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Original Research Article

Studies on Impact of Drip Fertigation and Biofertigation on Water and Nutrient Use Efficiency of Arabica Coffee (*Coffea arabica*)

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A B S T R A C T

Coffee is one of the important commercial plantaion crop grown in the sub tropics of the world. Coffee being a perennial crop requires proper moisture and nutrients for higher productivity. Recently drip fertigation technology gaining importance due to saving of water and nutrients as it applies water and nutrients near to the root zone in a précised manner. The present experiment studies on impact of drip fertigation and biofertigation on water and nutrient use efficiency of Arabica coffee (*Coffea arabica*) cv. Chandragiri" was initiated at Green Pearl Estate. The treatments included three levels of nitrogen, Phosphorous and potassium and liquid biofertlizers with combinations through fertigation. The experiment was laidout in a Randomized Blocks Design (RBD) with three replications. Application of 75 per cent RDF through fertigation and biofertigation recorded the highest leaf nitrogen content, phosphorus content and potassium at vegetative, flowering, fruit development and harvest stages. application of 75 per cent RDF through fertigation and biofertigation registered the highest available soil nitrogen content, phosphorus content and potassium content at vegetative, flowering, fruit development and harvest stages and it revealed a decreasing trend from vegetative to harvest stages invariably. Significant difference was noticed on water and fertilize use efficiency. Among the different treatment combinations the treatment, 75 per cent RDF through fertigation and biofertigation recorded the highest water use efficiency and fertilizer use efficiency. This was followed by the treatment 100 per cent RDF through fertigation and biofertigation. The lowest water and fertilizer use efficiency values were recorded by absolute control treatment.

Keywords

Coffee, Dripfertigation, Biofertigation, Water use efficiency, Nutrient use efficiency.

Introduction

Coffee (*Coffea* sps) is one of the most important commercial crops grown worldwide in more than 50 countries coming under the plant family Rubiaceae. Coffee consumption has been associated with reduced risk of several diseases including cancers, parkinsons' disease, hepatitis, kidney stones and also for increased mental alertness, reduction of fatigue and improvement in the performance on vigilance tasks. Efficient use of applied nutrients is necessary for optimum growth and yield. The concentration and uptake of nutrients in crops varies with age of crop, season, plant parts, stage of crop and cultivars. During the vegetative stage, plant absorbs nutrients vigorously to build up plant frame work and excess nutrients are stored within the plant and translocated to fruits for further development. In scheduling of nutrient supply programme, analysis of plant nutrient status has been found to be useful to prevent the deficiency (or) toxic effects of nutrients in any horticultural crop. Plant analysis serves as an elegant tool for understanding the growth and physiology of plants at various phases of their growth (Hartz and Hochmuth, 1996). Coffee plant being perennial in nature has the dual function of nurturing the developing berries and production of fresh wood for the succeeding crop. Irrigation is an expensive operation, but it can produce highly economic responses, especially, when combined with appropriate fertilizer treatment and effective crop production by undertaking cultural operations in time (Mitchell, 1988). The most important factor that limits the production of coffee even in well managed estates is long drought period. Drip fertigation promotes nutrient use efficiency besides ensuring water use efficiency. Efficient use of nutrients is achieved through fertigation approaches, where the nutrient and water inputs are quantified precisely and applied at critical stage of crop growth. Fertigation reduces the nutrient loss that would normally occur with conventional methods of fertilizer application and thus permits better availability and uptake of nutrients by crops, leading to higher yield with high fertilizer use efficiency. With this view the present investigation was carried out to find out the nutrient and water use efficiency of Arabica coffee.

Materials and Methods

The present investigation on "Studies on impact of drip fertigation and biofertigation on water and nutrient use efficiency of Arabica coffee (*Coffea arabica*) cv. Chandragiri" was initiated at Green Pearl Estate at Kottachedu, Yercaud, Tamil Nadu during 2008-2009 to standardize the drip fertigation technologies along with biofertigation to increase the growth and yield of coffee through water use efficiency and fertilizer use efficiency. The present experiment was carried out with six-year-old coffee plants of cv. Chandragiri from 2008 to 2009. The spacing adopted was at 1.8 m X 1.8 m, with a plant population of 1200 plants acre^{-1}. The treatments included three levels of nitrogen, Phosphorous and potassium and liquid biofertlizers with combinations through fertigation. The experiment was laid out in a Randomized Blocks Design (RBD) with three replications. Totally eleven treatments including Absolute control (T1), Drip irrigation alone (T2), Soil application of NPK 50% RDF (T3), Soil application of NPK 75% RDF (T4), Soil application of NPK 100% RDF (T5), Drip fertigation 75 % RDF (t6), Drip fertigation 100 % RDF (T7), Drip fertigation 125 % RDF (T8), Drip fertigation 75 % RDF + Liquid biofertilizers (T9), Drip fertigation 100 % RDF + Liquid biofertilizers (T10) and Drip fertigation 125 % RDF + Liquid biofertilizers (T11). Recommended dose of fertilizers for five-year-old trees of coffee plant was 70: 55: 75 Kg NPK year^{-1}acre^{-1} (as per the package of practices of coffee). The fertilizer dose was increased for the second year crop to the level of 80: 62: 80 g NPK plant^{-1} year^{-1}. Liquid biofertilizers were applied through drip irrigation system @ 50 ml each in liquid form as per the Tamil Nadu Agricultural University recommendation containing *Azospirillum* and Phosphobacteria (Anon., 2010). For fertigation, the above fertilizers were divided into twenty splits and applied at fortnightly intervals. Fertigation and liquid biofertilizers were given at three time intervals as per the technical programme. Biometrical observations *viz.*, leaf nitrogen, phosphorous and potassium contents were done at four stages *viz.*, vegetative, flowering, fruit development and at harvest (Piper, 1966). Available soil nitrogen

(Subbiah and Asija, 1956), phosphorus (Olsen *et al.*, 1954) and potassium content (Stanford and English 1949), Fertilizer use efficiency and Water use efficiency.

For computing Fertilizer use efficiency, total quantity of N, P and K applied through fertilizers was considered and it was calculated by using the formula

$$FUE = \frac{\text{Yield (Kg ha}^{-1}\text{)}}{\text{Kg nutrient applied (N+P+K)}}$$

For computing water use efficiency the total water applied including drip irrigation and effective rainfall with allowances made for runoff and changes in soil water storage was considered**.**

$$WUE = \frac{\text{Yield (Kg ha}^{-1}\text{)}}{\text{mm of water applied}}$$

The statistical analysis of data was done by adopting the standard procedures of Panse and Sukhatme (1985).

Results and Discussion

Significant differences were noticed among the different treatments for leaf nitrogen, phosphorus and potassium content at all stages of crop growth (Table 1, 2 and 3). The highest leaf nitrogen and phosphorus content were recorded at flowering stage and leaf potassium content at fruit development stage, which gradually decreased thereafter. The plants receiving 75 per cent RDF through fertigation and biofertigation (T_9) recorded the highest leaf nitrogen content (2.38 per cent, 3.42 per cent, 3.18 per cent and 2.73 per cent and 2.47 per cent, 3.87 per cent, 3.30 per cent and 2.92 percent), phosphorus content (0.151 per cent, 0.158 per cent, 0.150 per cent and 0.142 per cent and 0.153 per cent, 0.161 per cent, 0.150 per cent and 0.145 per cent) and potassium content (1.67 per cent,3.12 per cent,3.60 per cent and 3.40 per cent and 1.70 per cent, 3.30 per cent, 3.67 per cent and 3.30 per cent) during the year 2008 and 2009 respectively at vegetative, flowering, fruit development and harvest stages. This was closely followed by T_{10} (100 per cent RDF through fertigation and biofertigation) which registered leaf nitrogen content of 2.29 per cent, 3.37 per cent, 3.06 per cent and 2.71 per cent and 2.38 per cent, 3.69 per cent, 3.23 per cent and 2.78 per cent, leaf phosphorus content of 0.150 per cent, 0.157 per cent, 0.142 per cent and 0.133 per cent and 0.152 per cent, 0.155 per cent and 0.137 per cent and leaf potassium content of 1.63 per cent, 3.10 per cent, 3.40 per cent and 2.98 per cent and 1.69 per cent, 3.27 per cent, 3.46 per cent and 3.11 per cent during 2008 and 2009 respectively, at all the above said stages of growth. The lowest leaf nitrogen content (1.59 per cent, 2.25 per cent, 2.0 percent and 1.95 per cent and 1.74 per cent, 2.60 per cent, 2.20 per cent and 1.97 per cent), leaf phosphorus content (0.128 per cent, 0.127 per cent, 0.099 per cent and 0.110 per cent and 0.124 per cent, 0.127 per cent, 0.099 per cent and 0.112 per cent) and leaf potassium content (1.39 per cent, 2.10 per cent, 2.48 per cent and 2.12 per cent and 1.49 per cent, 2.25 per cent, 2.58 per cent and 2.20 per cent) were recorded by absolute control treatment (T_1) during 2008 and 2009 at all the stages of crop growth.

Pooled mean values also showed that the application of 75% RDF through fertigation and biofertigation recorded the highest leaf nitrogen content (2.43 per cent, 3.65 per cent, 3.24 per cent 2.83 per cent), leaf phosphorus content (0.153 per cent, 0.160 per cent, 0.150 per cent and 0.144 per cent) and leaf potassium content (1.68 per cent, 3.21 per cent, 3.64 per cent and 3.35 per cent) at vegetative, flowering, fruit development and harvest stages respectively during both the season of 2008 and 2009. Application of 75% RDF fertigation and biofertigation increased the leaf nitrogen content at all four stages of crop growth might be due to accumulation of carbohydrates, which may take place gradually with the advancement of growth phase. Similar findings were also reported by Papadopoulos (1987b), Shirgure *et al.*, (2000), Petillo (2000), Colla *et al.*, (2001) and Umamaheswarappa *et al.*, (2005). Application of fertilizer through drip irrigation had resulted in the enhanced absorption of N by plants that ultimately led to higher leaf nitrogen. These are in line with the findings of Sivakumar (2007).

Azospirillum in the liquid biofertilizer involved in non-symbiotic nitrogen fixation. The atmosphere above the soil is rich in nitrogen, the *Azospirillum* might have aided to fixing up the atmospheric nitrogen in soil. Thus enhanced level of nitrogen and translocation might have resulted in higher leaf N content. Similar results were also reported by Jeeva (1987) in banana and Ganeshamoorthy (1994) in nutmeg. Application of 75% RDF drip fertigation and biofertigation treatments registered the highest P concentration in leaves could be attributed due to higher level of applied P through fertigation. More over application of P might have helped in the root proliferation leading to the formation of more number of feeder roots aiding in the uptake of available nutrients resulted in higher content of P in leaves. The phosphobacteria in biofertigation involved in solubilisation of immobile phosphates in soil and thus enhanced the uptake of P resulted in increased leaf P content. Corroborative results are also made by Krishnamoorthy and Rema (2004). The highest potassium content in leaves was found with the application of 75% drip fertigation and biofertigation. The results showed that the K content in leaves was higher at fruit development stage and thereafter the K content was found declining. Fontes *et al.*, (2000) and Dangler and Lacascio (1990) opined that application of N and K through drip irrigation increased the field by the way of maximizing the mobility of nutrients around the root zone.

Effect of drip fertigation and biofertigation on soil nutrient status

Available soil nitrogen content was significantly influenced by different fertigation treatments (Table 4, 5 and 6). Among the treatments, application of 75 per cent RDF through fertigation and biofertigation (T_9) registered the highest available soil nitrogen content (310.0, 307.65, 260.00 and 232.00 kg ha^{-1} and 336.00, 292.00, 273.37 and 258.00 kg ha^{-1} in 2008 and 2009 respectively), phosphorus content (33.20, 31.20, 28.20 and 26.80 kg ha^{-1} and 37.30, 34.20, 32.00 and 30.00 kg ha^{-1} in 2008 and 2009 respectively) and potassium content (430, 432, 440 and 336 kg ha^{-1} and 446, 450, 460 and 382 kg ha^{-1} in 2008 and 2009 respectively) at vegetative, flowering, fruit development and harvest stages and it revealed a decreasing trend from vegetative to harvest stages invariably. It was followed by the treatment T_{10} (available nitrogen, 30.21, 29.10, 27.30 and 26.00 kg ha^{-1} and 33.10, 29.80, 28.00 and 27.00 kg ha^{-1} of available phosphorus and 421, 422, 435 and 330 kg ha^{-1} and 426, 428, 452 and 348 kg ha^{-1} of available potassium). The lowest value of available soil nitrogen content (255.67, 237.30, 204.53 and 185.85 kg ha^{-1} and 261.57, 210.00, 243.00 and 193.72 kg ha^{-1} in 2008 and 2009 respectively) available soil phosphorus content (25.37, 22.32, 22.20 and 21.20 kg ha^{-1} and 26.10, 19.76, 20.00 and 19.19 kg ha^{-1} in 2008 and 2009 respectively) and available potassium content (313.82, 316.26, 340.65and 247.15 kg ha^{-1} and 317.07, 326.01, 351.04 and 260.97 kg ha^{-1} in 2008 and 2009 respectively) were recorded by absolute control T_1 at vegetative, flowering, fruit development and harvest stages of growth.

In the pooled mean values it was observed that the application of 75% RDF through fertigation and biofertigation recorded the highest soil nitrogen content (323.00, 299.83, 266.69 and 245.00 kg per hectare), soil phosphorus content (35.25, 32.70, 30.10 and 28.40 kg per hectare) and soil potassium content (438,441,450 and 359 kg per hectare) at vegetative, flowering, fruit development and harvest stages respectively in both the season of 2008 and 2009. All the drip fertigation and biofertigation treatments have registered the highest values of available soil nitrogen content. The increase in the contents of total nitrogen in the soil might be attributed to the higher availability of nitrogen coupled with related nitrification process enabling presence of nitrogen for a longer period in the soil. These are in line with the findings of Guminski (1968). *Azospirillum* lives in association with the root system of the plants and fixes atmospheric nitrogen through associative nitrogen content. Similar findings also made by Raghuramulu (2001). Similarly available P content in soil was greatly influenced by all the drip fertigation and biofertigation treatments. Soil P availability in the soil increased with increased levels of nutrients and phosphobacteria in the liquid biofertilizers. The phosphobacteria solubilize the immobile P by secretion of organic acids. Thus resulted in high available P in the soil. The present investigation is in agreement with that of Raghuramalu (2001) and Ravanachander (2009). The highest available soil K content was observed by drip fertigation and biofertigation treatments might be due to increased level of K and application of biofertilizers *viz*., *Azospirillum* and Phosphobacteria. *Azospirillum* and Phosphobacteria helps to convert into soil humus substances and mobilization of potassium due to the exchange reaction with soil particles as reported by Adherkin and Belayer (1971).

Effect of fertigation and biofertigation on water use efficiency and fertilizer use efficiency

The influence of different levels of fertigation and biofertigation on water use efficiency expressed significant difference among the treatments. Application of 75 per cent RDF through fertigation and biofertigation (T_9) registered the highest water use efficiency of 1.55 and 2.49 kg ha^{-1} mm^{-1} in 2008 and 2009 respectively. This was followed by treatment T_{10} (100 per cent RDF through fertigation and biofertigation) (1.35 and 2.09 in 2008 and 2009 respectively). Conventional method of application of 100 per cent RDF (T_5) recorded the water use efficiency of 1.10 and 1.78 kg ha^{-1} mm^{-1} in 2008 and 2009 respectively. The lowest water use efficiency values were recorded by absolute control treatment (0.89 and 1.53 kg ha^{-1} mm^{-1} in 2008 and 2009 respectively) (Table 7). Pooled mean values showed that the application of 75% RDF through fertigation and biofertigation recorded the highest water use efficiency (1.986 ha^{-1} mm^{-1}). The increase in water use efficiency in all the drip fertigation treatments over surface irrigation treatment was mainly due to considerable saving in irrigation water and increased yield. Corroborative results also made by Arunadevi *et al.*, (2007) in mulberry.

Table.1 Effect of drip fertigation and biofertigation on leaf nitrogen content (%) of coffee (*Coffea arabica*) cv. Chandragiri

Treatments	Vegetative stage		Mean	Flowering stage		Mean	Fruiting stage		Mean	Harvest stage		Mean
	2008	2009		2008	2009		2008	2009		2008	2009	
T_1	1.59	1.74	1.67	2.25	2.60	2.43	2.00	2.20	2.10	1.95	1.97	1.96
T_2	1.63	1.83	1.73	2.50	2.62	2.56	2.10	2.40	2.25	2.00	1.98	1.99
T_3	1.73	1.92	1.83	2.61	2.75	2.68	2.22	2.57	2.40	2.01	2.02	2.02
T_4	1.84	2.19	2.02	2.81	2.95	2.88	2.38	2.67	2.53	2.10	2.08	2.09
T_5	1.93	2.21	2.07	2.99	3.03	3.01	2.63	2.90	2.77	2.20	2.10	2.15
T_6	2.10	2.28	2.19	3.01	3.27	3.14	2.86	3.15	3.01	2.42	2.40	2.41
T_7	2.20	2.32	2.26	3.12	3.41	3.27	2.98	3.20	3.09	2.67	2.71	2.69
T_8	1.97	2.27	2.12	3.00	3.16	3.08	2.73	3.14	2.94	2.20	2.22	2.21
T_9	2.38	2.47	2.43	3.42	3.87	3.65	3.18	3.30	3.24	2.73	2.92	2.83
T_{10}	2.29	2.38	2.34	3.37	3.69	3.53	3.06	3.23	3.15	2.71	2.78	2.75
T_{11}	2.11	2.31	2.21	3.10	3.30	3.20	2.97	3.14	3.06	2.50	2.68	2.59
SED	**0.012**	**0.013**		**0.015**	**0.024**		**0.025**	**0.026**		**0.018**	**0.119**	
CD (0.05)	**0.025**	**0.028**		**0.031**	**0.047**		**0.053**	**0.054**		**0.037**	**0.249**	

Table.2 Effect of drip fertigation and biofertigation on leaf phosphorus content (%) of coffee (*Coffea arabica*) cv. Chandragiri

Treatments	Vegetative stage		Mean	Flowering stage		Mean	Fruiting stage		Mean	Harvest stage		Mean
	2008	2009		2008	2009		2008	2009		2008	2009	
T_1	0.128	0.124	0.126	0.127	0.127	0.127	0.099	0.099	0.099	0.110	0.112	0.111
T_2	0.128	0.127	0.128	0.128	0.129	0.129	0.116	0.118	0.117	0.115	0.115	0.115
T_3	0.129	0.128	0.129	0.131	0.133	0.132	0.127	0.128	0.128	0.117	0.117	0.117
T_4	0.129	0.130	0.130	0.136	0.138	0.137	0.129	0.129	0.129	0.117	0.120	0.119
T_5	0.130	0.132	0.131	0.139	0.140	0.140	0.130	0.130	0.130	0.118	0.121	0.120
T_6	0.133	0.134	0.134	0.147	0.149	0.148	0.135	0.136	0.136	0.123	0.125	0.124
T_7	0.148	0.152	0.150	0.156	0.154	0.155	0.137	0.140	0.139	0.130	0.130	0.130
T_8	0.132	0.133	0.133	0.141	0.142	0.142	0.134	0.134	0.134	0.120	0.120	0.120
T_9	0.151	0.153	0.152	0.158	0.161	0.160	0.150	0.150	0.150	0.142	0.145	0.144
T_{10}	0.150	0.152	0.151	0.157	0.155	0.156	0.142	0.142	0.142	0.133	0.137	0.135
T_{11}	0.132	0.142	0.137	0.149	0.151	0.150	0.136	0.137	0.136	0.126	0.127	0.127
SED	**0.001**	**0.0004**		**0.001**	**0.001**		**0.003**	**0.003**		**0.0004**	**0.0004**	
CD (0.05)	**0.002**	**0.001**		**0.001**	**0.001**		**0.006**	**0.006**		**0.001**	**0.001**	

Table.3 Effect of drip fertigation and biofertigation on leaf potassium content (%) of coffee (*Coffea arabica*) cv. Chandragiri

Treatments	Vegetative stage		Mean	Flowering stage		Mean	Fruiting stage		Mean	Harvest stage		Mean
	2008	2009		2008	2009		2008	2009		2008	2009	
T_1	1.39	1.49	1.44	2.10	2.25	2.18	2.48	2.58	2.53	2.12	2.20	2.16
T_2	1.42	1.50	1.46	2.27	2.40	2.34	2.60	2.59	2.60	2.20	2.30	2.25
T_3	1.45	1.52	1.49	2.30	2.52	2.41	2.84	2.93	2.89	2.40	2.61	2.51
T_4	1.48	1.56	1.52	2.35	2.60	2.48	2.85	2.98	2.92	2.63	2.63	2.63
T_5	1.49	1.57	1.53	2.54	2.84	2.69	2.98	2.99	2.99	2.73	2.67	2.70
T_6	1.50	1.59	1.55	2.90	3.03	2.97	3.10	3.10	3.10	2.89	2.89	2.89
T_7	1.61	1.63	1.62	3.00	3.20	3.10	3.20	3.14	3.17	2.90	2.93	2.92
T_8	1.50	1.57	1.53	2.74	3.00	2.87	3.00	3.03	3.02	2.78	2.83	2.81
T_9	1.67	1.70	1.68	3.12	3.30	3.21	3.60	3.67	3.64	3.40	3.30	3.35
T_{10}	1.63	1.69	1.66	3.10	3.27	3.19	3.40	3.46	3.43	2.98	3.11	3.05
T_{11}	1.58	1.61	1.60	2.93	3.10	3.02	3.01	3.21	3.11	2.90	2.99	2.95
SED	**0.004**	**0.007**		**0.028**	**0.026**		**0.027**	**0.027**		**0.023**	**0.026**	
CD (0.05)	**0.009**	**0.015**		**0.058**	**0.055**		**0.056**	**0.056**		**0.048**	**0.053**	

Table.4 Effect of drip fertigation and biofertigation on available soil nitrogen content (%) of coffee (*Coffea arabica*) cv. Chandragiri

Treatments	Vegetative stage		Mean	Flowering stage		Mean	Fruiting stage		Mean	Harvest stage		Mean
	2008	2009		2008	2009		2008	2009		2008	2009	
T_1	255.67	261.57	258.62	237.30	219.00	228.15	204.53	243.00	223.77	185.85	193.72	189.79
T_2	266.00	268.00	267.00	264.00	243.87	253.94	238.00	252.00	245.00	206.00	217.00	211.50
T_3	268.00	270.00	269.00	273.00	260.00	266.50	242.00	252.50	247.25	208.00	218.00	213.00
T_4	275.00	271.00	273.00	274.05	268.50	271.28	247.00	259.00	253.00	209.00	220.00	214.50
T_5	277.00	276.00	276.50	276.15	268.00	272.08	247.50	256.00	251.75	210.00	221.00	215.50
T_6	279.00	282.00	280.50	280.35	270.50	275.43	251.00	262.00	256.50	223.00	231.00	227.00
T_7	289.00	287.50	288.25	298.20	278.00	288.10	257.00	270.00	263.50	230.00	240.00	235.00
T_8	278.00	280.00	279.00	276.15	270.00	273.08	249.00	260.00	254.50	218.00	221.00	219.50
T_9	310.00	336.00	323.00	307.65	292.00	299.83	260.00	273.37	266.69	232.00	258.00	245.00
T_{10}	302.00	311.00	306.50	303.45	287.00	295.23	258.00	272.00	265.00	226.00	241.00	233.50
T_{11}	283.00	287.00	285.00	282.45	272.00	277.23	253.00	268.00	260.50	225.00	238.00	231.50
SED	**1.701**	**1.866**		**1.284**	**1.729**		**1.095**	**2.205**		**1.109**	**1.185**	
CD (0.05)	**3.549**	**3.892**		**2.677**	**3.607**		**2.285**	**4.599**		**2.314**	**2.472**	

Table.5 Effect of drip fertigation and biofertigation on available soil phosphorus content (%) of coffee (*Coffea arabica*) cv. Chandragiri

Treatments	Vegetative stage		Mean	Flowering stage		Mean	Fruiting stage		Mean	Harvest stage		Mean
	2008	2009		2008	2009		2008	2009		2008	2009	
T_1	25.37	26.10	25.74	22.32	19.76	21.04	22.20	20.00	21.10	21.20	19.19	20.20
T_2	26.10	26.45	26.28	24.30	25.20	24.75	23.40	24.02	23.71	21.63	23.70	22.67
T_3	26.70	27.60	27.15	24.80	25.30	25.05	24.10	24.60	24.35	23.00	24.00	23.50
T_4	26.80	27.65	27.23	25.20	26.30	25.75	24.30	24.70	24.50	23.80	24.20	24.00
T_5	27.00	28.50	27.75	26.10	26.40	26.25	24.60	25.90	25.25	23.85	24.80	24.33
T_6	28.00	29.10	28.55	26.30	27.40	26.85	25.30	26.70	26.00	24.00	25.60	24.80
T_7	30.13	32.60	31.37	28.40	29.20	28.80	25.40	27.30	26.35	25.50	26.50	26.00
T_8	27.70	28.80	28.25	26.10	27.30	26.70	24.60	26.40	25.50	23.90	25.40	24.65
T_9	33.20	37.30	35.25	31.20	34.20	32.70	28.20	32.00	30.10	26.80	30.00	28.40
T_{10}	30.21	33.10	31.66	29.10	29.80	29.45	27.30	28.00	27.65	26.00	27.00	26.50
T_{11}	29.10	30.30	29.70	27.20	28.10	27.65	25.38	26.90	26.14	24.80	25.80	25.30
SED		**0.146**		**0.146**	**0.862**			**0.851**		**0.146**	**0.816**	
CD (0.05)		**0.304**		**0.304**	**1.797**			**1.775**		**0.304**	**1.703**	

Table.6 Effect of drip fertigation and biofertigation on available soil potassium content (%) of coffee (*Coffea arabica*) cv. Chandragiri

Treatments	Vegetative stage		Mean	Flowering stage		Mean	Fruiting stage		Mean	Harvest stage		Mean
	2008	2009		2008	2009		2008	2009		2008	2009	
T_1	313.82	317.07	315.45	316.26	326.01	321.14	340.65	351.22	345.94	247.15	260.97	254.06
T_2	380.00	386.00	383.00	383.00	389.00	386.00	402.00	420.00	411.00	310.00	328.00	319.00
T_3	383.00	391.00	387.00	391.00	396.00	393.50	410.00	428.00	419.00	315.00	328.50	321.75
T_4	400.00	406.00	403.00	402.00	410.00	406.00	415.00	430.00	422.50	319.00	330.00	324.50
T_5	401.00	414.00	407.50	406.00	420.00	413.00	419.00	433.00	426.00	320.00	332.50	326.25
T_6	416.00	418.00	417.00	409.00	424.00	416.50	430.00	446.00	438.00	323.00	335.00	329.00
T_7	420.00	422.00	421.00	420.00	426.00	423.00	431.00	447.00	439.00	328.00	337.00	332.50
T_8	405.00	414.00	409.50	402.00	422.00	412.00	420.00	445.00	432.50	322.00	332.00	327.00
T_9	430.00	446.00	438.00	432.00	450.00	441.00	440.00	460.00	450.00	336.00	382.00	359.00
T_{10}	421.00	426.00	423.50	422.00	428.00	425.00	435.00	452.00	443.50	330.00	348.00	339.00
T_{11}	418.00	420.00	419.00	418.00	425.00	421.50	430.50	448.00	439.25	325.00	336.00	330.50
SED	**13.157**	**13.337**		**13.255**	**13.616**		**14.03**	**14.531**		**10.378**	**10.947**	
CD (0.05)	**27.446**	**27.822**		**27.649**	**28.404**		**29.23**	**30.311**		**21.648**	**22.835**	

Table.7 Effect of drip fertigation and biofertigation on nutrient use efficiency and water use efficiency of coffee (*Coffea arabica*) cv. Chandragiri

Treatments	Nutrient Use Efficiency (kg ha^{-1})		Mean	Water Use Efficiency (kg ha^{-1} mm^{-1})		Mean
	2008	2009		2008	2009	
T_1	3.640	4.160	3.900	0.890	1.530	1.210
T_2	4.790	4.900	4.845	0.980	1.600	1.290
T_3	7.710	7.153	7.432	1.010	1.690	1.350
T_4	7.370	7.230	7.300	1.050	1.700	1.375
T_5	7.790	7.450	7.620	1.100	1.780	1.440
T_6	10.110	9.900	10.005	1.220	1.900	1.560
T_7	11.280	11.990	11.635	1.300	2.070	1.685
T_8	9.201	9.883	9.542	1.200	1.890	1.545
T_9	15.450	15.800	15.625	1.524	2.449	1.986
T_{10}	14.660	15.050	14.855	1.350	2.090	1.720
T_{11}	10.150	10.160	10.155	1.290	1.950	1.620
SED	**0.202**	**0.195**		**0.017**	**0.026**	
CD (0.05)	**0.422**	**0.408**		**0.035**	**0.055**	

Higher water use efficiency under drip fertigation method was also reported by Ramesh (1986), Kadam and Mager (1992) and Shivakumar (1998).

Significant difference was noticed on fertilize use efficiency among the different treatment combinations. The treatment (T_9) i.e. 75 per cent RDF through fertigation and biofertigation recorded the highest fertilizer use efficiency (15.45 and 15.80 kg ha^{-1} during 2008 and 2009 respectively). This was followed by the treatment T_{10} (100 per cent RDF through fertigation and biofertigation) (14.66 and 15.05 kg ha^{-1} in 2008 and 2009 respectively). Conventional method of application of 100 per cent RDF recorded fertilizer use efficiency value of 7.84 and 7.61 kg ha^{-1} in 2008 and 2009 respectively. The treatment T_7 (100 per cent RDF drip fertigation) registered the fertilizer use efficiency value of 11.28 and 11.99 kg ha^{-1} in 2008 and 2009 respectively. The lowest fertilizer use efficiency values were recorded by absolute control treatment T_1 (3.64 and 4.16 kg ha^{-1} in 2008 and 2009 respectively) (Table 7). Pooled mean values showed that the application of 75% RDF through fertigation and biofertigation recorded the highest fertilizer use efficiency (15.625 kg ha^{-1}). Nutrient use efficiency revealed that application of 75% RDF drip fertigation and biofertigation was significantly superior over 100% and 125% RDF drip fertigation and biofertigation treatments. It was observed the FUE was decreased with increase in nutrient level. The higher nutrient efficiency observed under drip fertigation and biofertigation might be due to reduction in leaching, volatilization losses. Under drip fertigation system the maximum soil moisture distribution observed within 30 cm depth would have prevented the leaching of nutrients. The higher root growth under drip fertigation and biofertigation treatments increased the uptake of nutrients and also increased the nutrient use efficiency. These findings are in line with the findings of Bridgit *et al.,* (2007). Biofertilizers *viz*., *Azospirillum* and phosphobacteria solubilize the immobile mineral nutrients and convert it into easily available form thus enhancing the nutrient uptake which would have resulted in higher nutrient use efficiency. Further synthesis of phytohormones like IAA, Gibberellin and Cytokinin synthesized by *Azospirillum* and Phosphobacteria increased the root biomass and the higher enzyme activity in soil, increased the nutrient uptake. From the result it could be concluded that drip fertigation and biofertigation significantly increased the water and nutrient efficiency in coffee plantation by increasing root length and water and nutrient uptake by the plant.

Further the biofertilizers in the biofertigation make the immobile nutrients in to easily available form thus greatly enhancing the nutrient uptake resulted in higher nutrient use efficiency. The higher water and nutrient use efficiency ultimately resulted higher yield in Arabica coffee.

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