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Effect of Drip Fertigation and Biofertigation on Physiology of Arabica Coffee (*Coffea arabica*) cv. Chandragiri

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A B S T R A C T

The present investigation on effect of drip fertigation and biofertigation on physiology of arabica coffee (*Coffea arabica*) cv. Chandragiriwas undertaken at Green Pearl Estate Kottachedu village, Yercaud, Tamil Nadu. Totally eleven treatments were laid out in a randomized block design and replicated thrice. The results of the experiment revealed that application of 75 per cent RDF through fertigation and biofertigation increased the leaf area, specific leaf weight and fresh and dry weight of leaves at different phases of growth. Further, the characters like specific leaf weight and fresh and dry weight of leaves were found to be at their highest level during vegetative and flowering than the other stages studied. With respect to leaf area, there was an increasing trend from vegetative stage. It was further observed that the physiological parameters *viz*., total chlorophyll content, carbohydrate content and C/N ratio were at the highest by application of 75 per cent RDF through fertigation and biofertigation. With respect to different stages of plant growth, it was observed that total chlorophyll content, carbohydrate content and C/N ratio was high in flowering stage than the other stages. Among the enzymes studied, the activity of 'nitrate reductase' and peroxidase was the highest by application of 75 per cent RDF through fertigation and biofertigation. Their activity was higher from flowering to fruit development stages and declined towards harvest. In contrary, the IAA oxidase activity was found to be low at higherdoses of nutrient levels. Regarding stages, it was found to increase from vegetative, to fruit development followed by a decrease. The fruit weight, parchment weight and fruit outturn, revealed a similar trend of registering higher values by application of 75 per cent RDF through fertigation and biofertigation.

Keywords

Coffee, Drip, Biofertigation, Physiology, Yield.

Introduction

Indian coffee is known for its aroma and flavour and categorized as “mildes” in world coffee. 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. Kwashiorkor, disease caused by protein deficiency, is overcome by the consumption of coffee (Mathyalagan *et al.,* 1982). Coffee (*Coffea arabica* L.) occupies a place of pride among different plantation crops grown in India. Coffee cultivation is mostly confined to hilly tracts of Western and Eastern Ghats. In coffee growing areas of South India, December to March are dry months. Coffee being an evergreen plant requires maintenance of soil moisture during this period which is crucial for better growth and higher yield. Trickle irrigation has gained importance during the last decade due to increased productivity and greater water and nutrient savings. Application of urea helps reducing leaf and fruit drops besides encourages vegetative growth of current and subsequent crops and can have a positive impact on the quality of coffee, especially minerals, proteins, vitamins, acidity, colour and flavor component of coffee may be improved (Jayarama, 2000). Potassium plays a key role in the physiology of the coffee tree and particularly in the development of fruit (Snoeck and Lambot, 2004). In any crop management practice maintaining the physiological processes in an active state is highly indispensable. This resulted in plants to produce biomass through least destructive process of the several management practices followed to keep the plants physiologically active, one such way is providing water and nutrients optimally at appropriate stages. In the present study also, attempts were made in this direction through drip fertigation and biofertigation and its influence on physiological and biochemical characters was observed.

Materials and Methods

The experiment was conducted at Green Pearl Estate at Kottachedu, Yercaud during 2008 and 2009. The investigation was carried out with six year old coffee plants of cv. Chandragiri. The crop was planted at a distance of 1.8m x 1.8m with a plant population of 1200 plants acre^{-1}. Totally eleven treatments *viz.*, T_1 (absolute control), T_2 (Drip irrigation alone), T_3 (Soil application of NPK 50 % RDF), T_4 (soli application of NPK 75%), T_5 (Soli application of NPK 100%), T_6 (Drip fertigation 75% RDF), T_7 (Drip fertigation 100% RDF), T_8 (Drip fertigation 125% RDF), T_9 (Drip fertigation 75% RDF + Liquidbiofertilizerss), T_{10}(Drip fertigation 100% RDF + Liquidbiofertilizers) and T_{11} (Drip fertigation 125% RDF + Liquid bio fertilizers) were laid out in a randomized block design and replicated thrice. The biometrical observations *viz.*, plant height (cm), stem girth (cm), number of branches per plant, number of nodes per branches, percentage of fruit set, and yield per plant (kg) were recorded from randomly selected ten plants from each treatment and the data were subjected to statistical analysis as suggested by Panse and Sukhatme (1985).

Method of fertilizer application

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 kg NPK year^{-1}acre^{-1}. Liquid bio fertilizers were applied through drip irrigation system at 50ml each in liquid form as per the Tamil Nadu Agricultural University recommendation containing Azospyrillum and Phosphobacteria. For fertigation the above fertilizers were divided in to twenty splits and applied at fortnight intervals. Biofertigation was done at monthly interval as per the technical programme.

Results and Discussion

The different drip fertigation treatment significantly influenced the leaf area specific leaf weight and dry matter production in all the stages of growth during both the season. Among the different treatment combinations, the plants that received 75 per cent RDF through fertigation and biofertigation registered the highest leaf area (90.36, 95.60 and 95.70 cm^2 leaf^{-1} in 2008 and 92.31, 96.70, and 96.72 cm^2 leaf^{-1} in 2009), specific leaf weight (11.71, 15.14. 13.47 mg cm^2 in 2008 and 15.63, 17.57, 14.30 mg cm^2 in 2009) and dry matter content (1.58, 1.85, and 5.35 kg plant^{-1} and 1.70, 2.40, and 6.30 kg plant^{-1} during 2008 and 2009)during vegetative, flowering and at fruit development stages respectively. This was followed by T_{10} (100 per cent RDF through fertigation and biofertigation) (Table 1, 2 and 3). The lowest leaf area (84.20, 86.34 and 87.71 cm^2 leaf^{-1} and 84.00, 84.96 and 87.91 cm^2 leaf$^-$1), specific leaf weight (9.28, 8.99 and 7.88 mg cm^2 and 10.03, 9.17 and 7.91 mg cm^2) and dry matter content values (1.58, 1.85 and 5.35 kg plant^{-1} and 1.70, 2.40 and 6.30 kg plant^{-1}) were recorded by the absolute control treatment (T_1) in 2008 and 2009 respectively at all the stages of growth. Pooled mean values showed that the application of 75% RDF through fertigation and biofertigation recorded the highest leaf area (91.34 cm^2 leaf^{-1}, 96.15 cm^2 leaf^{-1} and 96.21 cm^2 leaf^{-1}), specific leaf weight (13.67, 16.36 and 13.89 mg cm^2) and dry matter content (1.58, 1.85, and 5.35 kg plant^{-1} and 1.70, 2.40, and 6.30 kg plant^{-1}) at vegetative, flowering and fruit development stage respectively in both the season. Leaf area is an important fundamental traits which determine the rate of photosynthesis through its effective interception of light energy and fixation of CO_2, facilitates dry matter production of crop plants as suggested by Shibles and Webber (1996).The favourable influence of nutrients on improving specific leaf weight was also reported by Sendurkumaran *et al.,* (1995) and Sadasivam (1995).

Significant difference was observed among the treatments, for total chlorophyll contents of leaves. Application of 75 per cent RDF through drip fertigation along with biofertigation registered the highest total chlorophyll content (2.13, 2.62, 2.26, 1.72 and 2.21, 2.91, 2.39, 1.79 mg g^{-1}) in both seasons 2008 and 2009 at all the stages of crop growth. It was followed by T_{10} (2.05, 2.35, 2.17 and 1.59 mg g^{-1} and 2.20, 2.38, 2.23 and 1.61 mg g^{-1} in 2008 and 2009 respectively at all stages of vegetative, flowering, fruit development and at harvest stage. The treatment T_5 (100 per cent RDF as soil application) recorded a total chlorophyll content of 1.77, 1.96, 1.75 and 1.39 mg g^{-1} and 1.78, 2.03, 1.42 and 1.39 mg g^{-1} during 2008 and 2009 respectively at all the stages of growth. While the, lowest total chlorophyll content was registered in absolute control treatment T_1 (1.48, 1.01, 1.50 and 0.99 mg g^{-1} and 1.50, 1.68, 1.53 and 0.99 mg g^{-1}) in 2008 and 2009 respectively at vegetative, flowering, fruit development and at harvest stages of growth.

Pooled mean values showed that the application of 75% RDF through fertigation and biofertigation recorded the highest total chlorophyll (2.17, 2.77, 2.33 and 1.76 mg g^{-1}) at vegetative, flowering, fruit development and harvest stage respectively in both the season (Table 4).

The increased chlorophyll content observed with drip fertigation treatment might be due to increased uptake of nutrients particularly N. The phenomenon of increased chlorophyll content with higher nutrients as observed in the present study was also reported by Meenakshi and Vadivel (2002). Venkataramanan (1988) revealed that being a constituent of chlorophyll accelerate higher synthesis of chlorophyll without altering the composition of chlorophyll a and b. Higher leaf area observed in the present experiment with the fertigation treatment of 75% RDF fertigation and biofertigation might have also resulted higher chlorophyll content.

The C/N ratio and leaf carbohydrate content were significantly influenced by different methods of fertilizer application. Among the different treatment combinations, the plants that received 75 per cent RDF drip fertigation and biofertigation (T_9) registered the highest C/N ratio of 8.10, 8.60, 8.06 and 6.29 and 9.00, 8.60, 8.10 and 6.60 and leaf carbohydrate content of 18.41, 27.65, 24.68 and 17.63 mg g^{-1} and 22.32, 31.50, 21.45 and 18.38 mg g^{-1}in 2008 and 2009 respectively at vegetative, flowering, fruit development and harvest stages. This was followed by T_{10} (100 per cent RDF drip fertigation and biofertigation) (7.80, 7.96, 7.38 and 5.90 and 8.20, 8.13, 7.00 and 6.05 C/N ratio and 16.14, 24.55, 21.58 and 15.41 mg g^{-1} and 18.63, 27.30, 22.12 and 16.21 mg g^{-1} leaf carbohydrate content in 2008 and 2009 respectively at all the stages of growth). The lowest C/N ratio (5.44, 6.14, 5.20 and 2.87 and 5.78, 6.14, 5.68 and 3.76) and leaf carbohydrate content (9.60, 17.68, 13.45 and 9.48 mg g^{-1} and 10.85, 16.21, 12.88 and 9.33 mg g^{-1}) values were registered by absolute control treatment in 2008 and 2009 respectively at all the stages of growth.

Pooled mean values showed that the application of 75% RDF through fertigation and biofertigation recorded the highest C/N ratio (8.55, 8.65, 8.08 and 6.45) and leaf carbohydrate content (20.37, 29.58, 25.07 and 18.01 mg g^{-1}) at vegetative, flowering, fruit development and harvest stage respectively in both the season (Table 5 and 6).

Higher carbohydrate content observed by this treatment might be due to increased uptake of nutrients and water. Higher nutrient and water use efficiency resulted in higher leaf area which ultimately increased the photosynthetic rate in turn helping in higher production of carbohydrates (Venkataramanan, 1988) in *Coffea arabica*. Estimated uptake of N and higher production of phytohormone like IAA, GA and kinetin due to *Azospirillum* and phosphobacteria increased the translocation of assimilates to site of source resulted in higher carbohydrate accumulation in the leaves. Nitrogen and carbohydrate composition in shoots are known to have a role in flower bud initiation and differentiation in coffee bush. Generally, it is an accepted fact that high total carbohydrate content in leaves with high C/N ratio favours flower bud initiation. It was observed that the carbohydrate content in leaves gradually increased from vegetative stage to flowering stage and thereafter it declines till harvest. Higher the starch and carbohydrate status, blossoms will be healthy and uniform as indicated in these studies. These findings are corroborative with Venkatesan (2006), Jayavalli (2006) and Gnanasekaran (2007) in mango. However, the increment in carbohydrates was greater than that of N content, as revealed by the steady increase of higher C/N ratio throughout the period.

The data recorded on 'nitrate reductase activity' and peroxidase activity of leaves at different stages revealed significant difference among the different fertigation treatments.

Application of 75 per cent RDF through drip fertigation and biofertigation (T_9) recorded the highest nitrate reductase activity and peroxidase activity at all the stages of crop growth during both the seasons *viz*., 2008 and 2009 (28.20, 29.31 and 23.41 µg NO_2 g^{-1} h^{-1} and 27.60, 29.75 and 24.12 µg NO_2 g^{-1} h^{-1} and 1.280, 1.760 and 0.920 Δ OD 430 nm min^{-1} h^{-1} and 1.320, 1.820 and 0.970 Δ OD 430 nm min^{-1} h^{-1}). It was followed by T_{10} which registered nitrate reductase activity of 27.30, 28.40 and 23.20 µg NO_2 g^{-1} h^{-1} and 27.30, 28.10 and 24.02 µg NO_2 g^{-1} h^{-1} and peroxidase activity of 1.100, 1.310, 0.910 and 1.220, 1.410, 0.960 Δ OD 430 nm min^{-1} h^{-1} in 2008 and 2009 respectively at all the stages of growth which was higher than the conventional method of application i.e., 100 per cent RDF as soil application (T_5). Whereas the lowest nitrate reductase and peroxidase activity of 18.40, 20.23 and 17.92 µg NO_2 g^{-1} h^{-1} and 16.60, 21.68 and 18.21 µg NO_2 g^{-1} $h^{-1}$and 0.610, 1.023 and 0.590 ∆ OD 430 nm min^{-1} h^{-1} and 0.669, 1.062 and 0.620 ∆ OD 430 nm min^{-1} h^{-1} in 2008 and 2009 respectively was noticed by absolute control at all the stages of growth (Table 7 and 8).

Pooled mean values also showed similar trend. Application of 75% RDF through fertigation and biofertigation recorded the highest nitrate reductase activity (27.90, 29.53 and 23.76 µg NO_2 g^{-1} h^{-1}) and peroxidase activity (1.300, 1.790 and 0.945 ∆ OD 430 nm min^{-1} h^{-1}) at vegetative, fruit development and harvest stage respectively in both the season.

In the present study higher nitrate reductase activity was observed with application of 75% RDF fertigation and biofertigation might have due to increased supply of nitrogen and moisture by high uptake of nutrients and water thus resulted the plant always physiologically active in state which would have resulted in higher nitrate reductase activity. Corroborative results were also made by Ranjeet and Juliano (1970); Sachdev *et al.,* (1987) and Venkataramanan (1988) Barlaan and Ichi (1997) opined that increase in N content increased the nitrate reductase activity since it was a substrate induced enzyme. In the present study, higher activity of peroxidase observed by drip fertigation and biofertigation treatments helped in maintaining optimum water potential in the plants and regulate the metabolic and physiological process could resulted in higher plant vigour and yield of coffee (Allen, 1995).

Application of 75 per cent RDF through drip fertigation and biofertigation (T_9) recorded the lowest IAA oxidase activity in leaves (19.962, 24.092 and 18.585 µg unoxidisedauxin g^{-1} h^{-1} and 19.844, 24.387, 33.60 and 18.585 µg unoxidisedauxin g^{-1} h^{-1} in 2008 and 2009 respectively during vegetative, fruit development and at harvest stages of growth. The plants that received 100 per cent RDF drip fertigation and biofertigation (T_{10}) recorded the next least for the trait IAA oxidase activity of leaves which registered 22.650, 25.600 and 20.120 µg unoxidisedauxin g^{-1} h^{-1} and 22.300, 25.600 and 20.220 µg unoxidisedauxin g^{-1} h^{-1} in 2008 and 2009 respectively at all the stages of growth. The highest IAA oxidase activity of leaves was registered by T_1 (26.850, 32.620 and 30.50 µg unoxidised auxin g^{-1} h^{-1} and 35.860, 34.620 and 33.30 µg unoxidised auxin g^{-1} h^{-1} in 2008 and respectively at all the stages of growth. Indole acetic acid (IAA) a prime bioregulator, regulates the apical dominance and initiation of vegetative and flower buds. Therefore higher activity of IAA oxidase cause reduction in auxin content and thereby decreases the normal growth of trees (Vijayakumar, 2001).

Pooled mean values showed that the application of 75% RDF through fertigation and biofertigation recorded the lowest IAA oxidase activity (19.903, 24.239 and 18.585 µg unoxidised auxin g^{-1} h^{-1}) at vegetative, fruit development and harvest stage respectively in both the season (Table 9).

With respect of fruit retention per cent, the treatment combination of 75 per cent RDF fertigation and biofertigation (T_9) recorded the highest fruit retention per cent of 91.20 and 96.00 during 2008 and 2009 respectively. It was followed by the treatment combination of 100 per cent of RDF fertigation and biofertigation (87.40

and 92.00 per cent) in 2008 and 2009 respectively. It was also observed that the treatments T_7 and T_{10} were on par with one another. However the lowest fruit retention per cent of 76.14 and 84.00 per cent were recorded by absolute control in both 2008 and 2009 respectively.

The pooled mean values of fruit retention per cent suggested that of 75 per cent RDF fertigation and biofertigation recorded the highest per cent of fruit retention of 93.60 per cent and was followed by 100 per cent RDF fertigation and biofertigation (89.70 per cent). The lowest per cent of fruit retention of 80.37 was recorded by absolute control (T_1).

The increased fruit retention observed by the drip fertigation and biofertigation might be due to increased uptake of nutrients which resulted in enhanced synthesis of hormones like auxins and gibberellins. Water applied through drip irrigation slowly near to the root zone always maintains soil moisture in field capacity range and no moisture stress occurred during the flowering and fruit development stage and thereby decreased the fruit drop.

This might have resulted in higher per cent of fruit retention. Similar results also made by Singh *et al.*, (2006) in mango. Biofertilizers *viz*., *Azospirillum* and phosphobacteria enhanced the uptake of N, P and K, water and production of phytohormones like IAA, GA and cytokinin would also have influenced the reproductive system of plants. These results are in line with the findings of Singh *et al.,* (1982) in tinda.

The different treatments registered a significant influence on 100 fruit weight, 100 fruit parchment weight and 100 fruit out turn (Table 10). The treatment receiving 75 per cent RDF fertigation and biofertigation (T_9) recorded the highest 100 fruit weight of 154.30 g and 162.30 g, 100 fruit parchment weight of 70.90 g and 74.60 g and 100 fruit out turn of 29.30 g and 31.00 g in 2008 and 2009 respectively. It was followed by T_{10} (Table 10). The lowest 100 fruit weight (142.49 g and 151.50 g), 100 fruit parchment weight (65.59 g and 69.90 g) and 100 fruit out turn (26.94 g and 28.80 g) values were recorded by T_1during 2008 and 2009 respectively.

Pooled mean values of 100 fruit weight, 100 fruit parchment weight and 100 fruit out turn showed that application of 75 per cent RDF fertigation and biofertigation recorded the highest 100 fruit weight of 158.30 g, 100 fruit parchment weight of 72.75 g and 100 fruit out turn of 30.15 g. Higher values observed for these traits with fertigation treatments might be due to higher water use efficiency and fertilizer use efficiency and higher uptake of nutrients *viz*., N, P and K.

Production of growth hormones like auxins, gibberellins and cytokinins by the biofertilizers increased the uptake of nutrients and water translocation of assimilates helped in increased weight of fruit, skin, mucilage and parchment. The results are in agreement with that of Deswal and Patil (1984), Mrinalini and Tiwari (1988) and Latha and Singh (1993).

From the results of the present study it could be concluded that the drip fertigation and biofertigation has significant influence on physiology of coffee plants. Application of 75 per cent RDF fertigation and biofertigation recorded the highest leaf area, specific leaf weight, dry matter production, CN ratio, leaf carbohydrate contend, 100 fruit weight, 100 fruit parchment weight and 100 fruit out turn.

Table.1 Effect of drip fertigation and biofertigation on leaf area per leaf of coffee (*Coffea arabica*) cv. Chandragiri

Treatments	Leaf area per leaf (cm^2)								
	Flowering stage			Fruit development stage			Vegetative stage		
	2009	2008	Mean	2009	2008	Mean	2009	2008	Mean
T_1	84.00	84.20	84.10	84.96	84.34	85.65	87.91	87.71	87.81
T_2	84.76	84.86	84.81	88.40	87.20	87.80	89.70	89.20	89.45
T_3	86.21	85.20	85.71	89.20	88.20	88.70	90.20	89.30	89.75
T_4	86.60	86.30	86.45	89.21	88.30	88.76	91.20	89.60	90.40
T_5	88.10	88.00	88.05	89.60	88.80	89.20	91.20	90.10	90.65
T_6	89.20	88.32	88.76	90.00	90.00	90.00	91.40	91.22	91.31
T_7	90.21	90.18	90.20	93.20	92.10	92.65	93.60	92.36	92.98
T_8	88.12	88.30	88.21	89.90	89.30	89.60	91.30	91.20	91.25
T_9	92.31	90.36	91.34	96.70	95.60	96.15	96.72	95.70	96.21
T_{10}	90.31	90.21	90.26	93.30	92.40	92.85	93.62	92.60	93.11
T_{11}	89.31	89.00	89.16	90.40	91.10	90.75	91.70	91.30	91.50
SED	**0.596**	**1.240**		**0.574**	**0.606**		**0.618**	**0.6184**	
CD (0.05)	**1.244**	**2.587**		**1.197**	**1.264**		**1.289**	**1.2899**	

Table.2 Effect of drip fertigation and biofertigation on specific leaf weight of coffee (*Coffea arabica*) cv. Chandragiri

Treatments	Specific Leaf Weight (mg cm^2)								
	Flowering stage			Vegetative stage			Fruit development stage		
	2008	2009	Mean	2008	2009	Mean	2008	2009	Mean
T_1	9.28	10.03	9.66	8.99	9.17	9.08	7.88	7.91	7.90
T_2	10.13	9.45	9.79	9.88	9.75	9.82	9.10	8.86	8.98
T_3	10.43	9.62	10.03	10.43	10.07	10.25	9.30	8.88	9.09
T_4	10.44	9.67	10.06	10.30	10.02	10.16	9.42	8.98	9.20
T_5	10.50	9.73	10.12	10.50	10.04	10.27	10.07	9.20	9.64
T_6	10.66	9.77	10.22	10.96	10.63	10.80	10.21	9.90	10.06
T_7	10.32	10.87	10.60	11.32	13.12	12.22	10.03	11.01	10.52
T_8	10.64	9.76	10.20	10.55	10.22	10.39	10.15	9.70	9.93
T_9	11.71	15.63	13.67	15.14	17.57	16.36	13.47	14.30	13.89
T_{10}	10.41	10.96	10.69	11.51	13.27	12.39	11.73	12.06	11.90
T_{11}	10.71	9.85	10.28	10.97	11.34	11.16	10.94	10.00	10.47
SED	**0.069**	**0.094**		**0.075**	**0.101**		**0.068**	**0.069**	
CD (0.05)	**0.144**	**0.196**		**0.156**	**0.217**		**0.142**	**0.145**	

Table.3 Effect of drip fertigation and biofertigation on dry matter production of coffee (*Coffea arabica*) cv. Chandragiri

Treatments	Dry matter production (kg/plant)								
	Vegetative stage		Mean	Flowering stage		Mean	Fruit Development stage		Mean
	2008	2009		2008	2009		2008	2009	
T_1	0.82	0.89	0.86	1.02	1.29	1.16	3.03	3.24	3.14
T_2	0.92	0.92	0.92	1.10	1.32	1.21	3.10	3.36	3.23
T_3	0.96	1.02	0.99	1.20	1.33	1.27	3.19	3.80	3.50
T_4	0.98	1.02	1.00	1.25	1.47	1.36	3.40	4.20	3.80
T_5	1.02	1.20	1.11	1.26	1.72	1.49	3.60	4.25	3.93
T_6	1.17	1.40	1.29	1.45	2.10	1.78	4.00	4.60	4.30
T_7	1.38	1.64	1.51	1.72	2.12	1.92	5.17	5.20	5.19
T_8	1.08	1.32	1.20	1.36	1.80	1.58	3.80	4.20	4.00
T_9	1.58	1.70	1.64	1.85	2.40	2.13	5.35	6.30	5.83
T_{10}	1.43	1.62	1.53	1.74	2.20	1.97	5.20	6.00	5.60
T_{11}	1.28	1.50	1.39	1.66	2.12	1.89	4.85	5.17	5.01
SED	**0.083**	**0.011**		**0.012**	**0.018**		**0.0490**	**0.0586**	
CD (0.05)	**0.174**	**0.023**		**0.025**	**0.038**		**0.1022**	**0.1222**	

Table.7 Effect of drip fertigation and biofertigation on nitrate reductase activity at vegetative, fruit development and harvesting stage of coffee (*Coffea arabica*) cv. Chandragiri

Treatments	Nitrate Reductase Activity (µg No_2 $g^{-1}h^{-1}$)								
	Vegetative stage			Fruit development stage			Harvesting stage		
	2008	2009	Mean	2008	2009	Mean	2008	2009	Mean
T_1	18.093	16.323	17.208	19.883	21.319	20.601	17.621	17.907	17.764
T_2	18.600	18.900	18.750	20.830	21.790	21.310	19.020	20.120	19.570
T_3	20.200	20.200	20.200	22.420	22.310	22.365	19.310	20.890	20.100
T_4	21.900	24.200	23.050	23.210	25.410	24.310	20.080	20.400	20.240
T_5	25.800	25.300	25.550	26.200	26.710	26.455	20.210	21.020	20.615
T_6	26.200	25.400	25.800	27.100	27.420	27.260	21.500	22.430	21.965
T_7	26.800	27.000	26.900	27.320	27.620	27.470	22.320	22.810	22.565
T_8	25.800	25.400	25.600	26.400	27.310	26.855	20.790	21.140	20.965
T_9	28.200	27.600	27.900	29.310	29.750	29.530	23.410	24.120	23.765
T_{10}	27.300	27.300	27.300	28.400	28.100	28.250	23.200	24.020	23.610
T_{11}	26.400	26.800	26.600	27.300	27.420	27.360	21.840	22.620	22.230
SED	**0.147**	**0.129**		**0.140**	**0.146**		**0.112**	**0.108**	
CD (0.05)	**0.306**	**0.271**		**0.292**	**0.304**		**0.234**	**0.225**	

Table.8 Effect of drip fertigation and biofertigation on IAA Oxidase activity at vegetative, fruit development and harvesting stage of coffee (*Coffea arabica*) cv. Chandragiri

Treatments	IAA Oxidase activity (µg unoxidised auxin)								
	Vegetative stage			Fruit development stage			Harvesting stage		
	2008	2009	Mean	2008	2009	Mean	2008	2009	Mean
T_1	26.850	35.860	31.355	32.620	34.620	33.620	30.500	33.300	31.900
T_2	25.600	33.920	29.760	31.400	33.600	32.500	29.210	32.200	30.705
T_3	25.200	31.400	28.300	30.220	32.800	31.510	28.900	29.210	29.055
T_4	24.810	30.800	27.805	29.400	31.600	30.500	26.600	26.800	26.700
T_5	24.600	25.100	24.850	26.800	30.200	28.500	22.200	23.300	22.750
T_6	24.600	25.000	24.800	27.800	30.600	29.200	22.300	22.600	22.450
T_7	23.950	23.600	23.775	26.200	26.500	26.350	21.200	21.300	21.250
T_8	24.610	26.400	25.505	28.400	31.400	29.900	24.200	24.800	24.500
T_9	19.962	19.844	19.903	24.092	24.387	24.239	18.585	18.585	18.585
T_{10}	22.650	22.300	22.475	25.600	25.600	25.600	20.120	20.220	20.170
T_{11}	24.200	24.500	24.350	26.700	30.400	28.550	21.600	21.600	21.600
SED	**0.109**	**0.198**		**0.162**	**0.162**		**0.168**	**0.196**	
CD (0.05)	**0.228**	**0.414**		**0.337**	**0.339**		**0.351**	**0.401**	

Table.9 Effect of drip fertigation and biofertigation on peroxidase Activity at vegetative, fruit development and harvesting stage of coffee (*Coffea arabica*) cv. Chandragiri

Treatments	Peroxidase Activity (changes in OD 430 nm per min^{-1} g^{-1} of leaves)								
	Vegetative stage			Fruit development stage			Harvesting stage		
	2008	2009	Mean	2008	2009	Mean	2008	2009	Mean
T_1	0.610	0.669	0.639	1.023	1.062	1.042	0.590	0.629	0.610
T_2	0.650	0.740	0.695	1.060	1.820	1.440	0.620	0.660	0.640
T_3	0.700	0.760	0.730	1.600	1.980	1.790	0.720	0.680	0.700
T_4	0.750	0.520	0.635	1.110	1.220	1.165	0.760	0.760	0.760
T_5	0.820	0.830	0.825	1.400	1.420	1.410	0.820	0.880	0.850
T_6	0.870	0.960	0.915	1.200	1.220	1.210	0.840	0.890	0.865
T_7	0.920	0.980	0.950	1.420	1.340	1.380	0.920	0.860	0.890
T_8	0.910	0.930	0.920	1.600	1.600	1.600	0.820	0.880	0.850
T_9	1.280	1.320	1.300	1.760	1.820	1.790	0.920	0.970	0.945
T_{10}	1.100	1.220	1.160	1.310	1.410	1.360	0.910	0.960	0.935
T_{11}	0.902	0.980	0.941	1.220	1.260	1.240	0.860	0.890	0.875
SED	**0.008**	**0.009**		**0.010**	**0.012**		**0.004**	**0.005**	
CD (0.05)	**0.016**	**0.019**		**0.021**	**0.024**		**0.009**	**0.010**	

Table.4 Effect of drip fertigation and biofertigation on total chlorophyll content of coffee (*Coffea arabica*) cv. Chandragiri

Treatments	Total Chlorophyll content (mg/g)											
	Vegetative stage		Mean	Flowering stage		Mean	Fruit Development stage		Mean	Harvesting stage		Mean
	2008	2009		2008	2009		2008	2009		2008	2009	
T_1	1.48	1.50	1.49	1.01	1.68	1.35	1.50	1.53	1.52	0.99	0.99	0.99
T_2	1.65	1.67	1.66	1.69	1.86	1.78	1.65	1.69	1.67	1.10	1.23	1.17
T_3	1.67	1.78	1.73	1.95	2.00	1.98	1.69	1.76	1.73	1.26	1.27	1.27
T_4	1.69	1.78	1.74	1.96	2.02	1.99	1.75	1.80	1.78	1.29	1.37	1.33
T_5	1.77	1.78	1.78	1.96	2.03	2.00	1.75	1.98	1.87	1.39	1.42	1.41
T_6	1.92	1.93	1.93	2.00	2.08	2.04	1.90	2.01	1.96	1.44	1.53	1.49
T_7	2.06	2.07	2.07	2.30	2.32	2.31	1.95	2.11	2.03	1.55	1.57	1.56
T_8	1.90	1.91	1.91	1.97	2.04	2.01	1.89	2.00	1.95	1.44	1.44	1.44
T_9	2.13	2.21	2.17	2.62	2.91	2.77	2.26	2.39	2.33	1.72	1.79	1.76
T_{10}	2.05	2.20	2.13	2.35	2.38	2.37	2.17	2.23	2.20	1.59	1.61	1.60
T_{11}	1.91	2.10	2.01	2.01	2.18	2.10	1.91	2.03	1.97	1.44	1.54	1.49
SED	**0.014**	**0.013**		**0.021**	**0.134**		**0.015**	**0.016**		**0.010**	**0.011**	
CD (0.05)	**0.029**	**0.028**		**0.043**	**0.280**		**0.031**	**0.030**		**0.021**	**0.023**	

Table.5 Effect of drip fertigation and biofertigation on CN ratio of coffee (*Coffea arabica*) cv. Chandragiri

Treatments	CN ratio											
	Vegetative stage		Mean	Flowering stage		Mean	Fruit Development stage		Mean	Harvesting stage		Mean
	2008	2009		2008	2009		2008	2009		2008	2009	
T_1	5.44	5.78	5.61	6.14	6.29	6.22	5.20	5.68	5.44	2.87	3.76	3.32
T_2	5.78	5.95	5.87	6.21	6.41	6.31	5.95	5.82	5.89	4.67	4.88	4.78
T_3	6.13	6.39	6.26	6.61	6.85	6.73	6.01	6.00	6.01	4.95	4.96	4.96
T_4	6.38	6.45	6.42	6.60	6.62	6.61	6.17	6.10	6.14	4.99	5.11	5.05
T_5	6.44	6.70	6.57	6.73	7.27	7.00	6.52	6.13	6.33	5.20	5.28	5.24
T_6	7.00	7.20	7.10	7.07	7.57	7.32	6.78	6.39	6.59	5.52	5.66	5.59
T_7	7.60	8.13	7.87	7.65	7.76	7.71	7.03	6.99	7.01	5.89	5.89	5.89
T_8	6.90	7.10	7.00	6.98	7.40	7.19	6.72	6.30	6.51	5.50	5.59	5.55
T_9	8.10	9.00	8.55	8.60	8.70	8.65	8.06	8.10	8.08	6.29	6.60	6.45
T_{10}	7.80	8.20	8.00	7.96	8.13	8.05	7.38	7.00	7.19	5.90	6.05	5.98
T_{11}	7.30	7.40	7.35	7.28	7.75	7.52	7.00	6.80	6.90	5.70	5.77	5.74
SED	**0.1365**	**0.1327**		**0.1866**	**0.1286**		**0.124**	**0.139**		**0.143**	**0.148**	
CD (0.05)	**0.2847**	**0.2767**		**0.3893**	**0.2682**		**0.258**	**0.288**		**0.298**	**0.308**	

Table.6 Effect of drip fertigation and biofertigation on Leaf Carbohydrate content of coffee (*Coffea arabica*) cv. Chandragiri

Treatments	Leaf Carbohydrate content (mg/100 g)											
	Vegetative stage		Mean	Flowering stage		Mean	Fruit Development stage		Mean	Harvesting stage		Mean
	2008	2009		2008	2009		2008	2009		2008	2009	
T_1	9.60	10.85	10.23	17.68	16.21	16.95	13.45	12.88	13.17	9.48	9.33	9.41
T_2	11.48	13.21	12.35	18.85	17.78	18.32	13.72	15.12	14.42	10.42	9.84	10.13
T_3	11.49	13.32	12.41	19.21	20.20	19.71	14.31	15.42	14.87	10.44	10.41	10.43
T_4	12.44	14.20	13.32	19.51	23.30	21.41	15.50	18.19	16.85	11.41	10.81	11.11
T_5	12.51	15.21	13.86	20.22	23.68	21.95	15.79	18.69	17.24	11.81	11.08	11.45
T_6	13.47	16.41	14.94	20.22	25.51	22.87	18.19	19.21	18.70	12.96	12.62	12.79
T_7	15.25	17.81	16.53	23.18	25.68	24.43	20.12	21.04	20.58	13.71	14.12	13.92
T_8	13.41	16.24	14.83	20.21	23.68	21.95	17.69	19.13	18.41	12.30	11.08	11.69
T_9	18.41	22.32	20.37	27.65	31.50	29.58	24.68	25.45	25.07	17.63	18.38	18.01
T_{10}	16.14	18.63	17.39	24.55	27.30	25.93	21.58	22.12	21.85	15.41	16.21	15.81
T_{11}	15.10	16.67	15.89	22.36	25.60	23.98	18.41	19.23	18.82	13.20	13.21	13.21
SED	**0.089**	**0.107**		**0.120**	**0.181**		**0.135**	**0.124**		**0.101**	**0.127**	
CD (0.05)	**0.186**	**0.223**		**0.251**	**0.377**		**0.281**	**0.259**		**0.210**	**0.265**	

Table.10 Effect of drip fertigation and biofertigation on yield characters of coffee (*Coffea arabica*) cv. Chandragiri

Treatments	Yield characters											
	Percentage of fruit retention		Mean	100 fruit weight (g)		Mean	Parchment weight (g)		Mean	100 fruit out turn (Clean coffee) (g)		Mean
	2008	2009		2008	2009		2008	2009		2008	2009	
T_1	76.14	84.60	80.37	142.49	151.50	147.00	65.59	69.90	67.75	26.94	28.80	27.87
T_2	82.56	85.90	84.23	146.60	153.79	150.20	67.10	70.71	68.91	27.50	29.19	28.35
T_3	81.99	86.30	84.14	147.10	155.77	151.44	67.60	70.70	69.15	27.70	29.20	28.45
T_4	81.61	86.90	84.25	147.40	153.80	150.60	67.82	71.62	69.72	27.90	29.60	28.75
T_5	82.56	87.50	85.03	147.90	155.70	151.80	67.81	71.60	69.71	28.00	29.61	28.81
T_6	83.13	89.50	86.31	149.30	158.70	154.00	68.81	73.11	70.96	28.14	30.18	29.16
T_7	87.02	91.60	89.31	151.90	160.00	155.95	69.83	73.12	71.48	28.89	30.54	29.72
T_8	83.13	87.50	85.31	149.20	156.20	152.70	68.80	71.80	70.30	28.00	29.68	28.84
T_9	91.20	96.00	93.60	154.30	162.30	158.30	70.90	74.60	72.75	29.30	31.00	30.15
T_{10}	87.40	92.00	89.70	153.60	160.70	157.15	70.60	73.90	72.25	29.20	30.80	30.00
T_{11}	85.02	89.80	87.41	149.70	158.72	154.21	68.82	73.00	70.91	28.40	30.19	29.30
SED	**0.565**	**0.608**		**0.985**	**1.109**		**0.435**	**0.473**		**0.187**	**0.209**	
CD (0.05)	**1.179**	**1.269**		**2.055**	**2.314**		**0.908**	**0.987**		**0.389**	**0.437**	

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