International Journal of Enhanced Research in Science, Technology & Engineering
ISSN: 2319-7463, Vol. 13 Issue 3, March-2024, Impact Factor: 8.375

Influence of Foliar Spray of Plant Growth Regulators on Physio-Chemical Properties during Pre Monsoon in Arabica Coffee Var. Sln. 9

Nagarathnamma, R.[1], Rajeshwari N. Babu[2], Muralidhara, H.R.[3]

[1]Research Assistant, Department of Plant Physiology, Central Coffee Research Institute
[2]Principal, Sahyadri College, Kuvempu University, Shivamogga, India
[3]Senior Liaison Officer, Coffee Board, Chikkamagaluru 577102

ABSTRACT

In a study on influence of foliar application of PGRs on physio-chemical properties of Arabica coffee during pre monsoon conducted at Coffee Research Sub Station, Chettalli results indicated that plant growth regulators were on par with each other but significantly superior to control and water sprayed plants. Higher relative water content (5.28 %), epicuticular wax (22.59 %), transpiration rate (108.43 %), stomatal conductance (33.3 %), intrinsic WUE (7.14 %), net photosynthesis (53.33 %), internal CO_2concentration(64.41 %), mesophyll efficiency (15.8 %), carboxylation efficiency (85.71 %), chlorophyll A (37.56 %), Chlorophyll B (19.39 %) and Total chlorophyll (32.36 %), Chlorophyll ratio (14.87 %) and nitrate reductase activity (59.04 %) was found in PGR treated plants during pre monsoon. The increased photosynthetic activities and parameters resulted in higher total carbohydrates (23.97 %), starch (49.02 %), soluble proteins (13.04 %), phenols (49.09 %) and proline(55.71 %) contents in coffee.

Key Words: PGRs, Coffee, RWC, Net Photosynthesis, Proline, Physiology

INTRODUCTION

Coffee is grown commonly in hilly tracts of Western Ghat regions of Karnataka. Being perennial plant, it suffers either it suffers during pre monsoon or excessive water logged conditions in monsoon. Among these two situations, pre monsoon condition is critical period during which the success of coffee crop depends on flowering. Improper and inadequate summer rainfall results in floral abnormalities in these cultivars. Irrigation is an important management practice to overcome the adverse effects of dry spells although excessive irrigation can adversely affect the yield. Early irrigation before the full maturity of flower buds can lead to floral abnormalities and running blossom which results in poor fruit set. Irrigation is an expensive operation and water resources are limited in many of the coffee estates, hence irrigating the plants at the correct time based on the needs of the plants is essential to increase the yield. Inadequate and uneven distribution of rainfall causes drought conditions in coffee, which affects vegetative growth, induces floral abnormalities, results in poor fruit set and prolonged drought after fruit set increases production of more pea berries and 'B' grade beans and ultimately loss in crop yield. Many physiological attributes like relative water content, epicuticular wax, photosynthetic efficiency,

Corresponding Author: Nagarathnamma R. Email ID: nagu_rediffmail.com, Research Assistant, Coffee Board, Chikkamagaluru , Karnataka, India – 577102

net photosynthesis, stomatal conductance, instantaneous and intrinsic water use efficiency, carboxylation and mesophyll efficiency, chlorophyll content etc get altered during the adverse and normal climatic conditions. So also many chemical compositions of plants like major nutrients, minor and micro nutrients, carbohydrates, starch, phenols, proline, soluble proteins etc also vary with climatic conditions to overcome adverse climatic conditions. These can be achieved during climatic variations by external supply of plant growth regulators. Exogenous application of plant growth regulators (PGRs) found useful to improve the physiological attributes (D'Souza *et al.*,1992) in coffee besides coffee yield. The foliar application of plant growth regulators also reported to be useful in improving the crop yield, vegetative growth besides quality. proline accumulation has been extensively employed in screening genotypes for drought tolerance besides physiological efficiency. Besides proline, a range of solutes accumulate during osmotic adjustment in both fully expanded and growing tissues. The solutes include inorganic ions, soluble carbohydrates and amino acids (Munns*et al.,* 1979; Ravens *et al.,* 1979; Jones *et al.,* 1980). There are also reports that nitrate reductase activity is adversely affected by moisture stress. Sairam and Dube (1984) have observed that stability of enzyme activity during moisture stress might be associated with drought tolerance.An attempt has been made in a study to evaluate the epicuticular wax (ECW) as one of the parameters for screening the cultivars for drought tolerance in coffee. The higher content of ECW with less decrease of Relative Water Content (RWC) during soil moisture stress period in coffee plants was observed (Anonymous, 2002). Increase of epicuticular wax content (ECW) during summer month and decrease during monsoon period in both arabica and robusta plants were reported and considered that this trait could be an important trait to assess drought tolerance ability in coffee plants (Anonymous, 2005; Divya, 2008).

The role of endogenous level of hormones directly or indirectly involved in physiological processes by exogenous application of plant growth regulators invites great attention in coffee.Under the circumstances of climatic variations, coffee undergoes many physio-chemical changes to overcome the variations of climate. In this regard, external plant growth regulators play important role during pre monsoon in managing the physiological properties and chemical composition of plants to get consistent higher yields and quality. As many growth regulators used in coffee were of chemical in nature, a study on the effect of foliar spray of natural plant growth regulators in comparison with chemical PGRs on physio-chemical properties of coffee was studied.

MATERIAL AND METHODS

Treatments:The study was conducted at Coffee Research sub Station, Chettalli during 2016 to 2018 for two seasons to confirm the results. The study was taken up in 20 year old Arabica coffee variety Sln. 9. Seven treatments were finalized as given below including the standard recommended PGR.

T1: No spray (control)
T2: Water spray (Control)
T3: Plant extract (*Gliricidia sepia*&*Lantana camara*) 1%
T4: Arka Microbial Consortium 1 % (ICAR)
T5: *Lantana camera* + Dimethyl *Sulfoxide* (DMSO) + $CuSo_4$ 1 %
T6: Salicylic acid 0.025 %
T7: Alpha (α) Napthyl Acetic Acid 0.025 % (Standard Recommendation in coffee)

Plant Material:Trial was conducted using Arabica Coffee cultivar Sln. 9. This is a cross between the arabica genotypes 'Hybrido de Timor (HDT)' and 'Tafarikela' and very popular among the growers. A tall Arabica variety with drooping branches and long internodes. The leaves are broader with bronze tip. The fruit clusters are tight, early ripening and gives around 65-70% `A' grade beans. A crop yield of 1000 Kg clean coffee per ha could be expected under well maintained estates.

Arka Microbial Consortia:Arka Microbial Consortium, developed by ICAR is a carrier based product which contains N fixing, P & Zn solubilizing and plant growth promoting microbes in a single formulation. 10 ml formulation was mixed in one liter water and used for spraying.

***Glyiricidia and Lantana Extraction*:** These being found in all tropical areas of coffee growing regions are available in plenty. Hence, were used to prepare extraction. Leaves of both *Glyricidia sepia* and *Lantana camara* were collected fresh. 2 Kg leaves of both were chopped into small pieces and immersed in 10 litre of boiled water and kept for 24 hours. Then the solution was filtered using a cloth and the filtrate was mixed with 200 litres of water. The extract so prepared was sprayed to the plants covering the lower surface of the leaves.

Dimethyl Sulfoxide (DMSO):Among the more important properties of DMSO, its ability to readily penetrate biological membranes to increase the uptake of essential plant nutrients and to influence the growth habit of crops is very important. Besides, Dimethyl Sulfoxide (DMSO) is a widely used solvent for the extraction of chlorophylls from leaves of higher plants. The method is preferred because the time-consuming steps of grinding and centrifuging are not required and the extracts are stable for a long time period (Dimosthenis Nikolopoulos*et al* 2008). Hence, in this study, to increase the efficacy and solubility of Lantana camera extract (1 %), DMSO and $CuSO_4$ were used in combination with these extracts as one of the treatments.

Salicylic Acid: Salicylic acid (SA) is one of the potential plant growth regulators (PGRs) that regulate plant growth and development by triggering many physiological and metabolic processes. Being less studied chemical in coffee, this was used as one of the treatments in the present study in comparison with the standard recommendation.

αNAA - Alpha Napthyl Acetic Acid *:* This is tested and recommended as standard in coffee by CCRI (Anon, 2014) mostly used only for inducing flowering and enhancing yield of coffee. Hence, this is included as one of the treatments for standard comparison.

Treatment Imposition:In this study, in order to understand the physio-chemical changes that occur in coffee due to foliar spray of plant growth regulators, the treatments were imposed twice. Once during post blossom and other one in pre monsoon. Observations were recorded both during pre monsoon in summer

Observations and Data Analysis*:* Observations were made one month after the second spray on various physio-chemical properties using standard prescribed methodologies. The observations recorded were analyzed by Randomized Complete Block Design and significance was tested 5 % probability.

RESULTS

Relative Water Content and Epicuticular Wax: Relative water content in plants was significantly and statistically high in PGR treated plants as compared to control and water sprayed plants. On an average over two years, PGR treated plants had relative water content ranging from 85.72 to 86.07 % which is 5.03 to 5.46 % higher compared to the relative water content of control (81.62 %) and water sprayed (81.86 %) plants. Data on relative water content and epicuticular wax is presented in Table 1. The plants treated with NAA had the highest epicuticular wax and the mean of two season indicated that epicuticular wax of plants was highest 21.14 µg/Cm^{2}in T7 followed by T6 (21.1 µg/Cm^2), T5 (21 µg/Cm^2), T3 (20.97 µg/Cm^2), T4 (20.96 µg/Cm^2) which were 22.15 to 23.2 % increase over control (17.16 µg/Cm^2) and water sprayed plants (17.27 µg/Cm^2).

Table 1. Relative water content and epicuticular wax as affected by Growth Regulators in yielding plants of Arabica Variety Sln. 9 in pre monsoon

Treatments	Relative Water Content (%)			Variation (%)	Epicuticular Wax (µg/Cm^2)			Variation (%)
	Year 1	Year 2	Mean		Year 1	Year 2	Mean	
T1	82.43	80.80	81.62		16.01	18.30	17.16	
T2	82.91	80.80	81.86		16.13	18.40	17.27	
T3	87.44	84.00	85.72	5.03	16.94	25.00	20.97	22.24
T4	88.14	84.00	86.07	5.46	16.91	25.00	20.96	22.15
T5	87.71	83.90	85.81	5.13	16.99	25.00	21.00	22.38
T6	87.91	84.10	86.01	5.38	17.19	25.00	21.10	22.97
T7	87.95	84.10	86.03	5.40	17.37	24.90	21.14	23.20
F Test 5 %	61.788*	139.259*	Mean	5.28	16.551*	730.905*	Mean	22.59
CD 5 %	0.791	0.328			0.312	0.293		

Transpiration Rate (E) and Stomata Conductance (gs): Data on transpiration rate and stomata conductance is presented in Table 2. The mean transpiration rate ranged from 1.59 to 1.71 m moles m^{-2} s^{-1} in the PGR treated plants which were 100 to 114.47 % increase over transpiration rate of control and water sprayed plants (0.8 m moles m^{-2} s^{-1}). Over two years, the mean stomatal conductance was 0.08 moles m^{-2} s^{-1} in the plants of PGR treatments compared to 0.06 moles m^{-2} s^{-1} in control and water sprayed in plants. In both the years, stomatal conductance was statistically and significantly higher in PGR treated plants compared to control and water sprayed treatments but were on par among them.

Instantaneous Water Use Efficiency and Intrinsic Water Use Efficiency: The mean of two seasons indicated that instantaneous water use efficiency in PGR treated plants ranged from 6.15 to 6.75 µmoles mmol^{-1} against 10.45 µmoles mmol^{-1} in the control and 9.48 in µ moles mmol^{-1} in water sprayed plants, which was 35.38 to 41.17 % lesser over control (Table 3).Intrinsic water use efficiency was statistically and significantly high in all PGR treated plants compared to control and water sprayed plants in both the years of study (Table 3). The average Intrinsic water use efficiency in PGR treated plants ranged from 120.02 µmol mol^{-1} to 124.17 µmol mol^{-1} compared to 113 µmol mol^{-1} under control and 105.41 µmol mol^{-1} with water sprayed plants, which were 6.21 to 8.81 % higher compared to control.

Table 2. Transpiration rate and stomatal conductance as affected by Growth Regulators in yielding plants of Arabica Variety Sln. 9 in pre monsoon

Treatments	Transpiration Rate (E) (m moles m^{-2} s^{-1})			Variation (%)	Stomatal Conductance (gs) (moles m^{-2} s^{-1})			Variation (%)
	Year 1	Year 2	Mean		Year 1	Year 2	Mean	
T1	1.19	0.40	0.80		0.056	0.056	0.06	
T2	1.19	0.40	0.80		0.056	0.054	0.06	
T3	1.98	1.20	1.59	100.00	0.078	0.078	0.08	33.3
T4	2.00	1.40	1.70	113.84	0.083	0.084	0.08	33.3
T5	2.00	1.30	1.65	106.92	0.075	0.08	0.08	33.3
T6	1.99	1.30	1.65	106.92	0.078	0.08	0.08	33.3
T7	2.01	1.40	1.71	114.47	0.079	0.079	0.08	33.3
F Test 5 %	161.365*	59.579*	Mean	108.43	11.997*	36.173*	Mean	33.3
CD 5 %	0.076	0.139			0.009	0.005		

Table 3. Instantaneous and intrinsic water use efficiency as affected by Growth Regulators in yielding plants of Arabica Variety Sln. 9 in pre monsoon

Treatments	Instantaneous Water Use Efficiency (IWUE) (µ moles $mmol^{-1}$)			Variation (%)	Intrinsic Water Use efficiency (Pn/gs) (µmol mol^{-1})			Variation (%)
	Year 1	Year 2	Mean		Year 1	Year 2	Mean	
T1	5.27	15.62	10.45		112.86	113.14	**113.00**	
T2	4.9	14.06	9.48		105.89	104.93	**105.41**	
T3	4.84	8.66	6.75	**-35.38**	121.93	126.41	**124.17**	
T4	4.8	7.49	6.15	**-41.17**	126.23	115.15	**120.69**	**6.81**
T5	4.76	8.11	6.44	**-38.39**	120.28	120.93	**120.61**	**6.73**
T6	4.77	8.06	6.42	**-38.58**	118.31	121.72	**120.02**	**6.21**
T7	4.73	7.67	6.20	**-40.64**	122.35	123.56	**122.96**	**8.81**
F Test 5 %	2.173NS	32.909*	Mean	-38.83	4.017*	3.153*	**Mean**	**7.14**
CD 5 %	0.309	1.448			8.358	10.189		

Net Photosynthesis and Internal Co_2 concentration: Table 4 shows data on net photosynthesis and internal CO_2 concentration. Similar to other parameters, net photosynthesis was also varying significantly. Net photosynthesis was significantly and statistically lower in the plants of control and water spray compared to PGR treated plants in both the years. Whereas, the net photosynthesis remained on par in plants treated with PGRs. On an average, net photosynthesis ranged from 9.46 to 9.55 µ moles m^{-2} s^{-1} among the PGR treated plants, which were 52.83 to 54.28 % higher as against 5.7 µ moles m^{-2} s^{-1} in water sprayed and 6.19 µ moles m^{-2} s^{-1} in control plants and 5.7 µ moles m^{-2} s^{-1} in water sprayed plants. As an indicator of increased photosynthesis, over two years, the mean indicated that PGR plants had internal CO_2 concentration ranging from 248.97 to 253.79 µl l^{-1}, which was 63.75 to 66.92 % higher when compared to 152.04 µl l^{-1} internal CO_2 concentration in control and 146.89 µl l^{-1} in water sprayed plants.

Table 4. Net photosynthesis and internal Co_2 concentration as affected by Growth Regulators in yielding plants of Arabica Variety Sln. 9 in pre monsoon

Treatments	Net Photosynthesis (Pn) (µ moles m^{-2} s^{-1})			Variation (%)	Internal CO_2 Concentration (Ci) (µl l^{-1})			Variation (%)
	Year 1	Year 2	Mean		Year 1	Year 2	Mean	
T1	6.12	6.26	6.19		152.5	151.58	152.04	
T2	5.75	5.64	5.70		151.19	142.59	146.89	
T3	9.52	9.58	9.55	54.28	254.51	253.07	253.79	66.92
T4	9.54	9.49	9.52	53.72	243.41	254.85	249.13	63.86
T5	9.46	9.46	9.46	52.83	249.86	248.08	248.97	63.75
T6	9.43	9.50	9.47	52.91	248.33	249.62	248.98	63.76
T7	9.44	9.49	9.47	52.91	251.45	246.51	248.98	63.76

F Test 5 %	237.436*	287.106*	Mean	53.33	132.98*	274.068*	Mean	64.41
CD 5 %	0.276	0.253			10.16	7.491		

Mesophyll Efficiency and Carboxylation Efficiency: Mesophyll efficiency being one of the most important photosynthetic parameter was found statistically significant and high in PGR treated plants compared to control and water sprayed plants during both the years of study (Table 5). Over the two years, mesophyll efficiency ranged from 3157.95 to 3253.33 in PGR treated plants which were 13.75 to 17.19 % increase over control (2776.3) and water sprayed plants (2690).As shown in Table 5, the mean carboxylation efficiency was 0.035 $\mu molm^{-2}s^{-1}(\mu l\ l^{-1})^{-1}$ in T3 and T4 followed by 0.034 $\mu molm^{-2}s^{-1}(\mu l\ l^{-1})^{-1}$ in T5, 0.030 $\mu molm^{-2}s^{-1}(\mu l\ l^{-1})^{-1}$ in T6 and 0.029 $\mu molm^{-2}s^{-1}(\mu l\ l^{-1})^{-1}$ in T7 which were 65.71 to 100 % increase over control and water sprayed plants (0.018 $\mu molm^{-2}s^{-1}(\mu l\ l^{-1})^{-1}$).

Chlorophyll Content (mg/g): On an average of two years, the highest 2.38 mg/g chlorophyll ‘a’ was present in the plants of T4 and T7 followed by 2.36 mg/g in T5 and T6, 2.35 mg/g in T3 which were 36.63 to 38.37 % increase over chlorophyll ‘a’ control (1.72 mg/g) and water sprayed plants (1.67 mg/g) of the study. Data on Chlorophyll ‘a’ and ‘b’ is shown in Table 6.6.

Similarly, chlorophyll ‘b’ also varied significantly among the PGR treated and control plants in both the years. PGR treated plants had statistically on par chlorophyll ‘b’. On an average of two years, the highest 0.805 mg/g chlorophyll ‘b’ was present in the plants of T6 followed by 0.785 mg/g in T3 and T4, 0.77 mg/g in T5 and 0.765 mg/g in T7 which were 16.79 to 22.9 % increase over Chlorophyll ‘b’ in control (0.655 mg/g) and water sprayed plants (0.645 mg/g).

Table 5. Mesophyll and Carboxylation efficiency as affected by Growth Regulators in yielding plants of Arabica Variety Sln. 9 in pre monsoon

Treatments	Mesophyl Efficiency (gm) Ci/gs			Variation (%)	Carboxylation Efficiency ($\mu molm^{-2}s^{-1}(\mu l\ l^{-1})^{-1}$)			Variation (%)
	Year 1	Year 2	Mean		Year 1	Year 2	Mean	
T1	2809.36	2742.96	**2776.16**		0.020	0.015	0.018	
T2	2711.81	2668.17	**2689.99**		0.020	0.016	0.018	
T3	3176.36	3330.29	**3253.33**	**17.19**	0.030	0.040	0.035	100.00
T4	3324.73	3086.84	**3205.79**	**15.48**	0.030	0.040	0.035	100.00
T5	3318.06	3156.94	**3237.50**	**16.62**	0.030	0.038	0.034	94.29
T6	3117.46	3198.43	**3157.95**	**13.75**	0.020	0.039	0.030	68.57
T7	3241.8	3196.61	**3219.21**	**15.96**	0.020	0.038	0.029	65.71
F Test 5 %	6.28*	7.926*	**Mean**	**15.80**	19.197*	122.087*	Mean	85.71
CD 5 %	239.519	217.702			0.002	0.002		

Table 6. Chlorophyll ‘a’ and ‘b’ as affected by Growth Regulators in yielding plants of Arabica Variety Sln. 9 in pre monsoon

Treatments	Chlorophyll ‘a’ Content (mg/g Fresh Wt)			Variation (%)	Chlorophyll ‘b’ Content (mg/g Fresh Wt)			Variation (%)
	Year 1	Year 2	Mean		Year 1	Year 2	Mean	
T1	1.64	1.80	1.72		0.51	0.80	0.655	
T2	1.64	1.70	1.67		0.49	0.80	0.645	
T3	2.30	2.40	2.35	36.63	0.67	0.90	0.785	19.85
T4	2.36	2.40	2.38	38.37	0.67	0.90	0.785	19.85
T5	2.32	2.40	2.36	37.21	0.64	0.90	0.770	17.56
T6	2.42	2.30	2.36	37.21	0.71	0.90	0.805	22.90
T7	2.36	2.40	2.38	38.37	0.63	0.90	0.765	16.79
F Test 5 %	281.402*	35.48*	Mean	37.56	5.566*	19.563*	Mean	19.39
CD 5%	0.050	0.125			0.088	0.029		

Total Chlorophyll and Chlorophyll Ratio: On an average, total chlorophyll content ranged from 3.10 to 3.17 mg/g in PGR treated plants which was 30.59 to 33.54 % increase over control (2.37 mg/g) and water sprayed plants (2.32 mg/g). In both the years, PGR treated plants had total on par with each other and significantly higher compared to control and water sprayed plants. Data on total chlorophyll and chlorophyll a/b ratio is shown in Table 7.The mean of two years indicated that NAA treated plants had the highest chlorophyll ratio of 3.31 followed by 3.22 in Microbial consortium and DMSO treated plants, 3.16 in *Glyricidia + Lantana* extract and 3.10 in Salicylic acid treated plants which were 11.13 to 18.85 % increase over control (2.79) and water spray (2.9) treatments.

Table 7. Total chlorophyll and chlorophyll a/b ratio as affected by Growth Regulators in yielding plants of Arabica Variety Sln. 9 in pre monsoon

Treatments	Total Chlorophyll (mg/g Fresh Wt)			Variation (%)	Chlorophyll a/b Ratio			Variation (%)
	Year 1	Year 2	Mean		Year 1	Year 2	Mean	
T1	2.14	2.60	2.37		3.36	2.21	2.79	
T2	2.13	2.50	2.32		3.54	2.25	2.90	
T3	2.97	3.30	3.14	32.28	3.62	2.69	3.16	13.29
T4	3.02	3.30	3.16	33.33	3.70	2.73	3.22	15.44
T5	2.96	3.30	3.13	32.07	3.84	2.60	3.22	15.62
T6	3.13	3.20	3.17	33.54	3.59	2.60	3.10	11.13
T7	2.99	3.20	3.10	30.59	3.97	2.65	3.31	18.85
F Test 5 %	105.541*	43.236*	Mean	32.36	0.62NS	11.023*	Mean	14.87
CD 5%	0.102	0.132			0.623	0.158		

Nitrate Reductase Activity (µmoles/Hour/g Fresh weight): The data is presented in Table 8. Nitrate reductase activity was found significantly and statistically high in both the years of study as compared to control and water treated plants. Over two years of study, PGR treated plants recorded Nitrate Reductase Activity ranging from 0.81 to 0.84 µmoles/Hour/g which were 55.77 % to 61.54 % increase over control (0.52 µmoles/Hour/g) and water sprayed plants (0.50 µmoles/Hour/g).

Table 6.8. Nitrate reductase activity as affected by Growth Regulators in yielding plants of Arabica Variety Sln. 9 in pre monsoon

Treatments	Nitrate Reductase Activity (µmoles/Hour/g of Fresh wt)			Variation (%)
	Year 1	Year 2	Mean	
T1	0.54	0.48	0.52	
T2	0.50	0.47	0.50	
T3	0.75	0.85	0.83	58.65
T4	0.76	0.86	0.83	59.62
T5	0.78	0.85	0.84	61.54
T6	0.72	0.87	0.81	55.77
T7	0.76	0.86	0.83	59.62
F Test 5 %	95.798*	81.122*	Mean	59.04
CD 5%	0.029	0.05		

Total Carbohydrates and Starch Content: Over the two years of study, highest Total carbohydrates was recorded under T6 (6.88 %), followed by *Glyricidia + Lantana* extract (6.8 %), DMSO (6.79 %) and Microbial Consortium (6.77 %) which were 23.34 to 25.34 % increase over control (5.49 %) and water sprayed plants (5.45 %). Total carbohydrate and starch contents are presented in Table 9.Over the period of study, average starch content was 2.72 % in T7, 2.7 % in T5, 2.69 % in T4, 2.65 % in T6 and 2.63 % in T3, which were 46.24 to 51.53 % increase over control (1.8 %) and water spray treatment (1.83 %).

Table 9. Total carbohydrates and starch content as affected by Growth Regulators in yielding plants of Arabica Variety Sln. 9 in pre monsoon

Treatments	Total Carbohydrates			Variation (%)	Starch Content (%)			Variation (%)
	Year 1	Year 2	Mean		Year 1	Year 2	Mean	
T1	5.47	5.50	5.49		1.49	2.10	1.80	
T2	5.39	5.50	5.45		1.66	2.00	1.83	
T3	6.40	7.20	6.80	23.97	2.45	2.80	2.63	46.24

T4	6.53	7.00	6.77	23.34	2.47	2.90	2.69	49.58
T5	6.47	7.10	6.79	23.70	2.49	2.90	2.70	50.14
T6	6.55	7.20	6.88	25.34	2.50	2.80	2.65	47.63
T7	6.45	7.10	6.78	23.52	2.54	2.90	2.72	51.53
F Test 5 %	89.261*	42.76*	Mean	23.97	83.861*	62.101*	Mean	49.02
CD 5%	0.134	0.291			0.121	0.120		

Phenol Content (%) and Proline Content (µmoles/g of Dry Wt): Over two years, the highest phenol content of 0.38 % was found in the plants treated with NAA followed by 0.373 % in T4, 0.37 % in T6, 0.368 % in T3 and the least 0.355 % in T5 treatment plants. These were 43.43 to 53.54 % increase over control (0.248 %) and water sprayed plants (0.235 %). Table 11 shows data of phenol content.When the average was taken, over two years, proline content was 2.09 µmoles/g in all PGR treated plants except 2.0 µmoles/g in Salicylic acid treated plants which were 57.14 to 50 % increase over control (1.33 µmoles/g) and water sprayed plants (1.38 µmoles/g). Data is given in Table 10.

Table 10. Phenol and proline content as affected by Growth Regulators in yielding plants of Arabica Variety Sln. 9 in pre monsoon

Treatments	Phenol Content (%)			Variation (%)	Proline Content (µmoles/g of Dry Wt)			Variation (%)
	Year 1	Year 2	Mean		Year 1	Year 2	Mean	
T1	0.21	0.285	0.248		1.26	1.4	1.33	
T2	0.18	0.29	0.235		1.26	1.5	1.38	
T3	0.27	0.465	0.368	48.48	1.77	2.4	2.09	57.14
T4	0.26	0.485	0.373	50.51	1.78	2.4	2.09	57.14
T5	0.25	0.46	0.355	43.43	1.78	2.4	2.09	57.14
T6	0.27	0.47	0.37	49.49	1.69	2.3	2	50
T7	0.27	0.49	0.38	53.54	1.78	2.4	2.09	57.14
F Test 5 %	11.599*	40.374*	Mean	49.09	46.406*	284.85*	Mean	55.71
CD 5%	0.026	0.035			0.088	0.064		

Soluble Protein: During both the years, soluble protein the PGR treated plants was statistically and significantly higher compared to control but were on par with each other. The mean soluble protein varied from 24.5 to 24.83 mg/g in PGR treated plants which were 12.41 to 19.93 % increase over control (21.79 mg/g) and water sprayed plants (21.78 mg/g).

Table 6.11. Soluble protein content as affected by Growth Regulators in yielding plants of Arabica Variety Sln. 9 in pre monsoon

Treatments	Soluble Protein (mg/g Fresh Wt)			Variation (%)
	Year 1	Year 2	Mean	
T1	18.98	24.6	21.79	
T2	19.05	24.5	21.78	
T3	22.17	26.9	24.54	12.6
T4	21.95	27.7	24.83	13.93
T5	22.08	27.1	24.59	12.85
T6	22.09	26.9	24.5	12.41
T7	21.93	27.5	24.72	13.42
F Test 5 %	125.003*	29.884*	Mean	13.04
CD 5%	0.324	0.596		

DISCUSSION AND CONCLUSION

From the results it can be seen that all plant growth regulators enhanced most of the physiological and chemical properties of Arabica in pre-monsoon significantly compared to control and water sprayed plants. And all the PGRs influenced almost on par with each other, where as both control and water sprayed plants had almost equal or on par physiological properties significantly lower to PGRs. Lower relative water content in control and water sprayed plants (5.28 % lower) could be attributed to lower epicuticular wax (22.59 % less) as c. The higher relative water content in PGR treated plants could be attributed to higher transpiration rate (108.43 % higher). Because of higher transpiration rate, PGR treated plants had extracted more water from roots and thereby resulted in higher turgidity of leaves. Higher internal CO_2 concentration (64.41 % higher) in PGR treated plants could be attributed to higher stomatal conductance (33.3 % high), which enhanced the exchange of gases across the atmosphere and leaf tissue. This in turn resulted in higher net photosynthesis in PGR treated plants (53.33 % high) compared to control and water sprayed plants. The increased CO_2 concentration has lead to increased mesophyll efficiency (15.8 %) and carboxylation efficiency (85.71 %) in PGR treated plants.

Higher net photosynthesis could be attributed to increased chlorophyll A (37.56 %) and B (19.39 %) and total chlorophyll (32.36 % high) contents that were resulted in PGR treated plants as compared to control and water sprayed plants. There was an increase of 59.04 % increase in nitrate reductase activity in PGR treated plants. The increased photosynthetic parameters in turn resulted in increased total carbohydrates (23.97 %) and starch (49.02 %). As indicator of plant resistance, in pre monsoon, increased phenol (49.09 %) and soluble proteins (13.04 %). As an indicator to stress increased proline (55.71 %) was also found in PGR treated plants compared to control and water sprayed plants. Mallikarjun*et al.*,.(2000) reported maintenance of higher physiological water use efficiency and carboxylation efficiency in drought tolerant cultivars at water stress conditions Studies conducted for two seasons using thirteen coffee genotypes indicated significantly higher net photosynthesis (pn) in Sln. 9, Sln. 1 R and Sln. 12 compared to rest of the cultivars. Under stressful conditions, these phenolics are drastically accumulated in the plant for survival (Lattanzio, 2013; Sharma et al., 2019). Phenolic compounds, namely esters, flavonoids, lignin, and tannins, act as antioxidants and fight against these abiotic stress conditions in the plant cells (Selmar, 2008).It was inferred in a study that proline accumulation is one of the major mechanisms of drought tolerance in plants (Rao et al., 2015; Yadav et al., 2019). The results can be supported by the earlier work of D Souza *et al.*, (2009) on biochemical and physiological changes in drought conditions which indicated that Soluble protein, proline and epicuticular wax increase significantly during drought and all other gas exchange parameters such as net photosynthesis, stomatal conductance, transpiration rate, carboxylation efficiency and instantaneous water use efficiency reduced significantly during the drought and returned to normal after relieving from stress. Chandragiri was found moderately drought tolerant compared to Sln. 9.

Overall study on use of plant growth regulators indicated that foliar application of plant growth regulators trigger the production of stress hormones and chemicals in coffee plants to mitigate drought situations in pre monsoon season resulting in better performance. Application of Glyricidia+Lantana, Lantana+DMSO, Microbial consortium, Salicylic acid and NAA had equal effects to manage physio-chemical properties of Arabica coffee in pre monsoon conditions.

ACKNOWLEDGMENT

The main author acknowledges greatly the contribution of third Author of this article for having rendering his valuable guidance in statistical analysis of the data and preparation of this manuscript. The main author greatfuly acknowledges the high valued suggestions and guidance of the second author for conducting this field trial. And the author is also very thankful to the Head, Division of Plant Physiology, The Deputy Director, Coffee Research Sub Station, Chettallli and The Director of Research, CCRI for having co-operated in taking up this study.

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