Improvement Generative Growth of *Coffea arabica* L. Using Plant Growth Regulators and Pruning

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Abstract. Pruning coffee plants is intended to stimulate generative growth that increases productivity to reach optimal. Plant Growth Regulator (PGR) makes it possible to exploit the production potential of plants. Pruning management, combined with the PGR in coffee plants, is expected to improve flowering and berry growth. The research was conducted for 7 mo from October 2017 to April 2018 at Gunung Gede, Bogor, West Java, Indonesia. A split–plot design with two treatment factors was used in this research. Pruning was placed as the main plot consisting of two levels, namely without (P0) and with pruning (P1). The PGR application was placed as a subplot, consisting of three dosages, namely without PGR (Z0), and concentrations of 0.3 mL L^{-1} (Z1) and 0.4 mL L^{-1} (Z2). The results showed, the pruning treatment significantly influenced microclimate, number of branches, B0, B1 and B2, number of berry sets, and berries. Pruning treatment had a very significant effect on microclimate, plant height, number of branches, number of coffee fruits, yields crops^{-1}, and productivity. Interaction both significantly affected plant height and B0. The best dosage had not yet been found.

Key words: Branches, coffee arabica, improve coffee flowering and berry growth, increase coffee production

1 Introduction

Indonesia is the fourth world coffee exporter after Brazil, Colombia, and Vietnam [1]. Coffee is one of the leading commodities in Indonesia, with positive impacts in socio–economic [2], health science [3, 4], and others. Coffee performance is not only in

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beans. But it is also shown by the side product, among others by solid waste, namely husks and pulp [5–7].

In order to become the largest coffee exporter, Indonesia must increase its coffee yield by developing some technologies. The availability of technologies, such as pruning and plant growth regulators are important. Pruning activities are very important so that coffee plants remain productive continuously [8]. Pruning is useful for breaking the life cycle of pests and diseases, forming a balanced plant canopy between branches, leaves, and fruit production, preventing fruit density, and shooting death. Trimming remnants can be used for soil mulch. Mulching can prevent soil erosion. Decomposed mulch can function as organic fertilizer [8]. In addition, pruning of coffee plants is intended to stimulate generative growth, so that productivity is more optimal and continuous throughout the year.

Plant growth regulators (PGR) in low concentrations can encourage, inhibit, or modify growth and development both in quantity and quality. PGR improves the absorption of nutrients by plants [9], PGR makes it possible to exploit the production potential of plants. In addition, PGR serves to accelerate the response of plants to the environment [10]. Plants can produce natural PGR, but their quantities are limited so that synthetic PGR needs to be added. PGR acts as activators plant cell metabolism, strengthens the immune system, and reacts physiologically. In *Coffea arabica* L. plants, the number of shoots can be increased with the application of growth regulators and fertilizers [11]. Pruning management, combined with the application of PGR in coffee plants, is expected to improve flowering and berry growth.

2 Material and methods

2.1 Study site and treatments

The experiment was conducted for 7 mo from October 2017 to April 2018 at Gunung Gede, Bogor, West Java, Indonesia Teaching Farm. The planting material used was the Catimor variety of coffee plants from Catura versus Hibrido De Timor, which was 3 yr old after planting. The growth regulator used was Paclobutrazol. PGR was applied by watering through the ground instead of spraying it directly to the plant parts to reduce the negative impact.

The dosage of fertilizers was listed in Table 1.

Table 1. Fertilizer dosage

Plant age (yr)	The early rainy season (g plant^{-1})				The end of the rainy season (g plant^{-1})			
	Urea	SP 36	KCl	Kieserit	Urea	SP 36	KCl	Kieserit
1	20	25	15	10	20	25	15	10
2	50	40	40	15	50	40	40	15
3	75	50	50	25	75	50	50	25
4	100	50	70	35	100	50	70	35
5 to 10	150	80	100	50	150	80	100	50
> 10	200	100	125	70	200	100	125	70

2.2 Trial set up

A split–plot design with two treatment factors was used in the research. Pruning was placed as the main plot consisting of two levels, namely without pruning (P0) and pruning (P1). The PGR application was placed as a subplot, consisting of three dosages of PGR, namely

without the application of PGR (Z0), application of concentrations of 0.3 mL L^{-1} (Z1), and 0.4 mL L^{-1} (Z2). Therefore, there were six treatment combinations, and each of them consists of three replications. There were 18 experimental units. Each experimental unit consisted of three coffee plants.

The parameters observed were microclimate, such as temperature, humidity. Vegetative growth like plant height, number of branches, and generative growth such as productive branches, number of B0 (branches not yet bearing fruit), B1 (branches that have been fruiting once), B2 (branches that have been fruiting twice), B3 (branches that have been fruiting three times), number of berry sets, number of berries, yields crops^{-1}, and productivity.

3 Results and discussions

3.1 Respon of microclimate to pruning treatment

Microclimate observations were carried out three times in the morning, noon, and afternoon. In general, the temperature begins to increase from morning to afternoon and then decrease in the afternoon. Pruning (P1) treatment has a significant effect on temperature at noon (Table 3) and afternoon (Table 4) but not significantly in the morning (Table 2) around the canopy coffee plant.

Table 2. Effect pruning treatment on the temperature in the morning (at 07.00 am)

Treatment	Age (months after application)					
	1	2	3	4	5	6
	Temperature (°C)					
Pruning						
P0	26.40a	26.24a	26.45a	27.26a	27.40a	27.35a
P1	26.53a	26.62a	26.40a	27.24a	27.30a	27.35a
Pr > F	No	No	No	No	No	No

Description: *: Significant difference ($p < 0.05$), **: Significant difference ($p < 0.01$), No: Not significant, P0: Without pruning, P1: Pruning

Table 3. Effect pruning treatment on the temperature at noon (at 12.00 o'clock)

Treatment	Age (months after application)					
	1	2	3	4	5	6
	Temperature (°C)					
Pruning						
P0	30.97b	31.05a	30.97b	31.11a	31.04a	31.21a
P1	31.32a	31.31a	31.34a	31.28a	31.35a	31.34a
Pr > F	*	No	*	No	No	No

Description: *: Significant difference ($p < 0.05$), **: Significant difference ($p < 0.01$), No: Not significant, P0: Without pruning, P1: Pruning

Table 4. Effect pruning treatment on the temperature in the afternoon (at 05.00 pm)

Treatment	Age (months after application)					
	1	2	3	4	5	6
	Temperature (°C)					
Pruning						
P0	26.31b	26.38b	26.44b	27.53a	27.64a	27.46a
P1	26.95a	26.94a	26.97a	27.75a	27.61a	27.84a
Pr > F	**	*	*	No	No	No

Description: *: Significant difference ($p < 0.05$), **: Significant difference ($p < 0.01$), No: Not significant, P0: Without pruning, P1: Pruning

Pruning (P1) treatment had a very significant effect on the humidity in the morning (Table 5) at the age of 5 MAP to 6 MAP (month after application) and afternoon (Table 7) at the age of 2 MAP to 4 MAP. At noon (Table 6), pruning treatment had a significant effect on the 4 MAP compared to the treatment without pruning (P0). Humidity began to decrease from morning to noon and increase in the afternoon. Pruning treatment could reduce the moisture, to reduce fruit desiccation.

Pruning techniques could improve air circulation and reduced humidity in the microclimate to reduce disease attacks. On the other hand, pruning will reduce photosynthesis competition between fruit and leaves [12].

Table 5. Effect of pruning treatment on Relative Humidity (RH) in the morning (at 7.00 am)

Treatment	Age (months after application)					
	1	2	3	4	5	6
	Relative humidity (%)					
Pruning						
P0	74.78a	76.77a	77.40a	69.77a	69.11b	69.44b
P1	76.88a	77.22a	78.22a	70.22a	70.55a	70.88a
Pr > F	No	No	No	No	**	**

Description: *: Significant difference ($p < 0.05$), **: Significant difference ($p < 0.01$), No: Not significant, P0: Without pruning, P1: Pruning

Table 6. Effect of pruning treatment on RH at noon (at 12.00 o'clock)

Treatment	Age (months after application)					
	1	2	3	4	5	6
	Relative humidity (%)					
Pruning						
P0	56.11a	57.11a	57.11a	55.77b	56.44a	56.33a
P1	56.00a	56.66a	56.66a	58.55a	58.22a	58.00a
Pr > F	No	No	No	*	No	No

Description: *: Significant difference ($p < 0.05$), **: Significant difference ($p < 0.01$), No: Not significant, P0: Without pruning, P1: Pruning

Table 7. Effect of pruning treatment on RH in afternoon (at 05.00 pm)

Treatment	Age (months after application)					
	1	2	3	4	5	6
	Relative humidity (%)					
Pruning						
P0	90.66a	91.22a	91.44a	79.44b	79.15a	80.33a
P1	87.77b	88.00b	87.88b	80.44a	79.55a	80.53a
Pr > F	*	**	**	**	No	No

Description: *: Significant difference ($p < 0.05$), **: Significant difference ($p < 0.01$), No: Not significant, P0: Without pruning, P1: Pruning

3.2 Response of vegetative growth *C. arabica* to pruning and PGR treatment

Pruning treatment had a very significant effect on plant height at the age of 2 MAP to 6 MAP (Table 8). Pruning treatment produced the lowest plant height and achieved optimal production. In addition, pruning was very useful in facilitating the harvesting of crops. The application of PGR treatment had no effect of planting height from beginning to end observation 0 MAP to 6 MAP. Interaction between pruning and PGR application had a significant effect on the plant height at the age of 2 MAP.

Table 8. Effect of pruning and PGR treatment to plant height

Treatment	Age (months after application)						
	0	1	2	3	4	5	6
	....(cm)..						
Pruning							
P0	164.37a	166.63a	177.04a	185.44a	188.55a	178.85a	183.96a
P1	166.63a	164.37a	149.00b	149.07b	149.07b	149.07b	148.70b
Pr > F	No	No	**	**	**	**	**
PGR application							
Z0	172.22a	166.39a	173.22a	170.27a	172.00a	167.66a	169.72a
Z1	159.17a	165.11a	159.16a	170.94a	172.55a	166.00a	169.44a
Z2	164.11a	157.56a	164.11a	160.55a	161.89a	158.22a	159.83a
Pr > F	No	No	No	No	No	No	No
Interaction	No	No	*	No	No	No	No

Description: *: Significant difference ($p < 0.05$), **: Significant difference ($p < 0.01$), No: Not significant, P0: Without pruning, P1: Pruning, Z0: 0 mL L^{-1}, Z1: 0.3 mL L^{-1}, Z2: 0.4 mL L^{-1}

Pruning treatment gave a very significant effect on the number of branches at the age of 1 MAP to 6 MAP (Table 9), but the application of PGR treatment did not affect the number of branches. The average number of branches was 49.85 branches on without pruning (P0) and 33.40 branches on pruning treatment (P1) in the last observation.

Pruning treatment stimulated new branches that are continuous in sufficient quantities to support the continuity of production. Pruning coffee plants facilitated the entry of light to stimulate the formation of evenly distributed flower primordia and perfect flowering [13]. The effect of pruning and PGR applications on the number of branches can be seen in Table 9.

Table 9. Effect of pruning and PGR treatment to the number of branches

Treatment	Age (months after application)						
	0	1	2	3	4	5	6
	....................................(Number of branches)...						
Pruning							
P0	38.370a	40.77a	41.22a	52.96a	53.22a	46.88a	49.85a
P1	25.04a	26.22b	33.15b	33.77b	33.85b	32.44b	33.40b
Pr > F	No	*	*	**	**	*	**
PGR application							
Z0	31.33a	34.33a	38.78a	43.72a	44.11a	39.72a	42.27a
Z1	30.11a	34.77a	38.67a	44.00a	44.11a	40.83a	42.66a
Z2	33.667a	34.11a	34.11a	42.38a	42.38a	38.44a	39.94a
Pr > F	No	No	No	No	No	No	No
Interaction	No	No	No	No	No	No	No

Description: *: Significant difference ($p < 0.05$), **: Significant difference ($p < 0.01$), No: Not significant, P0: Without pruning, P1: Pruning, Z0: 0 ml L^{-1}, Z1: 0.3 mL L^{-1}, Z2: 0.4 mL L^{-1}

3.3 The response of generative growth *C. arabica* to pruning and PGR treatment

Pruning and PGR application did not affect the productive branches formation. Unproductive branches were pruned so that the nutrients supplied could be channeled to the more productive branches. The effect of pruning and PGR treatment on productive branches were shown in Table 10.

Table 10. Effect of pruning and PGR treatment to productive branches

Treatment	Age (months after application)						
	0	1	2	3	4	5	6
	....................................(Productive branches)...............................						
Pruning							
P0	23.51a	23.70a	23.77a	24.51a	24.51a	23.77a	24.18a
P1	18.88a	23.55a	23.59a	23.00a	22.59a	23.18a	23.81a
Pr > F	No	No	No	No	No	No	No
PGR application							
Z0	22.611a	23.22a	24.111a	23.27a	22.94a	22.61a	23.50a
Z1	22.611a	23.27a	23.500a	24.16a	24.16a	24.55a	25.00a
Z2	18.778a	20.27a	23.278a	23.83a	23.55a	23.27a	23.50a
Pr > F	No	No	No	No	No	No	No
Interaction	No	No	No	No	No	No	No

Description: *: Significant difference ($p < 0.05$), **: Significant difference ($p < 0.01$), No: Not significant, P0: Without pruning, P1: Pruning, Z0: 0 mL L^{-1}, Z1: 0.3 mL L^{-1}, Z2: 0.4 mL L^{-1}

The effect of pruning showed a significant effect on the amount of B0 at 1 MAP (Table 11). The number of B0 reached 16.85 branches in the treatment without pruning while in the treatment of pruning around 12.74 branches. The PGR treatment did not seem to affect the amount of B0 from the beginning to the end of the observation. Interaction of pruning treatment and PGR were evident at 2 MAP.

Table 11. Effect of pruning and PGR treatment to the number of B0

Treatment	Age (months after application)					
	1	2	3	4	5	6
	..................................(Number of B0)...................................					
Pruning						
P0	16.85a	11.11a	9.98a	10.37a	17.03a	9.51a
P1	12.74b	10.63a	8.45a	9.51a	12.18a	7.88a
Pr > F	*	No	No	No	No	No
PGR application						
Z0	15.16a	9.61a	8.92a	9.00a	15.66a	6.72a
Z1	14.72a	8.66a	8.46a	10.11a	14.05a	9.22a
Z2	14.50a	14.33a	10.27a	10.72a	14.11a	6.72a
Pr > F	No	No	No	No	No	No
Interaction	No	*	No	No	No	No

Description: *: Significant difference ($p < 0.05$), **: Significant difference ($p < 0.01$), No: Not significant, P0: Without pruning, P1: Pruning, Z0: 0 mL L^{-1}, Z1: 0.3 mL L^{-1}, Z2: 0.4 mL L^{-1}

Pruning (P1) treatment had a very significant effect (Table 12) on yields (g plant^{-1}), fresh and dry fruit yields ha^{-1} at the second harvest compared to without pruning (P0). The yield plants^{-1} (Figure 1) in pruning treatment reached 1 668.36 g while without pruning only 958.56 g. The importance of pruning activities was to avoid cases of overbearing dieback, namely the death of coffee plants after experiencing heavy growth without being followed by proper maintenance, for example, fertilization and pruning [14]. The application of PGR and their interaction did not significantly affect the yield. Different from the result of [15], the application of a plant growth regulator increased at the number of internodes, the average number of fruits on the fourth and fifth node, and the length of reproductive branches. The productivity of coffee could be increased with the use of plant growth regulators [16].

Table 12. Effect of pruning and PGR treatment on *C. arabica* yields in the first and second harvest

Treatment application	Yield g plant^{-1}		Wet fruit yield (berries) kg ha^{-1}		Dry fruit yield (productivity) kg ha^{-1}	
Pruning	1	2	1	2	1	2
P0	2 381.88a	985.56b	4 763.76a	1 971.12a	952.75a	394.22a
P1	2 154.48a	1 668.36a	4 308.96a	3 336.72a	861.79a	667.34a
Pr > F	No	**	No	**	No	**
PGR application						
Z0	2 308.44a	1 526.64a	4 616.88a	3 053.28a	923.37a	610.66a
Z1	2 454.72a	1 236.00a	4 909.44a	2 472.00a	981.88a	494.40a
Z2	2 041.20a	1 218.24a	4 082.40a	2 436.48a	816.48a	487.29a
Pr > F	No	No	No	No	No	No
Interaction	No	No	No	No	No	No

Description: *: Significant difference ($p < 0.05$), **: Significant difference ($p < 0.01$), No: Not significant, P0: Without pruning, P1: Pruning, Z0: 0 mL L^{-1}, Z1: 0.3 mL L^{-1}, Z2: 0.4 mL L^{-1}

4 Conclusions

Pruning treatment significantly influenced microclimate, number of branches, B0, B1 and B2, number of berry sets, and berries. Pruning treatment had a very significant effect on microclimate, plant height, number of branches, number of coffee fruits, yields crops^{-1}, and productivity. Interaction between pruning and PGR significantly affected plant height and B0. The best dosage for PGR treatment had not yet been found.

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