrient requirement of the crop as many physical processes such as leaching, runoff, volatilization etc. leads to loss of applied nutrients besides affecting the environment. Fertigation has come in handy for this purpose. Fertigation not only supplies nutrients precisely and timely, it also leads to monetary gain and provide ecological safety by avoiding pollution of ground water resources (Patel and Rajput, 2000).

In Tamil Nadu, a dose of 100:40:140 g NPK tree year^{-1} is generally recommended (Anonymous, 2004) for cocoa. The tap roots (1.2 m deep) in cocoa acts as physical support and only lateral roots (20-30 cm) absorbs the moisture and nutrients. As cocoa is very sensitive to moisture stress and water logging, irrigation should be at its optimum level for better growth. Hence, the present study was aimed to evaluate the fertigation system involving drip, sprinkler irrigation methods; various levels of fertilizers with a comparison on the farmers practice (surface irrigation+soil application of RDF) on biometric characters of cocoa.

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MATERIALS AND METHODS

The age of cocoa trees selected for the study was six years which were intercropped with coconut of 30 years old. Cocoa was spaced at 10×10 feet (3×3 m) between the two rows of coconut. Besides, one cocoa plant was planted in between two coconut trees within the coconut row. The population of cocoa trees maintained were at 500 plants per ha. Flowering in cocoa was throughout the year and two peak harvest seasons viz., March to May and September to November were observed. Among these two seasons, March-April (flowering) to July (pod harvest) season is considered as lean cropping period while September (flowering) to December (pod harvest) season is considered as peak cropping period. Based on these observations on the fruiting behaviour, the fertigation treatments were scheduled to study its effect on yield and quality of cocoa. A cultural practice for cocoa was followed as per the package of practices standardized by Tamil Nadu Agricultural University for managing the crop except for the fertigation treatments envisaged in the study (Anonymous, 2004).

The drip line was laid out as per the spacing of cocoa trees i.e., 10×10 feet (3×3 m). For each tree in case of drip irrigation, two drippers were installed at 8 lph dripper^{-1}. Two half sub circle micro sprinklers were installed per tree at 60 lph micro sprinkler^{-1} to cover the entire basin. The micro sprinkler type was half sub circle with a height of 30 cm and it sprinkled an area of 60 cm. A venturi assembly was used for mixing fertilizer with irrigation water. Based on the water requirement of cocoa trees (20 litres tree day^{-1}), the duration of irrigation was worked out.

The experiment was laid out in Randomized Block Design (RBD) with thirteen treatments replicated thrice. The age of the trees was six years and the total number of trees in the experimental block was three hundred and ninety. The details of the treatments are as follows, T_1-Control-100% of RDF as surface application (100:40:140 g NPK plant year^{-1}) with flood irrigation, T_2-75% RDF as WSF through fertigation by drip irrigation, T_3-100% RDF as WSF through fertigation by drip irrigation, T_4-125% RDF as WSF through fertigation by drip irrigation, T_5-75% RDF as straight fertilizers through fertigation by drip irrigation, T_6-100% RDF as straight fertilizers through fertigation by drip irrigation, T_7-125% RDF as straight fertilizers through fertigation by drip irrigation, T_8-75% RDF as WSF through fertigation by micro sprinkler irrigation, T_9-100% RDF as WSF through fertigation by micro sprinkler irrigation, T_{10}-125% RDF as WSF through fertigation by micro sprinkler irrigation, T_{11}-75% RDF as straight fertilizers through fertigation by micro sprinkler irrigation, T_{12}-100% RDF as straight fertilizers through fertigation by micro sprinkler irrigation, T_{13}-125% RDF as straight fertilizers through fertigation by micro sprinkler irrigation.

For surface application and irrigation (T_1), an annual application of 100 g N, 40 g P_2O_5 and 140 g K_2O year^{-1} r in two split doses was made as per recommendation. The fertilizers were applied in two equal splits, the first dose in first week of April and the second dose in first week of September. Surface irrigation was done once in seven days interval. For drip and micro sprinkler treatments (T_2 to T_{13}), the fertilizers were applied through drip and micro sprinkler irrigation system (fertigation). Weighed quantity of fertilizers as per schedule was dissolved in water and then injected to sub-main through venturi and then to lateral lines as per the treatment. Drip and micro sprinkler irrigation was resorted once in a day. The fertilizers were applied through drip and micro sprinkler irrigation at weekly intervals.

Observations were taken from five randomly selected trees for each treatment. Observations on trunk girth, tree spread (East-West and North-South), leaf fresh weight and leaf dry weight were recorded at two stages per season viz., pod set stage and pod maturity and harvest stage. At pruning time, the fresh and dry weights of pruned branches removed were also recorded. For individual leaf measurements and analyzing leaf nutrient concentrations, the fourth leaf from the apex of matured branch was taken as indicator leaf (15 leaves per tree) as this is the most active part of the cocoa plant that absorbs nutrient from the soil (Denamany and Rosinah, 1994).

RESULTS

Trunk girth: The treatment T_4 (125 per cent 'Recommended Dose of Fertilizers' (RDF) as WSF through fertigation) registered the highest increment in trunk girth (1.29 and 1.95 cm during 2010 and 2011, respectively) which was followed by T_3 (1.28 and 1.81 cm during 2010 and 2011). The control (T_1-100 per cent RDF as surface application) registered the lowest trunk girth increment of 0.95 and 1.40 cm during 2010 and 2011, respectively (Table 1). Pooled mean values of 2010 and 2011 showed that fertigation with 125 percent RDF as WSF through drip irrigation (T_4) recorded highest increase in trunk girth per year (1.62 cm). It was followed by T_3 (1.55 cm) and the lowest value was recorded in T_1 (1.18 cm).

Canopy spread (cm): The increment in canopy spread ranged from 43.95 (T_1) to 75.47 cm (T_4) and 41.92 (T_1) to 61.85 cm (T_4) in first and second season during 2010 (Table 2). During 2011, the increment ranged from 46.48 (T_1) to 62.47 cm (T_4) and 45.92 (T_1) to 67.37 cm (T_4) in first and second season (Table 3). Pooled mean data showed that, T_4 recorded maximum increment in canopy spread

Table 1: Effect of drip and micro sprinkler fertigation on increment in trunk girth (cm) of cocoa at various growth stages

	2010					2011					
	1st season		2nd season			1st season		2nd season			
Treatments	Pod set stage	Pod maturity and harvest stage	Pod set stage	Pod maturity and harvest stage	Total increase in girth	Pod set stage	Pod maturity and harvest stage	Pod set stage	Pod maturity and harvest stage	Total increase in girth	Pooled analysis 2010-11
T_1	28.300	28.64 (0.34)	28.94 (0.30)	29.25 (0.31)	0.95	29.61 (0.36)	30.06 (0.45)	30.37 (0.31)	30.65 (0.28)	1.40	1.1800
T_2	29.470	29.89 (0.42)	30.27 (0.38)	30.71 (0.44)	1.24	34.10 (0.43)	34.58 (0.48)	35.05 (0.47)	35.36 (0.31)	1.69	1.4700
T_3	32.390	32.82 (0.43)	33.19 (0.37)	33.67 (0.48)	1.28	31.16 (0.45)	31.68 (0.52)	32.10 (0.42)	32.52 (0.42)	1.81	1.5500
T_4	33.280	33.73 (0.45)	34.15 (0.42)	34.57 (0.42)	1.29	35.04 (0.47)	35.53 (0.49)	36.04 (0.51)	36.52 (0.48)	1.95	1.6200
T_5	31.840	32.23 (0.39)	32.62 (0.39)	33.01 (0.39)	1.18	32.21 (0.42)	32.66 (0.45)	32.99 (0.33)	33.38 (0.39)	1.59	1.3900
T_6	34.460	34.88 (0.42)	35.22 (0.34)	35.63 (0.41)	1.17	33.46 (0.45)	33.97 (0.51)	34.36 (0.39)	34.78 (0.42)	1.77	1.4700
T_7	30.570	30.98 (0.41)	31.33 (0.35)	31.79 (0.46)	1.22	36.09 (0.46)	36.54 (0.45)	36.94 (0.40)	37.40 (0.46)	1.77	1.5000
T_8	28.000	28.40 (0.40)	28.80 (0.40)	29.14 (0.34)	1.14	29.56 (0.42)	29.91 (0.35)	30.35 (0.44)	30.66 (0.31)	1.52	1.3300
T_9	29.710	30.08 (0.37)	30.45 (0.37)	30.84 (0.39)	1.13	31.21 (0.37)	31.64 (0.43)	32.01 (0.37)	32.39 (0.38)	1.55	1.3400
T_{10}	33.110	33.49 (0.38)	33.87 (0.38)	34.30 (0.43)	1.19	34.72 (0.42)	35.11 (0.39)	35.40 (0.29)	35.82 (0.42)	1.52	1.3600
T_{11}	30.800	31.19 (0.39)	31.52 (0.33)	31.72 (0.27)	0.99	32.13 (0.41)	32.59 (0.46)	32.91 (0.32)	33.27 (0.36)	1.55	1.2700
T_{12}	29.580	29.98 (0.40)	29.96 (0.38)	30.22 (0.26)	1.04	30.54 (0.32)	31.01 (0.47)	31.37 (0.36)	31.84 (0.47)	1.62	1.3300
T_{13}	32.360	32.75 (0.39)	33.11 (0.36)	33.50 (0.39)	1.13	33.84 (0.34)	34.19 (0.35)	34.65 (0.46)	35.09 (0.44)	1.59	1.3700
SEd	0.5235	0.0067000	0.0064000	0.0081000		0.0076000	0.0084000	0.0086000	0.0085000		0.0243
CD (0.05)	1.0805	0.0138000	0.0132000	0.0167000		0.0157000	0.0174000	0.0178000	0.0176000		0.0501

Values in parenthesis indicate the increase in trunk girth compared to previous stage and season (cm)

Table 2: Effect of drip and micro sprinkler fertigation on increment in canopy spread (cm) of cocoa at various growth stages

	2010									
	1st season					2nd season				
	Pod set stage		Pod maturity and harvest stage			Pod set stage		Pod maturity and harvest stage		
Treatments	N/S	E/W	N/S	E/W	Total spread (N/S+E/W)	N/S	E/W	N/S	E/W	Total spread (N/S+E/W)
T_1	290.73	269.15	313.61 (22.88)	290.22 (21.07)	43.95	295.14	274.27	318.22 (23.08)	303.11 (18.84)	41.92
T_2	315.08	281.39	343.42 (28.34)	311.84 (30.45)	58.79	322.58	270.54	352.36 (29.78)	297.95 (27.41)	61.56
T_3	340.82	336.36	370.91 (30.09)	371.34 (34.98)	65.07	330.03	300.78	361.55 (31.07)	331.11 (30.33)	61.40
T_4	384.19	351.00	421.03 (36.84)	389.63 (38.63)	75.47	319.66	337.83	353.65 (30.07)	369.61 (31.78)	61.85
T_5	360.75	274.15	387.00 (26.25)	302.72 (28.57)	54.82	342.97	289.05	371.71 (28.74)	308.46 (19.41)	48.15
T_6	291.74	300.51	316.22 (24.48)	331.22 (30.71)	55.19	319.56	320.56	346.56 (27.00)	345.74 (25.18)	52.18
T_7	307.94	349.67	336.42 (28.48)	380.92 (31.25)	59.73	300.11	311.00	325.71 (25.60)	343.47 (32.47)	58.07
T_8	351.63	323.61	380.69 (29.06)	341.69 (18.08)	46.57	352.65	285.77	377.29 (24.64)	313.22 (27.45)	52.09
T_9	281.77	305.49	310.26 (28.49)	332.81 (27.32)	56.38	299.74	325.14	329.73 (29.99)	351.92 (26.78)	56.77
T_{10}	309.15	346.75	337.23 (28.08)	377.00 (30.25)	58.33	299.87	314.29	331.29 (31.42)	343.96 (29.67)	61.09
T_{11}	331.86	294.08	355.04 (23.18)	323.36 (29.28)	52.46	297.37	345.28	316.65 (19.28)	369.33 (24.05)	43.33
T_{12}	284.15	338.40	311.32 (27.17)	367.22 (28.82)	55.99	334.53	270.13	358.88 (24.35)	301.64 (31.51)	55.86
T_{13}	320.05	335.30	348.48 (28.43)	370.69 (35.39)	63.82	322.78	308.66	349.25 (26.47)	338.70 (30.04)	56.51
SEd	5.5042	5.7485	0.5409	0.6686		5.1321	5.3326	0.5491	0.5855	
CD (0.05)	11.3602	11.8645	1.1164	1.3799		10.5920	11.0061	1.1333	1.2084	

Values in parenthesis indicate the increase in tree spread compared to previous stage (cm)

Table 3: Effect of drip and micro sprinkler fertigation on increment in canopy spread (cm) of cocoa at various growth stages

	2010										
	1st season					2nd season					
	Pod set stage		Pod maturity and harvest stage			Pod set stage		Pod maturity and harvest stage			Pooled analysis 2010-11
Treatments	N/S	E/W	N/S	E/W	Total spread (N/S+E/W)	N/S	E/W	N/S	E/W	Total spread (N/S+E/W)	
T_1	292.36	277.22	314.51 (22.15)	301.55 (24.33)	46.48	287.16	312.33	308.36 (21.20)	337.05 (24.72)	45.92	44.57
T_2	289.81	280.30	317.07 (27.26)	312.49 (32.19)	59.45	302.66	241.87	327.97 (25.31)	272.88 (31.01)	56.32	59.03
T_3	303.82	289.61	326.51 (22.69)	328.87 (39.26)	61.95	382.19	319.27	416.48 (34.29)	344.26 (24.99)	59.28	61.93
T_4	297.05	263.11	331.07 (34.02)	291.56 (28.45)	62.47	299.14	389.13	326.76 (27.62)	428.88 (39.75)	67.37	66.79
T_5	290.32	343.71	315.91 (25.59)	366.25 (22.54)	48.13	267.32	324.18	276.42 (22.99)	350.18 (26.00)	46.52	49.41
T_6	285.46	291.50	309.58 (24.12)	322.50 (31.00)	55.12	289.10	300.97	291.99 (24.67)	330.19 (29.22)	53.89	54.10
T_7	330.64	270.85	356.86 (26.22)	301.14 (30.29)	56.51	253.43	371.66	315.48 (26.38)	400.30 (28.64)	55.02	57.33
T_8	296.51	291.36	316.62 (20.11)	323.78 (32.42)	52.53	292.62	301.70	313.14 (20.52)	330.41 (28.71)	51.70	50.72
T_9	287.37	275.09	319.56 (32.19)	300.08 (24.99)	57.18	263.29	298.28	285.48 (22.19)	329.02 (30.74)	52.93	55.82
T_{10}	312.07	271.89	341.61 (29.54)	300.50 (28.61)	61.41	326.39	274.00	359.48 (33.09)	300.50 (26.50)	59.59	60.11
T_{11}	286.54	312.20	309.76 (23.22)	344.07 (31.87)	51.83	301.44	283.14	319.03 (17.59)	315.95 (32.81)	50.40	49.51
T_{12}	318.93	273.48	343.20 (24.27)	300.76 (27.28)	51.55	279.63	313.71	309.23 (29.60)	338.07 (24.36)	53.96	54.34
T_{13}	291.76	304.01	322.76 (31.00)	325.69 (21.68)	52.68	272.71	321.39	302.93 (30.22)	347.31 (25.92)	56.14	57.29
SEd	4.9361	4.9091	0.5606	0.6054		5.5350	5.9641	0.5979	0.5811		0.9978
CD (0.05)	10.1877	10.1313	1.1570	1.2495		11.4238	12.3093	1.2340	1.1994		2.0593

Values in parenthesis indicate the increase in tree spread compared to previous stage (cm)

(NS+EW) (66.79 cm) which was followed by T_3 (61.93 cm). The control (T_1) registered the lowest increment (44.57 cm).

Leaf weight (g): Among the different treatment combinations observed in two crop stages, fertigation with 125% RDF as WSF through drip irrigation (T_4) registered the highest mean fresh and dry leaf weight of 4.110 and 2.410 g during the first season and 3.874 and 2.041 g during second season of 2010, respectively (Table 4). During 2011 also, T_4 exhibited higher leaf fresh weight (3.916 and 3.897 g) and leaf dry weight (1.906 and 1.799 g) in first and second season (Table 5). Pooled data revealed that, fertigation with 125% RDF as WSF through drip irrigation (T_4) recorded highest leaf fresh weight and dry weight (3.949 and 2.039 g) which was followed by the treatment T_3 (3.813 and 1.911 g). The lowest fresh and dry weight of leaf was observed in T_1 (3.331 and 1.658 g).

Fresh and dry weight of pruned branches (kg plant^{-1}): During the first year (2010), the fresh weight of pruned branches ranged from 3.723 (T_1) to 4.860 kg plant^{-1} (T_4) and 2.351 (T_1) to 3.071 kg plant^{-1} (T_4) in first and second season, respectively. The dry weight in the same year ranged from 2.142 (T_1) to 3.167 kg plant^{-1} (T_4) and 1.261 (T_1) to 1.689 kg plant^{-1} (T_4) in first and second season (Table 6).

During 2011, T_4 registered the highest fresh weight in both the seasons (4.220 and 3.104 kg plant^{-1}, respectively). The dry weight of pruned branches ranged from 1.511 (T_1) to 2.871 kg plant^{-1} (T_4) in the first season, while the range in the second season was 1.197 (T_1) to 1.572 kg plant^{-1} (T_4). Pooled data revealed that fresh weight of pruned branches ranged from 5.634 (T_1) to 7.628 kg plant^{-1} (T_4) and the dry weight ranged from 3.056 (T_1) to 4.650 kg plant^{-1} (T_4). The second best treatment was T_3 (7.289 and 4.345 kg plant^{-1}). The overall mean performance in first and second season during 2010 and 2011 indicated the superior performance of T_4 which was followed by T_3.

DISCUSSION

Cocoa being a perennial crop, it has the dual function of maturing wood frame work for the crop and producing fresh cropping wood frame study for the succeeding year simultaneously. Hence, adequate attention should be given towards fulfilling its nutritional requirements for greater life span.

Trunk girth: Among the treatments, application of 125% RDF as WSF through fertigation by drip irrigation recorded the highest values for increment in stem girth during both the seasons while the lowest values were recorded by control. Increased uptake of nutrients particularly nitrogen under such precise fertigation system could be attributed to expansion of trunk girth. The absorbed nitrogen ultimately might have been utilized by the plants in the formation of complex substances like protein and amino acids which in turn help to build up new tissues (Dixit *et al.*, 2003). The supply of nutrients at adequate doses would have increased the synthesis of IAA stimulating the cell elongation and increasing the trunk girth.

Table 4: Effect of drip and micro sprinkler fertigation on leaf weight (g) of cocoa at various growth stages

	2010											
	1st season						2nd season					
	Pod set stage		Pod maturity and harvest stage		Mean		Pod set stage		Pod maturity and harvest stage		Mean	
Treatments	Fresh weight	Dry weight	Fresh weight	Dry weight	Fresh weight	Dry weight	Fresh weight	Dry weight	Fresh weight	Dry weight	Fresh weight	Dry weight
T_1	3.286	1.874	3.502	1.612	3.394	1.743	3.109	1.684	3.443	1.722	3.276	1.703
T_2	3.900	1.978	3.861	1.886	3.881	1.932	3.666	1.819	3.718	1.891	3.692	1.855
T_3	4.119	2.134	3.991	2.131	4.055	2.133	3.821	2.005	3.897	1.991	3.859	1.998
T_4	4.196	2.730	4.024	2.090	4.110	2.410	3.744	2.074	4.004	2.008	3.874	2.041
T_5	3.790	1.945	3.796	1.944	3.793	1.945	3.500	1.699	4.001	1.799	3.751	1.749
T_6	3.491	2.028	3.942	1.999	3.717	2.014	4.008	2.120	3.665	1.826	3.837	1.973
T_7	3.605	1.911	3.812	1.926	3.709	1.919	3.521	1.751	3.749	1.899	3.635	1.825
T_8	3.862	1.893	3.769	1.861	3.816	1.877	3.475	1.793	3.518	1.764	3.497	1.779
T_9	3.949	2.104	3.881	1.660	3.915	1.882	3.307	1.822	3.801	1.900	3.554	1.861
T_{10}	4.005	2.008	3.820	1.788	3.913	1.898	3.705	1.800	3.900	2.003	3.803	1.902
T_{11}	3.574	1.901	3.612	1.822	3.593	1.862	3.800	1.780	3.786	1.804	3.793	1.792
T_{12}	3.910	2.084	3.698	1.851	3.804	1.968	3.764	1.894	3.607	1.907	3.686	1.901
T_{13}	3.614	2.068	3.865	1.800	3.740	1.934	3.349	1.867	3.879	2.000	3.614	1.934
SEd	0.0641	0.0381	0.0617	0.0617		0.0613	0.0322	0.0597	0.0316			
CD (0.05)	0.1324	0.0785	0.1274	0.1274		0.1264	0.066	0.1232	0.0652			

Table 5: Effect of drip and micro sprinkler fertigation on leaf weight (g) of cocoa at various growth stages

	2011													
	1st season						2nd season							
	Pod set stage		Pod maturity and harvest stage		Mean		Pod set stage		Pod maturity and harvest stage		Mean		Pooled analysis (2010 and 2011)	
Treatments	Fresh weight	Dry weight	Fresh weight	Dry weight	Fresh weight	Dry weight	Fresh weight	Dry weight	Fresh weight	Dry weight	Fresh weight	Dry weight	Fresh weight	Dry weight
T_1	3.321	1.649	3.127	1.598	3.224	1.624	3.586	1.531	3.269	1.591	3.428	1.561	3.331	1.658
T_2	3.624	1.620	3.690	1.648	3.553	1.634	3.692	1.669	3.687	1.682	3.690	1.676	3.704	1.774
T_3	3.505	1.712	3.429	1.721	3.467	1.717	3.826	1.892	3.916	1.700	3.871	1.796	3.813	1.911
T_4	3.732	1.986	4.100	1.826	3.916	1.906	4.007	1.786	3.786	1.812	3.897	1.799	3.949	2.039
T_5	3.417	1.537	3.088	1.611	3.253	1.574	3.781	1.550	3.629	1.652	3.705	1.601	3.626	1.717
T_6	3.364	1.691	3.703	1.752	3.534	1.722	3.784	1.690	3.592	1.616	3.688	1.653	3.694	1.841
T_7	4.012	1.786	3.417	1.597	3.715	1.692	3.962	1.626	3.800	1.829	3.881	1.728	3.735	1.791
T_8	3.672	1.596	3.600	1.604	3.636	1.600	3.598	1.637	3.627	1.599	3.613	1.618	3.641	1.719
T_9	3.812	1.663	3.291	1.681	3.552	1.672	3.620	1.694	3.554	1.602	3.587	1.648	3.652	1.766
T_{10}	3.912	1.743	3.524	1.638	3.718	1.691	3.827	1.702	3.492	1.678	3.660	1.690	3.774	1.795
T_{11}	3.716	1.622	3.647	1.635	3.682	1.629	3.822	1.801	3.593	1.626	3.708	1.714	3.694	1.749
T_{12}	3.911	1.715	3.299	1.608	3.605	1.662	3.719	1.722	3.722	1.714	3.721	1.718	3.704	1.812
T_{13}	3.501	1.816	3.331	1.714	3.416	1.765	3.600	1.599	3.454	1.630	3.527	1.615	3.574	1.812
SEd	0.0606	0.0266	0.0602	0.0267		0.0604	0.0281	0.0602	0.0272		0.0592	0.0290		
CD (0.05)	0.1252	0.0549	0.1242	0.0551		0.1247	0.0581	0.1242	0.0561		0.1222	0.0599		

Table 6: Effect of drip and micro sprinkler fertigation on pruning (Leaves and twigs) (kg plant^{-1}) of cocoa at various growth stages

	2010						2011							
	1st season						2nd season							
	Pod set stage		Pod maturity and harvest stage		Mean		Pod set stage		Pod maturity and harvest stage		Mean		Pooled analysis (2010 and 2011)	
Treatments	Fresh weight	Dry weight	Fresh weight	Dry weight	Fresh weight	Dry weight	Fresh weight	Dry weight	Fresh weight	Dry weight	Fresh weight	Dry weight	Fresh weight	Dry weight
T_1	3.723	2.142	2.351	1.261	3.037	1.702	2.974	1.511	2.220	1.197	2.597	1.354	5.634	3.056
T_2	4.105	2.308	2.770	1.398	3.438	1.853	3.675	2.412	2.615	1.284	3.145	1.848	6.583	3.701
T_3	4.606	2.946	2.851	1.542	3.729	2.244	4.113	2.630	3.008	1.400	3.561	2.101	7.289	4.345
T_4	4.860	3.167	3.071	1.689	3.966	2.428	4.220	2.871	3.104	1.572	3.662	2.222	7.628	4.650
T_5	3.842	2.386	2.691	1.385	3.267	1.886	3.683	2.024	2.675	1.291	3.179	1.658	6.446	3.544
T_6	3.867	2.150	2.591	1.289	3.229	1.720	3.995	2.194	2.746	1.557	3.371	1.876	6.600	3.596
T_7	4.101	2.527	2.370	1.289	3.236	1.908	4.101	1.995	2.800	1.420	3.451	1.708	6.687	3.616
T_8	3.848	2.345	2.452	1.279	3.150	1.812	3.334	1.628	2.441	1.338	2.888	1.483	6.038	3.295
T_9	4.322	2.802	2.991	1.600	3.657	2.201	3.674	1.783	2.767	1.390	3.221	1.587	6.878	3.788
T_{10}	4.200	2.487	2.815	1.586	3.508	2.037	3.811	1.681	2.509	1.487	3.160	1.584	6.668	3.621
T_{11}	3.987	2.324	3.004	1.679	3.496	2.022	3.007	1.599	2.314	1.221	2.661	1.410	6.157	3.432
T_{12}	4.081	2.401	2.692	1.305	3.387	1.853	3.558	1.894	2.558	1.374	3.058	1.634	6.445	3.487
T_{13}	4.169	2.565	2.445	1.272	3.307	1.919	3.792	1.638	2.819	1.509	3.306	1.574	6.613	3.493
SEd	0.0721	0.0481	0.0556	0.0292		0.0675	0.0483	0.0474	0.0247		0.1149	0.0679		
CD (0.05)	0.1488	0.0992	0.1148	0.0602		0.1394	0.0996	0.0978	0.0509		0.2371	0.1402		

Canopy spread (cm): Canopy spread is one of the deciding factors in cocoa for fruiting area which directly influences the vigour of the plant and in higher yield. Fertigation applied tress recorded more canopy spread, this might be due to the optimum moisture levels coupled with timely availability of nutrients met by the fertigation treatments.

Leaf weight (g): Similar to canopy spread, the leaf weight were also higher in fertigated trees. More availability of nitrogen and phosphorous would have helped in protein and carbohydrate synthesis resulting in increased production of leaves with higher dry weight (Neary *et al*., 1995).

Fresh and dry weight of pruned branches (kg plant^{-1}): On account of the fresh and dry leaves produced and the pruned shoots, fertigation treatment with 125% RDF as WSF by drip irrigation registered higher quantities when compared to other treatments. The leaf weight recorded during the second season was more when compared to the first season and an overall value showed that fresh and dry leaf weight were more at pod maturity and harvest stage. Increased dry matter assimilation due to added nutrients was reported by Krishnamoorthy *et al.* (2011) in turmeric with optimal nutrient availability.

A plausible reason for the increase in trunk girth, canopy spread and leaf weight is that, an accurate and timely dosing of fertilizers would have resulted in

improved fertilizer use efficiency of trees. This would have aided in building up a strong vegetative frame through the production of enhanced levels of auxins (Bhattacharyya, 2010). Through increased cell division process and greater cell division due to auxins, better growth of trees could have been achieved.

CONCLUSION

Studies taken up in fertigation with cocoa indicated that a dosage of 125% Recommended Dose of Fertilizer as water soluble fertilizer through fertigation by drip irrigation (T_4) can remarkably improved the plant biometric characters.

REFERENCES

Anonymous, 2004. Crop production techniques of horticultural crops. Directorate of Horticulture and Plantation Crops. Chennai and Tamil Nadu Agricultural University, Coimbatore, pp: 289.

Bhattacharyya, R.K.A.K., 2010. Effect of drip irrigation and fertigation on yield and yield attributing characters of banana cv. Barjahaji (AAA). Adv. Plant Sci., 23: 653-655.

Denamany, G. and R. Rosinah, 1994. Recruitment methods on soil and leaf analysis for processing. Convention Staff Cocoa Research Division. Agricultural Research and Development Institute of Malaysia (MARDI), pp: 1-10.

Dixit, A., D. Sharma, N. Agarwal and P. Dubey, 2003. Effect of drip irrigation and mulch on mango yield and fruit characters. Plant Arch., 3: 199-202.

Elain Apshara, S., V.R. Bhat, K.S. Ananda, R.V. Nair and D. Suma, 2009. Evaluation and identification of high yielding trees in Nigerian cocoa germplasm. J. Plantation Crops, 37: 111-116.

Krishnamoorthy, C., K. Soorianathasundaram, K. Rajamani and P.K. Selvaraj, 2011. Impact of fertigation on leaf nutrient status in turmeric (*Curcuma longa* L.) cv. BSR 2. Asian J. Hort., 6: 162-166.

Neary, P.E., C.A. Storlie and J.W. Paterson, 1995. Fertilization requirement for drip irrigation bell pepper grown on loamy sand soils. Proceedings of the 5th International Microirrigation Congress, April 2-6, 1995, Florida, pp: 187-193.

Patel, N. and T.B.S. Rajput, 2000. Effects of fertigation on growth and yield of onions. Proceedings of the International Conference Micro and Sprinkler Irrigation Systems, February 8-10, 2000, Jalgaon, Maharashtra, pp: 77.