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Performance of Coffea canephora (Robusta Coffee) Var. CxR Seedlings with Plant Growth Regulators

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ABSTRACT

The growth and development of coffee seedlings in Robusta variety C x R was studied using various growth regulators. *Glyricidia sepium* + *Lanatana camera* extract (1 %), Arka Microbial Consortium (1 %), Lantana camera + DMSO + $CuSo_4$ (1 %), Salicylic Acid (0.025 %) and Alpha Napthyl Acetic Acid (0.025 %) were used as PGRs for boosting growth of coffee seedlings in comparison with control and water sprayed seedlings. Final growth parameters were recorded at six months age when seedlings were ready for field planting. The results indicated that the increase of growth parameters were statistically significant in PGR treated seedlings. The seedlings of CxR were 12.07 to 13.04 % taller and had 33.1 to 37.1 % more longer roots. 41.76 to 48.35 % more nodes with 40 to 45 % higher internode length were found. 42.78 to 48.89 % more leaves with 147.99 to 165.63 % higher leaf area were found in robusta seedlings treated with PGRs. Shoot and root weight of robusta seedlings was respectively 45.23 to 50.62 % and 32.5 to 34.17 % higher in PGR treated robusta seedlings. Significant increase in major nutrients viz. Nitrogen, Phosphorus, Potassium and minor nutrients viz. Calcium, Magnesium and Sulphur status of leaves was found with PGR treated seedlings. All the growth parameters increased were statistically on par among the different PGRs used in the study. Whereas, the control and water sprayed seedlings recorded significantly lower growth parameters as compared to PGRs sprayed seedlings. Hence, the study highlights the importance on use of PGRs in boosting the growth and development of robusta coffee seedlings.

Key Words: Robusta Coffee Seedlings, Glyricidia and Lantana extract, Microbial Consortium, Napthyl Acetic Acid, Salicylic acid, PGR

INTRODUCTION

Coffee is the important economical crop of farmers in the Western Ghats regions of South India. *Coffea arabica* and *Coffea canephora* commonly known as Arabica and Robusta respectively are the two major species grown across India. Among these, cost of cultivation for Arabica coffee is very high due to major pests and diseases to be managed throughout the year. The plant protection measures in Arabica are consuming large number of man days. Meanwhile, the availability of labour is becoming a major constraint in coffee tracts. Hence, many coffee growers have switched over to growing of robusta coffee. Robusta plants come for bearing only after 4^{th} or 5^{th} year and the economical yield starts only after seven or eight years. Being widely spaced crop, faces huge competition from weeds. Hence, establishment of good robusta coffee plantation is mainly influenced by planting of healthy and vigorous coffee seedlings.

The Central Coffee Research Institute, India has recommended using good quality nursery mixture containing Jungle Soil, Farm Yard Manure and Sand in 6:2:1 ratio to raise seedlings in polybags of size 9 x 6 inch dimension. However, in recent decades, the availability of fertile jungle soil and good quality Farm Yard Manure has become scarce and growers are using very small bags of 5 x 4 inch size with poor soil and Farm Yard Manure. Coffee Research Station

recommends to plant seedlings at 6 or 18 months old in main field when they attain ideal growth and development. Due to lack of good nursery mixture, it has become very difficult for growers to raise good seedlings of 6 months old and usually wait for two season seedlings i.e. 18 months to take up planting. Hence, there is a need to boost the growth of coffee seedlings by external means such that they can be planted at 6 months age only instead of waiting for one more season. However, application of excessive fertilizers leads to succulent growth of seedlings instead of hard seedlings. This has lead to an attempt on usage of growth regulators to promote seedlings growth.

Over decades, many attempts have been made in the field of Agriculture Research in different crops to identify different plant growth regulators, including both chemicals and plant extracts that have PGR properties. Among such materials, NAA, Salicylic Acid, Microbial consortia and plant extracts such as *Glyricidia sepia* and *Lantana camera* are common. Even the oldest chemical, DMSO as a carrier of agricultural toxicants, first received attention by Norris and Freed (1963). Its unique solvent and membrane transport properties (Jacob Bischel, and Herschler, 1964) might have played important role in such influence.

Many studies were conducted to boost the growth of seedlings using plant extracts like *Lantana camera* (Anon, 2003), *Glyricidia sepium* (Anon, 2004) and Salicylic acid (Anon, 2006) that have growth promoting properties. However, these studies limited to only increase the crop yield. Not much emphasis was given in the past to boost growth of seedlings using these extracts. Among the natural plant growth promoting materials, most abundantly available in coffee growing regions of South India are *Glyricidia sepia* and *Lantana camera* which are commonly known as Glyricida and Lantana respectively. Glyricidia is grown as temporary shade tree in young coffee plantations and as a nutrient supplement plant in other fields. The other one is *Lantana camera* grown naturally as a weed all over the waste lands. Growth promoting natural properties of *Lantana camera* L. one percent leaf extract had been observed by George Daneil *et al* (2010) to significantly increase the water use efficiency and yield of robusta in various parts of coffee growing tracts.

Many attempts have been made in the past to boost the growth of coffee seedlings with organic manures (Muralidhara *et al*., 1996), many commercial composts (Kamala Bai *et al*, 2002) and bio-fertilizers (Biradar *et al*., 2006; Panneer Selvam (2008). Even though many studies have been conducted in coffee to promote the growth of coffee seedlings, the outcomes are very few with usage of costly or rarely available external inputs. As the earlier studies concentrated only towards the addition of composts, biofertilizers into the nursery mixture and much effort were not made to take up foliar sprays to boost growth of seedlings, this study was taken up at Coffee Research Sub Station, Chettalli, Kodagu District, Karnataka in India during 2016-18 for two seasons using Sln. 9 with the following objectives.

- To know the effect of PGR formulations on growth and development of Robusta coffee seedlings
- To understand the nutritional changes that occur in seedlings with PGR

MATERIAL AND METHODS

Treatments: The study was conducted at Coffee Research sub Station during 2016 to 2018 for two seasons to confirm the results. The study was taken up in seedlings using 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 (*Glyricidia sepia* & *Lantana camera*) 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 Coffee variety CxR. This is a interspecific hybrid of Arabica and Robusta coffee with drooping branches and very popular among the growers. 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: All the formulations were sprayed to coffee seedlings on the lower side of leaves, one month after transplanting into polybags at monthly interval till they attain planting stage (6 Months).

Observations and Data Analysis: Observations were made on growth and nutritional parameters. The growth parameters are plant height, root length, number of nodes, internode length, number of leaves, leaf area, shoot & root weight. To understand the nutritional changes, observations were made on nutritional contents of leaves in seedlings. Major nutrients namely Nitrogen, Phosphorus and Potassium, minor nutrients namely Calcium, Magnesium and Sulphur were analyzed using standard prescribed methodologies. The observations recorded were analyzed by Randomized Complete Block Design and significance was tested 5 % probability.

RESULTS

Plant height and root length: Plant height of robusta CxR seedlings was significantly influenced by PGR treatments. On an average, highest 23.4 cm plant height was recorded with Glyricidia + Lantana and Salicylic acid followed by 23.3 cm in Microbial consortium, 23.2 in DMSO and NAA seedlings which were 12.07 to 13.04 % increase over control (20.7 cm) and water sprayed seedlings (20.9 cm). Mean root length varied from 20.1 cm the least with NAA to 20.7 cm the highest with Glyricidia + Lantana which were 33.1 to 37.1 % increase over the root length of control (15.1 cm) and water sprayed seedlings (14.9 cm). Data on plant height and root length is presented in Table 1.

Number of Nodes and Internode Length: Data on number of nodes and internode length is presented in Table 2. In the two year study, number of nodes and internode length was significantly higher in PGR treated seedlings as compared to control and water sprayed seedlings. Over two years, the number of nodes ranged from 6.45 to 6.75 in PGR treated seedlings and 4.5 in control and water sprayed seedlings which was 41.76 to 48.35 % increase over control. On an average of two years, both control and water sprayed seedlings had 3 cm internode length and PGR treated seedlings had internode length of 4.2 to 4.35 cm which was 40 to 45 % increase over control.

Table 1. Plant height and root length of CxR seedlings at 6 months stage as affected by PGRs

Treatment	Plant Height (cm)			Variation (%)	Root Length (cm)			Variation (%)
	Year 1	Year 2	Mean		Year 1	Year 2	Mean	
T1	20.9	20.4	20.7		11.12	19	15.1	
T2	21	20.7	20.9	**1.00**	11.08	18.8	14.9	**-1.3**
T3	23.1	23.6	23.4	**13.04**	18.03	23.4	20.7	**37.1**
T4	23.1	23.5	23.3	**12.56**	17.77	23	20.4	**35.1**
T5	22.9	23.4	23.2	**12.07**	17.89	23.1	20.5	**35.8**
T6	23	23.7	23.4	**13.04**	17.05	23.3	20.2	**33.8**
T7	23	23.4	23.2	**12.07**	17.49	22.8	20.1	**33.1**
F 5 %	62.6*	63.4*			88.5*	58.0*		
C.D. 5 %	0.31	0.45			0.84	0.66		

Table 2. Number of nodes and internode length of C x R seedlings at 6 months stage

Treatments	Number of Nodes			Variation (%)	Internode Length (cm)			Variation (%)
	Year 1	Year 2	Mean		Year 1	Year 2	Mean	

T1	4.1	5.0	4.5		2.6	3.4	3.0	
T2	4.1	4.9	4.5	**-1.10**	2.5	3.5	3.0	**0.00**
T3	5.8	7.1	6.45	**41.76**	3.4	5.1	4.25	**41.67**
T4	6.2	7.3	6.75	**48.35**	3.6	4.8	4.2	**40.00**
T5	6.1	6.9	6.5	**42.86**	3.6	5.1	4.35	**45.00**
T6	6.0	7.1	6.55	**43.96**	3.5	5.2	4.35	**45.00**
T7	5.9	7.1	6.5	**42.86**	3.6	5	4.3	**43.33**
F Test 5 %	33.017*	30.508*			48.401*	41.344*		
C.D.5 %	0.406	0.475			0.173	0.295		

Number of leaves and leaf area: Data on number of leaves and leaf area of robusta seedlings is presented in Table 3. PGR treated seedlings had more leaves and larger leaf area which were significantly higher compared to those of control seedlings. Number of leaves of PGR treated seedlings from two years study varied from 12.85 to 13.4 with PGR treatments, which was 42.78 to 48.89 % increase over control (9) and water sprayed (8.9) seedlings. On an average, Salicylic acid recorded the highest 552.65 Cm^2 leaf area. 548.65, 537.45, 534.15 and 515.95 Cm^2 leaf area was recorded in the seedlings of NAA, Glyricidia + Lantana, Microbial consortium and DMSO respectively which was 147.99 to 165.63 % increase over control (208.05 Cm^2) and water sprayed (210.65 Cm^2) seedlings.

Shoot Weight and Root Weight: Among the growth parameters, shoot weight is one of the most important aspects. During the study period PGR treated recorded significantly higher shoot weight compared to control and water sprayed seedlings. The mean shoot weight was highest with NAA (36.3 grams) followed by Salicylic acid (36.25 grams), DMSO (35.95 Grams), Glyricidia + Lantana (35.65 grams) and Microbial consortium (35 grams) which was 45.23 to 50.62 % increase over control (24.2 grams) and water sprayed (24.05 grams) seedlings. Result on root weight was similar to shoot weight and PGR treated robusta seedlings recorded significantly higher root weights. Over a period of two years, root weight was highest with NAA (8.05 grams), 8 grams with DMSO and Salicylic acid, 7.95 grams with Glyricidia + Lantana and Microbial consortium which were 32.5 to 34.17 % higher compared to root weight of control (6.0 Grams) and water sprayed (6.05 grams) seedlings. Data on shoot and root weight is given in Table 4.

Table 3. Number of leaves and leaf area in Robusta CxR seedlings at 6 months stage

Treatments	No. of Leaves			Variation	Leaf Area (Cm^2)			Variation
	Year 1	Year 2	Mean	(%)	Year 1	Year 2	Mean	(%)
T1	8.10	9.90	9.00		148.40	267.70	208.05	
T2	8.10	9.70	8.90	**-1.11**	157.90	263.40	210.65	**1.25**
T3	11.50	14.20	12.85	**42.78**	460.90	614.00	537.45	**158.33**
T4	12.30	14.50	13.40	**48.89**	517.60	550.70	534.15	**156.74**
T5	12.20	13.80	13.00	**44.44**	499.80	532.10	515.95	**147.99**
T6	12.00	14.20	13.10	**45.56**	501.90	603.40	552.65	**165.63**
T7	11.80	14.10	12.95	**43.89**	477.20	620.10	548.65	**163.71**
F Test 5 %	33.017*	30.508*			120.189*	50.737*		
C.D.	0.812	0.948			37.161	54.668		

Table 4. Shoot and root weight of Robusta CxR seedlings at 6 months stage.

Treatments	Shoot Weight (Gram)			Variation	Root Weight (Gram)			Variation
	Year 1	Year 2	Mean	(%)	Year 1	Year 2	Mean	(%)
T1	22.3	25.9	24.1		5.5	6.5	6.00	
T2	22.0	26.1	24.05	**-0.21**	5.5	6.6	6.05	**0.83**
T3	31.3	40.0	35.65	**47.93**	6.9	9.0	7.95	**32.50**
T4	30.2	39.8	35.00	**45.23**	6.9	9.0	7.95	**32.50**
T5	31.4	40.5	35.95	**49.17**	7.0	9.0	8.00	**33.33**
T6	31.9	40.6	36.25	**50.41**	7.0	9.0	8.00	**33.33**
T7	32.6	40.0	36.30	**50.62**	7.1	9.0	8.05	**34.17**
F Test 5 %	114.604*	133.26*			39.905*	249.95*		
C.D.5%	1.054	1.469			0.288	0.187		

Shoot to Root Ratio and Root to Shoot Ratio: Data on these parameters in shown in Table 5. In the two years of study, shoot to root ratio was significantly high in PGR treated seedlings ranging from 4.4 to 4.6 in the both the years as compared to shoot to root ratio of control and water treated seedlings that ranged from 4 to 4.1. Over the period of two years, average shoot to root ratio was 4.4 to 4.6 among the PGR treated seedlings which was an increase of 9.76 to 12.2 % increase over control (4.1) and water sprayed (4) seedlings. The root to shoot ratio was significantly higher in control and water sprayed seedlings as compared to PGR treated seedlings in both the years. The mean root to shoot

ratio was 0.13 in all PGR treated seedlings which was 23.53 % lesser compared to root to shoot ratio of 0.17 with control and water treated seedlings.

Table 5. Shoot to root and root to shoot ratio in CxR robusta seedlings at 6 months age

Treatments	Shoot to Root Ratio			Variation	Root to Shoot Ratio			Variation
	Year 1	Year 2	Mean	(%)	Year 1	Year 2	Mean	(%)
T1	4.1	4.0	4.1		0.19	0.16	0.17	
T2	4.0	4.0	4.0	**-2.44**	0.18	0.15	0.17	**0.00**
T3	4.6	4.4	4.5	**9.76**	0.15	0.11	0.13	**-23.53**
T4	4.4	4.4	4.4	**7.32**	0.15	0.11	0.13	**-23.53**
T5	4.5	4.5	4.5	**9.76**	0.14	0.11	0.13	**-23.53**
T6	4.6	4.6	4.6	**12.20**	0.14	0.11	0.13	**-23.53**
T7	4.6	4.4	4.5	**9.76**	0.14	0.11	0.13	**-23.53**
F Test 5 %	6.986*	6.601*			45.702*	254.388*		
C.D. 5 %	0.225	0.229			0.007	0.003		

Plant Nutrient Status

Nutrients status of both major and minor nutrients was significantly higher in PGR treated seedlings (Table 6 and 7) during both the years of study as compared to control and water sprayed seedlings. Among the major nutrients, nitrogen content varied from 2.66 to 2.69 % in PGR treated seedlings of robusta as compared to 2.26 and 2.23 % nitrogen in control and water sprayed seedlings, which were 17.7 to 19.03 % increase over control. Mean phosphorus over two years was 0.16 % same in all PGR treated seedlings which was 33.33 % increase over 0.12 % phosphorus of control and water sprayed seedlings. On average potassium content was varying from 2.86 to 2.91 % in seedlings of PGR treatments which were 23.81 to 25.97 % increase over the potassium content of control (2.31 %).

Calcium content of CxR seedlings treated with PGRs ranged from 1.07 % to 1.13 % which were 30.35 to 101.97 % increase over the calcium content of control (0.56 %) seedlings. The mean magnesium content was 43.58 to 58.78 % higher in PGR treated seedlings compared to 0.3 % Magnesium of control seedlings. Over two years, sulphur content was also higher in PGR treated seedlings ranging from 0.23 to 0.24 % and was 74.9 to 78.71 % higher compared to 0.13 % sulphur content of control seedlings.

The results obtained from the study influence of PGRs on growth and development of six months old coffee seedlings indicated that the growth parameters observed and studied varied significantly in most of the cases. All PGR treated seedlings had statistically and significantly higher growth when compared to growth of seedlings in control and water sprayed seedlings in both Arabica and Robusta coffee. The parameters were statistically on par among within all the PGR treatments. Similarly, growth parameters were statistically on par between control and water sprayed seedlings. As per the statistical analysis, all plant growth regulators had equal influence on growth parameters of coffee seedlings. Glyricidia and Lantana have been proved to be good growth regulators in improving coffee in earlier studies conducted and reported (Anon, 2003; Anon,2004) at Central Coffee Research Institute. Even the Salicylic acid (Anon, 2006) also has proved in improving coffee. The improvement in growth parameters of seedlings using Microbial consortium could be attributed to its composition that contains N fixing, P & Zn solubilizing and plant growth promoting microbes as a single formulation. Use of microbial consortium also reported to improve the growth of coffee seedlings as evidenced by Panneer Selvam *et al*. 2008. Enhanced growth parameters using NAA could be attributed to growth promoting characters of NAA by enhancing root growth. Eric Randy and Barney (2016) reported similar results with usage of NAA nearer to concentration used in this study (100-150 ppm) for boosting robusta clonal seedlings. In an another study, similar results were obtained with Cindy Liana (2022) where the results of the study showed that presenting IBA with a concentration of 300 ppm had a significant effect on the parameters of shoot height, root wet weight and root dry weight and the administration of NAA with concentrations of 100 ppm and 200 ppm gave the best results on the number of leaves, root length, root wet weight, root dry weight of robusta seedlings. Salicylic acid also as growth promoter enhanced the growth of coffee seedlings. This can be supported by the study of Novie and Fakhrusy (2021) who reported that In general, the application of salicylic acid could enhance the growth of Robusta coffee seedlings. The application of 0.6 mM salicylic acid increased plant growth of coffee seedlings. There was different response to concentration of application salicylic acid for both clones. The application of 0.6 mM salicylic acid could increase plant growth of BP 308, include plant height, leaf area, stem dry mass, leaf dry mass, root/shoot ratio and total dry mass. Meanwhile, on Sintaro clone, application of 1.2 mM salicylic acid could increase leaf area, stem, leaf and total dry mass.

As a universal solvent and absorbent, DMSO mixed with CuSo4, Glyricidia Lantana enhanced the growth of coffee seedlings in the present study. Even though studies using DMSO are limited in coffee, a study using with Dymethyl sulphoxide (DMSO) on carrot plants grown under field conditions on the leaves to determine its effects on fresh biomass accumulation indicated that when $7xl0^{-3}$ M solution sprayed on two occasions during plant development,

increase in root fresh weight was 28%, root length 10% and shoot fresh weight 41 % higher in DMSO treated plants than in control plants (San Miguel et al 2003).

In case of control and water sprayed seedlings, growth parameters were on par statistically with each other but had significantly inferior growth compared to that of seedlings grown using PGRs. The on par growth between control and water sprayed seedlings could be attributed to the reason that even in normal maintenance of nursery, water spraying or irrigation everyday is common for moisture and micro climate maintenance. Hence, spray of water as treatment during treatment imposition had no special effect on growth and development of coffee seedlings. Overall the present study indicated the positivity of using plant growth regulators in improving growth and development of coffee seedlings. Farmers therefore can make use of either chemical or natural growth regulators depending on the kind of agriculture practice during the cultivation or raising nursery for growth better quality and superior seedlings than that they grow in normal practice.

Table 6. Major nutrients status of Robusta Variety C x R seedlings at 6 months stage

Treatments	Nitrogen (%)			Variation (%)	Phosphorus			Variation (%)	Potassium			Variation (%)
	Year 1	Year 2	Mean		Year 1	Year 2	Mean		Year 1	Year 2	Mean	
T1	2.11	2.40	2.26		0.13	0.11	0.12		2.06	2.55	2.31	
T2	2.08	2.38	2.23	**-1.33**	0.13	0.11	0.12	**0.00**	2.07	2.56	2.32	**0.43**
T3	2.67	2.70	2.69	**19.03**	0.17	0.15	0.16	**33.33**	2.74	3.00	2.87	**24.24**
T4	2.62	2.70	2.66	**17.70**	0.17	0.15	0.16	**33.33**	2.76	3.01	2.89	**25.11**
T5	2.65	2.68	2.67	**18.14**	0.17	0.14	0.16	**33.33**	2.77	3.04	2.91	**25.97**
T6	2.63	2.71	2.67	**18.14**	0.17	0.14	0.16	**33.33**	2.73	2.98	2.86	**23.81**
T7	2.63	2.70	2.67	**18.14**	0.17	0.15	0.16	**33.33**	2.79	2.99	2.89	**25.11**
F Test 5 % 5 %	282.993*	130.3*			161.04*	61.592*			286.227*	59.903*		
C.D.	0.038	0.033			0.005	0.005			0.049	0.069		

Table 7. Minor nutrients status of Robusta Variety C x R seedlings at 6 months stage

Treatments	Calcium %			Variation (%)	Magnesium %			Variation (%)	Sulphur %			Variation (%)
	Year 1	Year 2	Mean		Year 1	Year 2	Mean		Year 1	Year 2	Mean	
T1	0.49	0.63	0.56		0.30	0.29	0.30		0.17	0.09	0.13	
T2	0.53	0.66	0.60	**6.34**	0.33	0.31	0.32	**8.11**	0.17	0.09	0.13	**-1.14**
T3	1.08	1.11	1.10	**95.71**	0.37	0.48	0.43	**43.58**	0.23	0.23	0.23	**74.90**
T4	1.14	1.12	1.13	**101.97**	0.41	0.50	0.46	**53.72**	0.23	0.23	0.23	**74.90**
T5	1.06	1.11	1.09	**93.92**	0.40	0.54	0.47	**58.78**	0.24	0.23	0.24	**78.71**
T6	1.10	1.10	1.10	**96.60**	0.41	0.51	0.46	**55.41**	0.24	0.22	0.23	**74.90**
T7	1.04	1.09	1.07	**90.35**	0.39	0.48	0.44	**46.96**	0.23	0.24	0.24	**78.71**
F Test 5 % 5 %	62.422*	445.86*			11.664*	65.523*			289.407*	253.445*		
C.D.	0.088	0.026			0.033	0.029			0.005	0.01		

DISCUSSION AND CONCLUSION

As per the statistical analysis, all plant growth regulators had equal influence on growth parameters of coffee seedlings in Robusta coffee. The growth parameters were statistically on par among the PGR treatments. Glyricidia and Lantana have been proved to be good growth regulators to improve coffee in earlier studies conducted and reported (Anon, 2003; Anon,2004) at Central Coffee Research Institute. Even the Salicylic acid (Anon, 2006) also has proved in improving coffee. The improvement in growth parameters of seedlings using Microbial consortium could be attributed to its composition that contains N fixing, P & Zn solubilizing and plant growth promoting microbes as a single formulation. Use of microbial consortium also reported to improve the growth of coffee seedlings as evidenced by Panneer Selvam *et al*. 2008. Enhanced growth parameters using NAA could be attributed to growth promoting characters of NAA by enhancing root growth. Eric Randy and Barney (2016) reported similar results with usage of NAA nearer to concentration used in this study (100-150 ppm) for boosting robusta clonal seedlings. In an another study, similar results were obtained with Cindy Liana (2022) where the results of the study showed that presenting IBA with a concentration of 300 ppm had a significant effect on the parameters of shoot height, root wet weight and root dry weight and the administration of NAA with concentrations of 100 ppm and 200 ppm gave the best results on the

number of leaves, root length, root wet weight, root dry weight of robusta seedlings. Salicylic acid also as growth promoter enhanced the growth of coffee seedlings. This can be supported by the study of Novie and Fakhrusy (2021) who reported that In general, the application of salicylic acid could enhance the growth of Robusta coffee seedlings. The application of 0.6 mM salicylic acid increased plant growth of coffee seedlings. There was different response to concentration of application salicylic acid for both clones. The application of 0.6 mM salicylic acid could increase plant growth of BP 308, include plant height, leaf area, stem dry mass, leaf dry mass, root/shoot ratio and total dry mass. Meanwhile, on Sintaro clone, application of 1.2 mM salicylic acid could increase leaf area, stem, leaf and total dry mass.

As a universal solvent and absorbent, DMSO mixed with CuSo4, Glyricidia Lantana enhanced the growth of coffee seedlings in the present study. Even though studies using DMSO are limited in coffee, a study using with Dymethyl sulphoxide (DMSO) on carrot plants grown under field conditions on the leaves to determine its effects on fresh biomass accumulation indicated that when $7xl0^{-3}$ M solution sprayed on two occasions during plant development, increase in root fresh weight was 28%, root length 10% and shoot fresh weight 41 % higher in DMSO treated plants than in control plants (San Miguel et al 2003).

In case of control and water sprayed seedlings, growth parameters were on par statistically with each other but had significantly inferior growth compared to that of seedlings grown using PGRs. The on par growth between control and water sprayed seedlings could be attributed to the reason that even in normal maintenance of nursery, water spraying or irrigation everyday is common for moisture and micro climate maintenance. Hence, spray of water as treatment during treatment imposition had no special effect on growth and development of coffee seedlings. Overall the present study indicated the positivity of using plant growth regulators in improving growth and development of coffee seedlings. Farmers therefore can make use of either chemical or natural growth regulators depending on the kind of agriculture practice during the cultivation or raising nursery for growth better quality and superior seedlings than that they grow in normal practice.

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