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Influence of Foliar Spray of Plant Growth Regulators on Physio-Chemical Properties of *Coffea arabica* Var. Sln. 9 during Post Monsoon

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ABSTRACT

In a study on influence of foliar application of PGRs on physio-chemical properties of Arabica coffee during post monsoon conducted at Coffee Research Sub Station, Chettalli during 2016-2018, results indicated that plant growth regulators were on par with each other but significantly superior to control and water sprayed plants. Having overcome the excessive moisture stress of monsoon, PGR treated plants had higher relative water content (10.39 %), epicuticular wax (24.74 %), transpiration rate (37.85 %), stomatal conductance (43.45 %), instantaneous WUE (16.47 %), intrinsic WUE (16.34 %), net photosynthesis (63.9 %), internal CO_2 concentration (67.44 %), mesophyll efficiency (18.72 %), carboxylation efficiency (39.15 %), chlorophyll A (20.52%), Chlorophyll B (57.04 %) and Total chlorophyll (28.97 %), Chlorophyll ratio (-27.02 %) and nitrate reductase activity (28.39 %) during post monsoon and performed better than the control and water sprayed plants. The increased photosynthetic activities and parameters resulted in higher total carbohydrates (24.37 %), starch (51.36 %), soluble proteins (23.49 %), phenols (25 %) and proline (53.17 %) contents in coffee.

Key Words: PGRs, Coffee, Net Photosynthesis, Proline, Coffee Physiology, Glyricidia, Lantana, Microbial consortium, Salicylic acid, NAA

INTRODUCTION

Coffee is grown commonly in hilly tracts of Western Ghat regions of Karnataka that receive heavy rains during monsoon, accounting to 60-70 % of the total annual rainfall. Monsoon condition is very critical period during which the success of coffee crop depends on maintenance of optimum moisture and good drainage, prevention of fruits drop and hormonal balance. Severe monsoon usually leads to wet feet condition of coffee plants in which severe hormonal imbalance will occur leading to black rot and pre mature fruit drop due to lack of aeration and high relative humidity. Hence, there is a need to manage the situation of monsoon to increase the yield. However, in monsoon it is very difficult to take up any kind of spray either chemicals or plant growth regulators due to continuous wet condition and rains to manage physiology of coffee plants. After monsoon, coffee once again faces moisture stress, a long dry condition of post monsoon. Hence, there is a need to take up preventive measure in pre monsoon itself such that coffee manages physiologically during monsoon and better crop can be achieved.

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Many physiological attributes like relative water content, epicuticular wax, photosynthetic efficiency, 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 monsoon and post monsoon season 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 during post monsoon 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 cessation of monsoon rains 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 of plants under the study varied significantly in both the years with PGR treatments significantly as compared to control and water sprayed plants (Table 1). The mean relative water content was highest 88.36 % with Microbial consortium followed by 88.21 with *Glyricidia* + *Lantana* Extract, 88.02 with NAA, 87.94 with DMSO and 87.5 with Salicylic acid treatments which were 10.11 to 10.75 % increase over control (73.47 %) and water sprayed plants (75.86 %).. Both the years, PGR treated plants had epiculticular wa statistically on par with each other but were significantly higher compared to control and water sprayed plants. Over a period of two years study, Epicuticular wax ranged from 25.85 µg/Cm^2 to 26.18 µg/Cm^2 which were 23.86 to 25.42 % increase over control (20.87 µg/Cm^2) and water sprayed plants (20.35 µg/Cm^2).

Stomatal Conductance (gs) and Transpiration Rate (E): The mean stomatal conductance over two years indicated that Microbial consortium, DMSO, Salicylic acid plants had same stomatal conductance of 0.08 followed by 0.078 moles m^{-2} s^{-1} in NAA and 0.077 moles m^{-2} s^{-1} in *Glyricidia* + *Lantana* extract treated plants which were 39.09 to 45.45 % increase over stomatal conductance of control and water treated plants (0.055 moles m^{-2} s^{-1}). Data is presented in Table 2. The mean of two seasons indicated that highest transpiration rate was found with DMSO (2.02 m moles m^{-2} s^{-1}) followed by Salicylic acid (2.0 m moles m^{-2} s^{-1}), NAA (1.99 m moles m^{-2} s^{-1}), *Glyricidia* + *Lantana* (1.98 m moles m^{-2} s^{-1}) and Microbial consortium (1.95 m moles m^{-2} s^{-1}) which were 35.07 to 39.93 % increase over control (1.44 m moles m^{-2} s^{-1}) and water sprayed (1.45 m moles m^{-2} s^{-1}) plants.

Instantaneous Water Use Efficiency and Intrinsic Water Use Efficiency: Table 3 shows data on instantaneous and intrinsic water use efficiency. The mean Instantaneous Water Use Efficiency was found highest in the plants treated with Microbial consortium plants (4.95 µ moles mmol^{-1}) followed by *Glyricidia* + *Lantana* (4.87 µ moles mmol^{-1}), NAA (4.85 µ moles mmol^{-1}), Salicylic acid (4.82 µ moles mmol^{-1}), DMSO (4.77 µ moles mmol^{-1}), water sprayed (4.30 µ moles mmol^{-1}) and control (4.17 µ moles mmol^{-1}). Instantaneous water use efficiency were 14.53 to 18.73 higher in PGR treated plants compared to Instantaneous Water Use Efficiency of control water sprayed plants. The mean Intrinsic Water Use efficiency was highest with *Glyricidia* + *Lantana* (128.25 µmol mol^{-1}) followed by NAA (125.67 µmol mol^{-1}), DMSO (122.54 µmol mol^{-1}), Microbial consortium (121.92 µmol mol^{-1}) and lastly Salicylic acid (121.78 µmol mol^{-1}) treated plants which were 14.22 to 20.3 % increase over Intrinsic Water Use efficiency in control (106.61 µmol mol^{-1}) and water sprayed plants (110.76 µmol mol^{-1}).

Net Photosynthesis and Internal CO_2 Concentration: On an average over two years, *Glyricidia* + *Lantana* had the highest net photosynthesis 9.52 followed by Salicylic acid and NAA (9.51 µ moles m^{-2} s^{-1}), DMSO (9.5 µ moles m^{-2} s^{-1}) and Microbial consortium (9.46 µ moles m^{-2} s^{-1}) which is 63.24 to 64.19 % increase in net photosynthesis over the control (5.8 µ moles m^{-2} s^{-1}) and water sprayed plants (6.03 µ moles m^{-2} s^{-1}). Data is presented in Table 4. Mean of two season indicated that highest Internal CO_2 Concentration was in T5 (251.12 **µl l^{-1}**) followed by T4 (250.93 **µl l^{-1}**), T6 (250.82 **µl l^{-1}**), T7 (249.14 **µl l^{-1}**) and T3 (247.62 **µl l^{-1}**) which were 65.9 to 68.24 % increase over Internal CO_2 Concentration of control (149.26 **µl l^{-1}**) and water sprayed plants (150.01 **µl l^{-1}**). Table 7.4 shows data on net photosynthesis and internal Co_2 concentration.

Mesophyll Efficiency and Carboxylation Efficiency: In all the PGR treated plants Mesophyl Efficiency was significantly higher compared to control and water sprayed plants during the two year of study. As seen from Table 5, over the two years, average mesophyll efficiency was highest with *Glyricidia + Lantana* (3340.15) followed by 3292.6 in T7, 3238.19 in T4, 3236.86 in T5 and 3208.27 in T6 which were 16.72 to 21.52 % increase over control (2748.72) and water treated (2747.78) plants. As indicated by the average of two years, Carboxylation Efficiency was highest in *Glyricidia + Lantana* (0.034 $\mu molm^{-2}s^{-1}(\mu l\ l^{-1})^{-1}$) followed by NAA (0.033 $\mu molm^{-2}s^{-1}(\mu l\ l^{-1})^{-1}$), 0.0325 $\mu molm^{-2}s^{-1}(\mu l\ l^{-1})^{-1}$ both in Microbial consortium and DMSO, the least 0.0315 $\mu molm^{-2}s^{-1}(\mu l\ l^{-1})^{-1}$ was found in Salicylic acid which were 34.04 to 44.68 % increase over 0.0235 $\mu molm^{-2}s^{-1}(\mu l\ l^{-1})^{-1}$ Carboxylation Efficiency in control and water sprayed plants.

Nitrate Reductase Activity: Nitrate reductase activity of plants was significantly higher in PGR treatments in both the years of study compared to control and water sprayed plants (Table 6). On an average over two years, NAA treated plants had highest nitrate reductase activity of 0.815 **µmoles/Hour/g** followed by *Glyricidia + Lantana* (0.8 **µmoles/Hour/g**) and 0.79 **µmoles/Hour/g** in Microbial consortium and DMSO, 0.785 **µmoles/Hour/g** in Salicylic acid treated plants which were 26.61 to 31.45 % increase over nitrate reductase activity in plants of control (0.65 **µmoles/Hour/g**) and water sprayed plants (0.64 **µmoles/Hour/g**).

Chlorophyll content: Over two years of study, the average Chlorophyll a content was highest 2.57 g/gram in *Glyricidia + Lantana* and Microbial consortia treated plants, 2.53 g/gram in plants treated with DMSO and 2.525 mg/gram with NAA, the least 2.52 mg/gram in Salicylic acid which were 19.43 to 21.8 % increase over control (2.11 mg/gram) and water sprayed (2.05 mg/gram) plants. Chlorophyll content data is presented in Table 7. The mean indicated that 0.675 mg/gram chlorophyll 'b' was found both in control and water sprayed plants which were 54.07 to 57.58 % lower compared to the chlorophyll 'b' content that ranged from 1.04 to 1.075 mg/gram in various PGR treated plants.

Total Chlorophyll and Chlorophyll Ratio: On an average, Total chlorophyll ranged from the lowest 3.54 mg/g with NAA to the highest 3.62 mg/g with *Glyricidia + Lantana* treated plants which was 27.11 to 29.98 % increase over control (2.79 mg/g) and water sprayed plants (2.73 mg/g). Over two years, the mean chlorophyll a/b ratio remained higher in control (3.38) and water spray (3.35) plants which was 28.15 to 29.19 % lesser compared to 2.39, 2.42, 2.43, 2.54 and 2.55 with DMSO, Salicylic acid, NAA, *Glyricidia + Lantana* and Microbial consortia treated plants respectively (Table 8).

Total Carbohydrates and Starch Content: Total carbohydrate contents of plants treated with PGRs was significantly higher in both the years compared to control and water sprayed plants. The mean indicated that total carbohydrates ranged from 7.15 to 7.39 in PGR treated plants which were 22.35 to 26.54 % increase over control (5.84 %) and water sprayed plants (5.7 %). Data is presented in Table 9. The average starch content in PGR treated plants ranged from 5.62 % in Salicylic acid to 5.88 % in Microbial consortium which was 47.96 to 54.94 % increase over control (3.8 %) and water sprayed (3.89 %) plants. Data on total carbohydrates and starch content is shown in Table 7.9.

Soluble Protein, Proline and Phenol contents:. The mean indicated that PGR plants had higher soluble protein ranging from 26 to 26.3 mg/gram of fresh weight which was 22.76 to 24.2 % increase over the soluble protein content of control (21.18 mg/g) and water sprayed (21.04 mg/g) plants. Data on soluble protein is shown in Table 10. Overall, the average proline content was highest with NAA (2.27 µmoles/g) followed by Microbial consortium (2.26 µmoles/g), DMSO (2.19 µmoles/g), *Glyricidia + Lantana* (2.18 µmoles/g) and Salicylic acid (2.11 µmoles/g) which were 46.69 to 58.19 % increase over control (1.44 µmoles/g) and water sprayed (1.46 µmoles/g) plants. Over the two years, mean phenol content was 0.25 % in both control and water sprayed plants. Among the PGR treatments, DMSO and NAA recorded the highest phenol of 0.32 % followed by Salicylic acid (0.31 %), *Glyricidia + Lantana* (0.308 %) and the least 0.035 % with Microbial consortium. The phenol content in the plants of PGR treatments was 22 to 28 % increase over control.

Table 1. Relative water content and epicuticular wax as affected by PGRs in Arabica variety Sln. 9 yielding plants in post monsoon

Treatments	Relative Water Content (%)			Variation (%)	Epicuticular wax ($\mu g/Cm^2$)			Variation (%)
	Year 1	Year 2	Mean		Year 1	Year 2	Mean	
T1	86.10	73.47	79.79		20.32	21.42	20.87	
T2	85.98	75.86	80.92		19.63	21.06	20.35	
T3	92.99	83.42	88.21	**10.55**	23.18	29.17	26.18	**25.42**
T4	92.96	83.76	88.36	**10.75**	23.12	28.58	25.85	**23.86**
T5	92.43	83.45	87.94	**10.22**	22.90	29.40	26.15	**25.30**
T6	92.47	83.23	87.85	**10.11**	22.93	29.06	26.00	**24.56**
T7	92.67	83.37	88.02	**10.32**	22.94	29.06	26.00	**24.58**
F Test 5 %	147.914*	193.691*	Mean	10.39	83.692*	45.123*	Mean	24.74
C.D. 5 %	0.657	0.765			0.402	1.396		

Table 2. Stomatal conductance and transpiration rate as affected by PGRs in Arabica variety Sln. 9 yielding plants in post monsoon

Treatments	Stomatal Conductance (gs) (moles m^{-2} s^{-1})			Variation (%)	Transpiration Rate (E) (m moles m^{-2} s^{-1})			Variation (%)
	Year 1	Year 2	Mean		Year 1	Year 2	Mean	
T1	0.056	0.054	0.055		1.54	1.34	1.44	
T2	0.055	0.055	0.055		1.53	1.37	1.45	
T3	0.076	0.077	0.077	**39.09**	1.98	1.98	1.98	**37.50**
T4	0.082	0.078	0.080	**45.45**	1.92	1.97	1.95	**35.07**
T5	0.076	0.083	0.080	**45.45**	2.06	1.97	2.02	**39.93**
T6	0.080	0.080	0.080	**45.45**	2.01	1.98	2.00	**38.54**
T7	0.079	0.077	0.078	**41.82**	1.98	2.00	1.99	**38.19**
F Test 5 %	14.569*	35.275*	Mean	43.45	13.16*	138.024*	Mean	37.85
C.D. 5 %	0.007	0.005			0.153	0.064		

Table 3. Instantaneous and intrinsic water use efficiency in Arabica plants in post 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	4.07	4.26	4.17		107.59	105.63	106.61	
T2	3.86	4.73	4.30		103.57	117.94	110.76	
T3	4.92	4.82	4.87	**16.93**	129.56	126.94	128.25	**20.30**
T4	5.03	4.86	4.95	**18.73**	118.92	124.91	121.92	**14.36**
T5	4.70	4.84	4.77	**14.53**	128.01	117.07	122.54	**14.94**
T6	4.79	4.86	4.83	**15.85**	121.35	122.2	121.78	**14.22**
T7	4.90	4.79	4.85	**16.33**	125.31	126.03	125.67	**17.88**
F Test 5 %	4.57*	2.606*	Mean	16.47	3.608*	2.84*	**Mean**	16.34
C.D. 5 %	0.522	0.326			12.976	10.838		

Table 4. Net photosynthesis and internal Co_2 concentration as affected by PGRs in Arabica variety Sln. 9 yielding plants in post 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	5.92	5.67	5.8		146.91	151.61	149.26	
T2	5.64	6.42	6.03		148.01	152.01	150.01	
T3	9.55	9.48	9.52	**64.19**	244.22	251.02	247.62	**65.9**
T4	9.42	9.5	9.46	**63.24**	247.93	253.92	250.93	**68.11**
T5	9.51	9.49	9.5	**63.93**	250.27	251.97	251.12	**68.24**
T6	9.47	9.54	9.51	**64.02**	251.41	250.22	250.82	**68.04**
T7	9.49	9.53	9.51	**64.11**	249.91	248.37	249.14	**66.92**
F Test 5 %	121.699*	117.287*	Mean	63.9	271.394*	180.48*	**Mean**	67.44
C.D. 5 %	0.402	0.387			7.364	8.849		

Table 5. Mesophyll and carboxylation efficiency as affected by PGRs in Arabica variety Sln. 9 yielding plants in post monsoon

Treatments	**Mesophyl Efficiency (gm) Ci/gs**			**Variation (%)**	**Carboxylation Efficiency (μmol$m^{-2}s^{-1}$(μl l^{-1})$^{-1}$)**			Variation (%)
	Year 1	**Year 2**	**Mean**		**Year 1**	**Year 2**	**Mean**	
T1	2669.25	2828.19	2748.72		0.019	0.028	0.0235	
T2	2708.99	2786.56	2747.78		0.017	0.030	0.0235	
T3	3318.29	3362.00	3340.15	**21.52**	0.025	0.043	0.0340	**44.68**
T4	3127.82	3348.56	3238.19	**17.81**	0.026	0.039	0.0325	**38.30**
T5	3368.06	3105.65	3236.86	**17.76**	0.025	0.040	0.0325	**38.30**
T6	3225.71	3190.82	3208.27	**16.72**	0.025	0.038	0.0315	**34.04**
T7	3296.67	3288.53	3292.60	**19.79**	0.025	0.041	0.0330	**40.43**

F Test 5 %	4.432*	5.675*	**Mean**	18.72	19.197*	26.053*	Mean	39.15
C.D. 5 %	340.672	245.052			0.002	0.003		

Table 6. Nitrate reductase activity as affected by PGRs in Arabica variety Sln. 9 yielding plants in post monsoon

Treatments	**Nitrate Reductase Activity (µmoles/Hour/g of Fresh wt)**			Variation (%)
	Year 1	**Year 2**	**Mean**	
T1	0.59	0.65	0.62	
T2	0.61	0.64	0.625	
T3	0.8	0.8	0.8	**29.03**
T4	0.8	0.78	0.79	**27.42**
T5	0.8	0.78	0.79	**27.42**
T6	0.8	0.77	0.785	**26.61**
T7	0.8	0.83	0.815	**31.45**
F Test 5 %	**284.31***	**7.544***	**Mean**	28.39
C.D. 5 %	**0.014**	**0.066**		

Table 7. Chlorophyll 'a' and 'b' content as affected by PGRs in Arabica variety Sln. 9 yielding plants in post monsoon

Treatments	Chlorophyll a Content (mg/g Fresh Wt)			Variation (%)	Cholorophyll b Content (mg/g Fresh Wt)			Variation (%)
	Year 1	Year 2	Mean		Year 1	Year 2	Mean	
T1	2.42	1.80	2.110		0.55	0.80	0.675	
T2	2.40	1.70	2.050		0.55	0.80	0.675	
T3	2.74	2.40	2.570	**21.80**	1.20	0.90	1.050	**55.56**
T4	2.74	2.40	2.570	**21.80**	1.18	0.90	1.040	**54.07**
T5	2.66	2.40	2.530	**19.91**	1.24	0.90	1.070	**58.52**
T6	2.74	2.30	2.520	**19.43**	1.25	0.90	1.075	**59.26**
T7	2.65	2.40	2.525	**19.67**	1.23	0.90	1.065	**57.78**
F Test 5 %	25.082*	35.48*	Mean	20.52	76.874*	19.563*	Mean	57.04
C.D. 5 %	0.073	0.125			0.092	0.029		

Table 7.8. Total chlorophyll and chlorophyll a/b ratio as affected by PGRs in Arabica variety Sln. 9 yielding plants in post 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	2.97	2.60	2.79		4.54	2.21	3.38	
T2	2.95	2.50	2.73		4.44	2.25	3.35	
T3	3.94	3.30	3.62	**29.98**	2.38	2.69	2.54	**-24.89**
T4	3.92	3.30	3.61	**29.62**	2.36	2.73	2.55	**-24.59**
T5	3.90	3.30	3.60	**29.26**	2.18	2.60	2.39	**-29.19**
T6	3.98	3.20	3.59	**28.90**	2.24	2.60	2.42	**-28.30**
T7	3.88	3.20	3.54	**27.11**	2.20	2.65	2.43	**-28.15**
F Test 5 %	98.397*	43.236*	Mean	28.97	96.785*	11.023*	Mean	-27.02
C.D. 5 %	0.116	0.132			0.271	0.158		

Table 9. Total carbohydrates and starch content as affected by PGRs in Arabica variety Sln. 9 yielding plants in post monsoon

Treatments	**Total Carbohydrates (%)**			Variation (%)	**Starch Content (%)**			Variation (%)
	Year 1	**Year 2**	**Mean**		**Year 1**	**Year 2**	**Mean**	
T1	6.60	5.08	5.84		4.15	3.44	3.80	
T2	6.38	5.02	5.70		4.23	3.54	3.89	
T3	7.47	6.96	7.22	**23.54**	6.44	4.96	5.70	**50.20**

T4	7.54	6.92	7.23	**23.80**	6.48	5.28	5.88	**54.94**
T5	7.50	7.17	7.34	**25.60**	6.57	4.80	5.69	**49.80**
T6	7.49	7.29	7.39	**26.54**	6.38	4.85	5.62	**47.96**
T7	7.51	6.78	7.15	**22.35**	6.50	5.18	5.84	**53.89**
F Test 5 %	41.495*	56.918*	Mean	24.37	179.863*	41.606*	Mean	51.36
C.D. 5 %	0.189	0.317			0.205	0.290		

Table 10. Soluble protein, proline and phenol content as affected by PGRs in Arabica variety Sln. 9 yielding plants in post monsoon

Treatments	Soluble Protein (mg/g Fresh Wt)			Variation (%)	Proline Content (µmoles/g of Dry Wt)			Variation (%)	Phenol Content (%)			Variation (%)
	Year 1	Year 2	Mean		Year 1	Year 2	Mean		Year 1	Year 2	Mean	
T1	21.44	20.91	21.18		1.51	1.36	1.44		0.26	0.24	0.250	
T2	21.06	21.02	21.04		1.59	1.33	1.46		0.26	0.24	0.250	
T3	26.40	25.97	26.19	**23.66**	2.44	1.91	2.18	**51.57**	0.29	0.33	0.308	**23.00**
T4	26.43	25.64	26.04	**22.95**	2.60	1.91	2.26	**57.14**	0.31	0.30	0.305	**22.00**
T5	26.23	26.24	26.24	**23.90**	2.47	1.90	2.19	**52.26**	0.31	0.33	0.320	**28.00**
T6	26.08	25.91	26.00	**22.76**	2.33	1.88	2.11	**46.69**	0.31	0.31	0.310	**24.00**
T7	26.29	26.31	26.30	**24.20**	2.63	1.91	2.27	**58.19**	0.33	0.31	0.320	**28.00**
F Test 5 %	114.661*	197.627*	Mean	23.49	43.151*	260.765*	Mean	53.17	2.777*	9.52*	Mean	25
C.D. 5 %	0.564	0.432			0.177	0.042			0.040	0.031		

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 post-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 (10.39 % lower) could be attributed to lower epicuticular wax (24.74 % less) as compared to PGR treated plants. The higher relative water content in PGR treated plants could be attributed to higher transpiration rate (37.85 % higher). Because of higher transpiration rate, PGR treated plants had extracted more water from sub soil through roots and thereby resulted in higher turgidity of leaves. Higher internal CO_2 concentration (67.44 % higher) in PGR treated plants could be attributed to higher stomatal conductance (43.45 % 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 (63.9 % high) compared to control and water sprayed plants. The increased CO_2 concentration has lead to increased mesophyll efficiency (18.72 %) and carboxylation efficiency (39.15 %) in PGR treated plants.

Higher net photosynthesis could be attributed to increased chlorophyll A (20.52 %) and B (57.04 %) and total chlorophyll (28.97 % high) contents that were resulted in PGR treated plants as compared to control and water sprayed plants. There was an increase of 28.39 % increase in nitrate reductase activity in PGR treated plants. The increased photosynthetic parameters in turn resulted in increased total carbohydrates (24.37 %) and starch (51.36 %). As an indicator of plant resistance against the rot diseases of monsoon and to manage with adverse effects of monsoon, PGR treated plants had increased phenol (25 %) and soluble proteins (23.49 %) and proline (53.17 %) 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 water logged conditions of monsoon and resulting in better performance during post monsoon. Application of Glyricidia+Lantana, Lantana+DMSO, Microbial consortium, Salicylic acid and NAA had equal effects to manage physio-chemical properties of Arabica coffee in post monsoon conditions.

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