Foliar Spray of Botanicals as Plant Growth Regulators on Physio-Chemical Properties of *Coffea canephora* Var. C x R during Post Monsoon

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ABSTRACT

In a study on influence of foliar application of PGRs on physio-chemical properties of Robusta coffee during post 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 (8.94 %), epicuticular wax (29.94 %), transpiration rate (41.34 %), stomatal conductance (43.42%), Instantaneous WUE (4.72 %), intrinsic WUE (1.4 %), net photosynthesis (43.48 %), internal CO_2 concentration (47.3 %), mesophyll efficiency (4.59 %), carboxylation efficiency (46.77 %), chlorophyll A (32.08 %), Chlorophyll B (90.64 %) and Total chlorophyll (44.5 %), Chlorophyll ratio (-23.42 %) and nitrate reductase activity (45.41 %) was found in PGR treated plants during post monsoon. The increased photosynthetic activities and parameters resulted in higher total carbohydrates (53.04 %), starch (21.02 %), soluble proteins (41.46 %), phenols (40.44 %) and proline (42.94 %) contents in coffee.

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

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.

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 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 Robusta coffee variety CxR. 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 Robusta cv. C *x* R (*Coffea canephora Pierre ex froehner*)**:** This variety is being cultivated commonly in the coffee growing zones of India. It is a selected cultivar known for large bush size with robust growth. The leaves are broad and oblong. It is a semi drooping type with large number of secondary and tertiary branches. The long internodes of 5 to 7 cm with large clusters of fruits vary from 25 to 50 per cropping nodes. This variety found to have high root biomass, good water use efficiency, vigorous growth and resistance to major pest and diseases. The cultivar possesses high carbon exchange rates. The fruits are bolder in size with around 70 % `AB' grades. The fruits are reddish to dark red in color. A crop yield of 1800 to 2000 per ha could be expected under well cultivation practices.

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 one month after cessation of monsoon in post monsoon season.

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 is the indication of turgidity of plants. It was statistically and highly significant during the two years of study among all the PGR treated plants (Table 1). The average Relative Water Content of two years indicated that all PGR treated plants had Relative Water Content ranging from 80.4 to 81.5 % which was 7.9 to 9.4 % increase over control (74.5 %) and water sprayed (74.8 %) plants. In the two years of study on PGRs, Epicuticular Wax was found significantly and statistically high among the PGR treated plants as compared to control. The mean Epicuticular Wax of two years indicated that Epicuticular Wax ranged from 23.1 to 23.4 µg/Cm^2 in PGR treated plants which was 29.1 to 30.7 % increase over control (17.9 µg/Cm^2) and water sprayed (18.4 µg/Cm^2) plants.

Table 1. Relative water content and epicuticular wax as affected by PGRs in Robusta variety CxR yielding plants in Post Monsoon

Treatments	Relative Water Content			Variation (%)	Epicuticular *Wax* (µg/Cm^2)			Variation (%)
	Year 1	Year 2	Mean		Year 1	Year 2	Mean	
T1	79.2	69.7	74.5		12.7	23.1	17.9	
T2	78.6	70.9	74.8		13.1	23.7	18.4	
T3	83.2	79.6	81.4	9.30	16.6	30.2	23.4	30.70
T4	82.4	78.4	80.4	7.90	16.3	30.0	23.2	29.60
T5	82.4	80.1	81.3	9.10	16.6	30.2	23.4	30.70
T6	82.3	80.8	81.5	9.40	16.2	29.9	23.1	29.10
T7	82.8	79.5	81.2	9.00	16.3	30.0	23.2	29.60
F Test 5 %	31.962*	34.793*	Mean	8.94	67.622*	66.498*	Mean	29.94
C.D. 5 %	0.796	1.928			0.512	0.985		

Transpiration rate and Stomatal Conductance: The mean Transpiration rate was highest 2.2 m moles m^{-2} s^{-1} in DMSO followed by 2.1 m moles m^{-2} s^{-1} in all other treatments which was 40 to 46.7 % increase over Transpiration rate in control (1.5 m moles m^{-2} s^{-1}) and water sprayed (1.4 m moles m^{-2} s^{-1}) plants. Table 2 shows data on transpiration rate and stomatal conductance. The average Stomatal Conductance over two years was highest in Microbial consortium treated plants (0.083 moles m^{-2} s^{-1}) followed by 0.081, 0.080, 0.078 and 0.077 moles m^{-2} s^{-1} in Salicylic acid, DMSO, NAA and *Glyricidia* + *Lantana* treated plants respectively which were 37.84 to 48.65 % higher compared to almost same Stomatal Conductance in control (0.056 moles m^{-2} s^{-1}) and water sprayed (0.055 moles m^{-2} s^{-1}) plants.

Table 2. Transpiration rate and stomatal conductance as affected by PGRs in Robusta variety CxR yielding plants in Post 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	1.41	1.60	1.5		0.057	0.054	0.056	
T2	1.34	1.55	1.4		0.055	0.055	0.055	
T3	2.33	1.90	2.1	40.00	0.073	0.080	0.077	37.84

T4	2.33	1.91	2.1	40.00	0.082	0.083	0.083	48.65
T5	2.34	1.96	2.2	46.70	0.082	0.078	0.080	44.14
T6	2.36	1.87	2.1	40.00	0.078	0.084	0.081	45.95
T7	2.41	1.84	2.1	40.00	0.078	0.078	0.078	40.54
F Test 5 %	326.093*	16.383*	Mean	41.34	14.45*	101.526*	Mean	43.42
C.D. 5 %	0.066	0.097			0.007	0.003		

Instantaneous Water Use Efficiency and Intrinsic Water Use Efficiency: Data on instantaneous and intrinsic water use efficiency is presented in Table 3. In the two years study, Instantaneous Water Use Efficiency was statistically and significantly high among the PGR treated plants as compared to control and water treated plants in the second year only. Mean Instantaneous Water Use Efficiency was 4.61 µ moles mmol^{-1} *Glyricidia* + *Lantana*, 4.52 µ moles mmol^{-1} in Salicylic acid, 4.62 µ moles mmol^{-1} in NAA, 4.57 in DMSO and 4.52 µ moles mmol^{-1} in Microbial consortium among the PGR treated plants, which was 3.67 to 5.85 % higher compared to Instantaneous Water Use Efficiency of control (4.36 µ moles mmol^{-1}) and water treated (4.51 µ moles mmol^{-1}) plants. Statistically and significantly higher Intrinsic Water Use Efficiency was recorded in PGR treated plants compared to control and water sprayed plants in the two years of study. On an average, both control (120.1 µmol mol^{-1}) and water sprayed (120 µmol mol^{-1}) plants had the same Intrinsic Water Use Efficiency which was 3.42 % higher compared to Microbial consortium (116 µmol mol^{-1}) and 2.72 % higher to Salicylic acid (116.8 µmol mol^{-1}), but 6.52 % lower to *Glyricidia* + *Lantana* (127.9 µmol mol^{-1}), 3.38 % lower to DMSO (124.1 µmol mol^{-1}) and 3.25 % lower to NAA (124 µmol mol^{-1}).

Table 3. Instantaneous and intrinsic water use efficiency as affected by PGRs in Robusta variety CxR yielding plants in Post Monsoon

Treatments	Instantaneous WUE (µ moles mmol^{-1})			Variation (%)	Intrinsic WUE (Pn/gs) (µmol mol^{-1})			Variation (%)
	Year 1	Year 2	Mean		Year 1	Year 2	Mean	
T1	3.8	4.9	4.36		94.8	145.4	120.1	
T2	4.2	4.9	4.51		102.5	137.5	120.0	
T3	3.8	5.4	4.61	**5.73**	126.0	129.9	127.9	**6.52**
T4	3.8	5.2	4.52	**3.67**	110.5	121.4	116.0	**-3.43**
T5	4.0	5.2	4.57	**4.70**	116.4	131.9	124.1	**3.38**
T6	3.7	5.3	4.52	**3.67**	114.5	119.2	116.8	**-2.72**
T7	3.6	5.6	4.62	**5.85**	114.7	133.2	124.0	**3.25**
F Test 5 %	2.677*	4.502*	Mean	4.72	4.005*	11.682*	Mean	1.40
C.D. 5 %	0.257	0.3			12.388	6.466		

Net Photosynthesis and Internal CO_2 Concentration: Over a period of two years, the average Net Photosynthesis was highest 9.63 in DMSO followed by 9.5 in *Glyricidia* + *Lantana*, 9.46 in NAA, 9.36 in Microbial consortium, 9.3 in Salicylic acid treated plants which were 41.1 to 44.2 % increase over Net Photosynthesis of control (6.59) and water treated plants (6.52). Data is shown in Table 4. Internal CO_2 Concentration over two years was highest 220.5 µl l^{-1} in Microbial consortium followed by 219.8 µl l^{-1} in NAA, 218.1 µl l^{-1} in *Glyricidia* + *Lantana*, 217.5 µl l^{-1} in DMSO and 212.6 µl l^{-1} in Salicylic acid treated plants which were 47.17 to 49.17 % increase over Internal CO_2 Concentration in control (147.8 µl l^{-1}) and water sprayed (150 µl l^{-1}) plants.

Table 4. Net photosynthesis and Internal CO2 concentration as affected by PGRs in Robusta variety CxR yielding plants in Post Monsoon

Treatments	Net Photosynthesis			Variation (%)	Internal CO_2 Concentration			Variation
	Year 1	Year 2	Mean		Year 1	Year 2	Mean	
T1	5.36	7.81	6.585		140	155.6	147.8	
T2	5.54	7.49	6.515		141.2	158.8	150	
T3	8.89	10.11	9.5	**44.27**	234	202.3	218.1	47.6
T4	8.82	9.9	9.36	**42.14**	233.7	207.3	220.5	49.17
T5	9.23	10.03	9.63	**46.24**	227.1	207.9	217.5	47.17
T6	8.71	9.88	9.295	**41.15**	225.8	199.4	212.6	43.85
T7	8.7	10.21	9.455	**43.58**	225.6	213.9	219.8	48.69
F Test 5 %	118.575*	85.256*	Mean	43.48	105.357*	31.752*	Mean	47.3
C.D. 5 %	0.378	0.31			10.369	10.584		

Mesophyll Efficiency and Carboxylation Efficiency: The mean Mesophyll Efficiency of two seasons indicated that *Glyricidia + Lantana* extract treated plants had the highest Mesophyll Efficiency of 2955.8 with followed by 2885.3 in NAA, 2800.1 in DMSO, 2731.0 in Microbial consortium and the least 2681 in Salicylic acid treated plants, which were 1.63 to 9.99 % increase over Mesophyll Efficiency in control (2687.3) and water sprayed plants (2766.1). Data is presented in Table 5. The mean Carboxylation Efficiency was 0.034 and 0.035 $\mu molm^{-2}s^{-1}(\mu l\ l^{-1})^{-1}$ in control and water sprayed plants which were 45.59 to 47.06 % less compared to Carboxylation Efficiency of 0.51 $\mu molm^{-2}s^{-1}(\mu l\ l^{-1})^{-1}$ in Salicylic acid followed by 0.050 $\mu molm^{-2}s^{-1}(\mu l\ l^{-1})^{-1}$ in other treatments.

Nitrate Reductase Activity: Nitrate Reductase Activity also statistically and significantly higher in all PGR treated plants in both the years of study. Mean Nitrate Reductase Activity ranged from 0.800 to 0.815 µmoles/Hour/g in various PGR treated plants which were 44.14 to 46.85 % increase over Nitrate Reductase Activity in control (0.555 µmoles/Hour/g) and water sprayed (0.56 µmoles/Hour/g) plants. Data is presented in Table 6.

Chlorophyll 'a' and Chlorophyll 'b': Significantly higher Chlorophyll 'a' was found in the plants treated with PGRs in both the years of study (Table 7). The mean Chlorophyll 'a' was 2.88, 2.87, 2.87, 2.86 and 2.85 mg/g respectively in T3, T5, T6, T7 and T4 treatments which was 31.3 to 32.7 % increase over Chlorophyll 'a' content of control (2.17 mg/g) and water sprayed (2.19 mg/g) plants. Chlorophyll 'b' content in PGR treated plants were significantly and statistically high in comparison to Chlorophyll 'b' content of control and water sprayed plants but were on par with each other (Table 7). The mean Chlorophyll 'b' content was 0.62 and 0.63 in control and water sprayed plants respectively, which was 85.5 to 95.2 % lower compared to Chlorophyll 'b' content of PGR treated plants that ranged from 1.15 to 1.21 mg/g.

Table 5. Mesophyll and Carboxylation efficiency as affected by PGRs in Robusta variety CxR yielding plants in Post Monsoon

Treatments	Mesophyll 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	2466.6	2908.0	2687.3		0.03	0.038	0.034	
T2	2619.5	2912.5	2766.0		0.03	0.040	0.035	
T3	3300.1	2611.6	2955.8	**9.99**	0.05	0.050	0.050	47.06
T4	2915.2	2546.9	2731.0	**1.63**	0.05	0.049	0.050	45.59
T5	2865.0	2735.2	2800.1	**4.20**	0.05	0.050	0.050	47.06
T6	2959.9	2402.0	2681.0	**-0.23**	0.05	0.051	0.051	48.53
T7	2970.4	2800.2	2885.3	**7.37**	0.05	0.049	0.050	45.59
F Test 5 %	3.876*	6.672*	Mean	4.59	102.46*	18.164*	Mean	46.77
C.D. 5 %	333.724	181.678			0.003	0.003		

Table 6 Nitrate reductase activity as affected by PGRs in Robusta variety CxR yielding plants in Post Monsoon

Treatments	Nitrate Reductase Activity (µmoles/Hour/g of Fresh wt)			Variation (%)
	Year 1	Year 2	Mean	
T1	0.51	0.6	0.555	
T2	0.51	0.61	0.56	
T3	0.69	0.92	0.805	45.05
T4	0.71	0.92	0.815	46.85
T5	0.69	0.91	0.8	44.14
T6	0.71	0.9	0.805	45.05
T7	0.69	0.93	0.81	45.95
F Test 5 %	68.57*	107.047*	Mean	45.41
C.D. 5 %	0.028	0.036		

Total Chlorophyll and Chlorophyll a/b Ratio: Over a period of two years study, Total Chlorophyll content ranged from 4.01 to 4.07 mg/g in various PGR treated plants which were 43.7 to 45.9 % increase over 2.79 and 2.78 mg/g Total Chlorophyll in control and water sprayed plants. Table 8 shows data on total chlorophyll and chlorophyll a/b. In contrast to total chlorophyll content, Chlorophyll a/b Ratio was statistically and significantly lower in all PGR treated plants as compared to control and water sprayed plants during both the years of study. The average Chlorophyll a/b Ratio was 3.49 and 3.53 in control and water sprayed plants which were 22.1 to 24.9 % higher as compared to the Chlorophyll a/b Ratio under PGR treated plants that ranged from 2.62 under Microbial consortium to 2.72 under *Glyricidia + Lantana* treatments. Data is shown in Table 8.

Table 7. Chlorophyll 'a' and 'b' in Robusta variety CxR yielding plants in Post Monsoon

Treatments	Chlorophyll 'a' (mg/g Fresh Wt)			Variation (%)	Chlorophyll b (mg/g Fresh Wt)			Variation (%)
	Year 1	Year 2	Mean		Year 1	Year 2	Mean	
T1	2.12	2.21	2.17		0.71	0.52	0.62	
T2	2.11	2.26	2.19		0.71	0.54	0.63	
T3	2.74	3.02	2.88	32.70	1.43	0.86	1.15	85.50
T4	2.65	3.04	2.85	31.30	1.51	0.84	1.18	90.30
T5	2.70	3.03	2.87	32.30	1.53	0.88	1.21	95.20
T6	2.73	3.01	2.87	32.30	1.50	0.87	1.19	91.90
T7	2.67	3.04	2.86	31.80	1.51	0.85	1.18	90.30
F Test 5 %	39.429*	163.196*	Mean	32.08	152.548*	120.22*	Mean	90.64
C.D. 5 %	0.113	0.075			0.076	0.036		

Table 8. Total chlorophyll and Chlorophyll a/b ratio as affected by PGRs in Robusta variety CxR yielding plants in Post Monsoon

Treatments	Total Chlorophyll (mg/g fresh weight)			Variation (%)	Chlorophyll a/b Ratio			Variation (%)
	Year 1	Year 2	Mean		Year 1	Year 2	Mean	
T1	2.82	2.76	2.79		3.05	3.93	3.49	
T2	2.82	2.74	2.78		3.04	4.01	3.53	
T3	4.17	3.85	4.01	43.70	1.96	3.47	2.72	-22.10
T4	4.16	3.90	4.03	44.40	1.78	3.45	2.62	-24.90
T5	4.23	3.82	4.03	44.40	1.80	3.46	2.63	-24.60
T6	4.22	3.92	4.07	45.90	1.85	3.53	2.69	-22.90
T7	4.18	3.86	4.02	44.10	1.81	3.59	2.70	-22.60
F Test 5 %	167.604*	277.836*	Mean	44.5	78.089*	13.476*	Mean	-23.42
C.D. 5 %	0.127	0.08			0.165	0.158		

Total Carbohydrates and Starch: Statistically and significantly higher Total Carbohydrate was found in PGR treated plants as compared to control and water sprayed plants in the two years of the study. Data is presented in Table 9. Mean Total Carbohydrates was almost same 6.5 % in control and 6.49 % in water sprayed plants. Highest mean Total Carbohydrates was found in plants treated with DMSO (10.03%) followed by 10.01, 9.92, 9.91 and 9.87% with *Glyricidia + Lantana*, NAA, Salicylic acid and Microbial consortium respectively which was 51.8 to 54.3 % increase over control. Table 19 provides data on total carbohydrates and starch content. The mean starch content was almost same both 5.8 and 5.81 % in control and water treated plants respectively. Microbial consortium plants had 22.6 % higher starch (7.11 %) followed by 22.4 % higher in NAA (7.1 %), 21.7 % higher in *Glyricidia + Lantana* (7.06 %), 20.3 % higher in Salicylic acid (6.98 %) and 18.1 % higher in DMSO (6.85 %) plants.

Table 9. Total carbohydrates and starch as affected by PGRs in Robusta variety CxR yielding plants in Post Monsoon

Treatments	Total Carbohydrates (%)			Variation (%)	Starch (%)			Variation (%)
	Year 1	Year 2	Mean		Year 1	Year 2	Mean	
T1	7.19	5.80	6.50		6.56	5.04	5.80	
T2	6.85	6.13	6.49		6.45	5.16	5.81	
T3	11.03	8.98	10.01	54.00	8.14	5.97	7.06	21.70
T4	10.81	8.93	9.87	51.80	8.11	6.10	7.11	22.60
T5	11.22	8.84	10.03	54.30	7.78	5.92	6.85	18.10
T6	10.94	8.87	9.91	52.50	8.09	5.86	6.98	20.30
T7	10.89	8.95	9.92	52.60	8.11	6.08	7.10	22.40
F Test 5 %	168.181*	84.891*	Mean	53.04	28.364*	11.355*	Mean	21.02
C.D. 5 %	0.366	0.385			0.35	0.321		

Proline and Phenol Content: All PGR treated plants had significantly and statistically higher proline content compared to control and water sprayed plants in both the years of the study (Table 10). The average proline content of plants was 1.46 µmoles/g in both control and water treated plants which was 41.4 to 45.2 % less compared to proline content of PGR treated plants that ranged from 2.07 µmoles/g the lowest in DMSO to 2.12 µmoles/g the highest in *Glyricidia* + *Lantana*. Phenol content of PGR treated plants was statistically higher compared to control and water treated plants during the two years of study. The mean phenol content was highest 0.325 % in NAA treated plants followed by 0.32, 0.315 and 0.305 respectively in DMSO, *Glyricidia* + *Lantana* & Microbial consortium and Salicylic acid which were 35.6 to 44.4 % increase over 0.255 % phenol in control and 0.23 % phenol in water sprayed plants (Table 7.20).

Table 10. Proline and Phenol content as affected by PGRs in Robusta variety C x R yielding plants during post monsoon

Treatments	Proline (µmoles/g of Dry Wt)			Variation (%)	Phenol (%)			Variation (%)
	Year 1	Year 2	Mean		Year 1	Year 2	Mean	
T1	1.31	1.61	1.46		0.18	0.27	0.225	
T2	1.31	1.61	1.46		0.20	0.26	0.230	
T3	2.25	1.99	2.12	45.20	0.29	0.34	0.315	40.00
T4	2.15	2.02	2.09	42.80	0.29	0.34	0.315	40.00
T5	2.13	2.00	2.07	41.40	0.29	0.35	0.320	42.20
T6	2.17	1.99	2.08	42.50	0.29	0.32	0.305	35.60
T7	2.15	2.02	2.09	42.80	0.29	0.36	0.325	44.40
F Test 5 %	88.121*	115.104*	Mean	42.94	119.933*	8.971*	Mean	40.44
C.D. 5 %	0.109	0.043			0.01	0.031		

Soluble Protein: Soluble Protein varied significantly among the treatments and PGR treated plants recorded significantly higher Soluble Protein compared to Soluble Protein in control and water sprayed plants. The mean Soluble Protein among the PGR treated plants ranged from 27.39 to 27.71 mg/g which was 40.7 to 42.3 % increase over Soluble Protein of 19.47 mg/g in control and 19.56 mg/g in water sprayed plants. Table 11 shows data on soluble protein.

Table 11. Soluble protein content as affected by PGRs in Robusta variety C x R yielding plants during post monsoon

Treatments	Soluble Protein (mg/g Fresh Wt)			Variation (%)
	Year 1	Year 2	Mean	
T1	18.7	20.2	19.47	
T2	18.9	20.2	19.56	
T3	29.4	25.4	27.39	40.70
T4	29.8	25.1	27.44	40.90
T5	29.7	25.3	27.53	41.40
T6	30.2	25.2	27.71	42.30
T7	30.4	24.9	27.64	42.00
F Test 5 %	671.118*	46.825*	Mean	41.46
C.D. 5 %	0.513	0.87		

DISCUSSION AND CONCLUSION

From the results it can be seen that all plant growth regulators enhanced most of the physiological and chemical properties of Robusta 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 (8.94 % lower) could be attributed to lower epicuticular wax (29.94 % less) as compared to PGR treated plants. The higher relative water content in PGR treated plants could be attributed to higher transpiration rate (41.34 % 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 (47.3 % higher) in PGR treated plants could be attributed to higher stomatal conductance (43.42 % 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 (43.48 % high) compared to control and water sprayed plants. The increased CO_2 concentration has lead to increased mesophyll efficiency (4.59 %) and carboxylation efficiency (46.77 %) in PGR treated plants.

Higher net photosynthesis could be attributed to increased chlorophyll A (32.08 %) and B (90.64 %) and total chlorophyll (44.5 % high) contents that were resulted in PGR treated plants as compared to control and water sprayed plants. There was an increase of 45.41 % increase in nitrate reductase activity in PGR treated plants. The increased photosynthetic parameters in turn resulted in increased total carbohydrates (53.04 %) and starch (21.02 %). As indicator of plant resistance, in pre monsoon, increased phenol (40.44 %) and soluble proteins (41.46 %). As an indicator to stress increased proline (42.94 %) 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 excessive moisture situations in 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 Robusta coffee in post monsoon conditions passing through monsoon.

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