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The effect of liquid foliar treatments and pruning combinations on the growth of productive phase arabica coffee plants (*Coffea arabica* L.)

Abstract. In recent years, productivity decline in arabica coffee has become a real issue in Indonesia. This decay has been brought about by various external and internal factors that are beyond human control. Various factors, including suboptimal cultivation practices, take part in this process. The objective of the present study was to evaluate the effect of pruning combined with foliar fertilizer application (coconut water and sugarcane molasses) and 6-benzylaminopurine (BAP) on the vegetative growth of arabica coffee plants during the production phase. The research was conducted at Ciparanje Experimental Field, Universitas Padjadjaran, using a randomized complete block design with seven treatments including a control (without pruning and foliar application), application of coconut water (75%, 750 mL L^{-1}), sugarcane molasses (2 mL L^{-1}), and BAP at 60 ppm, each applied with and without pruning, and four replications. In this research, the main parameters observed included the number and length of the lateral branches, leaf chlorophyll index, leaf area, canopy width, number of fruit clusters per branch and per tree, and coffee cherry fruit weight. It emerged that the combination of pruning and the use of sugarcane molasses at 2 mL L^{-1} significantly increased lateral branch formation, leaf area, and the number of fruit clusters per tree. The integration of pruning with foliar treatments effectively supported optimal growth of productive-phase arabica coffee plants.

Keywords: 6-benzylaminopurine · Coconut water · Coffee cherry · Lateral branches · Sugarcane molasses

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Introduction

Arabica coffee is one of the most significant Indonesian coffee commodities. This implies that the product makes a substantial contribution to agricultural income for the country. According to the United States Department of Agriculture (2024), Indonesia placed 16th globally regarding the production of arabica coffee. Thus, this shows the contribution of the Indonesian coffee Industry to the global economy. However, this is also paired with the significant potential for growth, i.e., increased demand for the product globally. Looking at the national levels of the industry, it has been observed that there has been a decline in the production of the product over the recent past. Data from the United States Department of Agriculture (2024) indicate a reduction from 78,000 tons of arabica coffee produced in 2020/2021 to 72,000 tons of the product from 2022/2023. This shows that there are still various issues to be solved related to the management of the plants.

The reduction of productivity for arabica coffee is not solely explained by land changes but is equally shaped by daily field-level farming activities. Fertilization and pruning activities for coffee farms, which contain arabica coffee, occur using traditional methods and not technology in most areas of Indonesia (Rico et al., 2021). This implies that fertilization and pruning take place in a poor manner relative to what is required for the development of coffee plants. Fertilizers play a vital role in ensuring the provision of substances required for the formation of coffee leaves or fruits (Ma et al., 2022). Pruning of coffee plants is effective for maintaining illumination within the plant and influencing the direction of plant development (Mohammed & Worku, 2025; Sharma et al., 2025).

Additionally, and most importantly, if fertilization and pruning are carried out properly, the actual effect of these two activities on the further improvement of the coffee plants becomes unmistakable. Previous studies revealed that the integration of pruning and fertilizer has positive effects on the cultivation management of arabica coffee plants. Integration of alternative pruning methods and fertilizer, either organic or inorganic, promotes the stem diameter, shoots, chlorophyll content, and soil qualities (Rohani et al., 2024). Pruning has been found to have an effect on the microclimate and the yield of the plants, and fertilization on the anatomy and physiological properties of the leaves (Muliasari et al., 2021; Soares et al., 2022).

Most of the coffee farmers in Indonesia still apply inputs directly to the soil, due to the fact that most of the necessary ones are NPK and urea, which are easy to obtain and easy to use. However, under field conditions, a large amount of these nutrients is usually lost through processes such as leaching, fixation by the soil, or competition with weeds, thus lowering nutrient availability for the plants (Asare et al., 2023; Barłóg et al., 2022; Little et al., 2021; Mao et al., 2024). In such a case, it is increasingly important to adopt more efficient fertilizer methods while ensuring sustainability.

One alternative fertilization that would help solve the problems stated above is foliar fertilization. The fertilizers would be used to provide nutrients to the leaves, which can be easily absorbed by the plant (Arsic et al., 2022; Niu et al., 2020). The materials that can be used as foliar fertilizers are sugarcane molasses and coconut water, and 6-benzylaminopurine (BAP) as a plant growth regulator. BAP makes use of cytokinin, which stimulates cell division and shoot development (Ali et al, 2021; Zarea & Karimi, 2023). On the other hand, molasses and coconut make use of nutrients as well as growth regulators, which improve plant metabolism and development (Salman, 2022; Stephen et al, 2024). The materials applied in this study are generally obtainable, although their availability and cost-effectiveness can differ across locations. Coconut water and molasses may represent relatively inexpensive inputs in some areas, while the inclusion of BAP, a synthetic plant growth regulator, may require additional investment depending on usage and sourcing. Consequently, the economic implications of these treatments depend on the location and were not the primary focus of this study.

Apart from fertilization, pruning is another significant factor to be followed during the cultivation of Coffee. Thus, pruning is a procedure to control the height of the plant, allow penetration of sufficient light, avoid pests, and prevent plant infection (Gokavi et al., 2021; Rahman et al., 2024). The application of pruning during the fruiting stage improves the number of fruitful branches and the photosynthetic surface area (Yang et al., 2023; Zhang et al., 2022). In relation to this, the explanation from the physiological perspective of pruning is essential for leaf and fruit development, which determines the productivity of the crop (Dong et al., 2019; Colodetti et al., 2020).

The combination of pruning and the application of liquid fertilizers has emerged as a potential approach for enhancing the productivity of arabica coffee varieties. It is observed that the sensitivity response takes place during pruning, which starts the healing process for the affected part of the plant, hence the need for increased nutrition. At this point, foliar fertilizers become significant in the recovery process, as they can provide the necessary nutrients for the development of new shoots (Xie et al., 2023). Aside from plant physiology, the combined effects of pruning and fertilization also have significant effects on soil. Rowe et al. (2022) found that these practices not only affect coffee yield but also impact environmental services like soil carbon and nitrogen content. Furthermore, Kurniawan et al. (2024) reported that pruning also increased soil total nitrogen content by 10-56% compared with unpruned trees. At the production level, Siahaan et al. (2020) found that the combined effects of pruning and fertilization significantly increased the number of productive branches, canopy diameter, fruit clusters, fruits per cluster, and seed weight. However, despite these positive results, studies that specifically examine the combined effects of these two practices are still relatively limited, highlighting the need for further research.

Based on these conditions, further research was needed on the integration of foliar treatments and pruning in Arabica coffee cultivation. Therefore, this study aimed to evaluate the effects of liquid foliar application and pruning on the growth and productivity of Arabica coffee plants during the production phase and to determine the most effective treatment combination for increasing yield. It was expected that the appropriate combination of foliar treatments and pruning, particularly through the use of molasses-based formulations and suitable pruning techniques, could improve plant growth and yield performance.

Materials and Methods

The experiment was conducted at the Ciparanje Experimental Field, Faculty of Agriculture, Universitas Padjadjaran, Jatinangor, Sumedang Regency, from December 2024 to April 2025, at an altitude of approximately 730 m above sea level. The plant material consisted of three-year-old arabica coffee plants of the Lini S 795 variety in the productive phase, grown at the experimental field. Materials used in this study included coconut water, sugarcane molasses, and liquid Benzyl Amino Purine (BAP). Other tools used in this experiment include hoes, pruning shears, watering cans, machetes, measuring tapes, vernier callipers, buckets, plant labels, stationery, a hand sprayer, and documentation tools. This study was arranged in a randomized complete block design (RCBD) with seven treatments and four replications. Each experimental unit contained two plants, making a total of 56 plants for treatment. The treatments applied were: (A) control without pruning and foliar application; (B) 75% of coconut water (750 mL L^{-1} water) with pruning; (C) 2 mL L^{-1} water sugarcane molasses with pruning; (D) 60 ppm (0.06 mL L^{-1} water) liquid BAP with pruning; (E) 75% of coconut water without pruning; (F) 2 mL L^{-1} water sugarcane molasses without pruning; and (G) 60 ppm (0.06 mL L^{-1} water) liquid BAP without pruning.

SPSS software was used to analyse the data obtained from the field experiments, considering 5 percent significance level for analysis of variance. The F-test at a probability level of 5 percent was used to test the significance of treatment effects. Then, when significant differences between treatment means occurred, DMRT was used at the 5 percent level of significance for further mean comparisons.

The research started by uprooting weeds and other remnants of old plants from around the plant units. The young coconut water used in this research was extracted from selected coconuts sourced from local markets, approximately seven to eight months after flowering, selected due to the smoothness of their green outer shells. This was collected in clean containers and filtered through a fine sieve to eliminate debris and any other impurities, and immediately applied to minimize nutrient degradation. In addition, the sugarcane molasses used in this experiment was a liquid fertilizer based on molasses (liquid waste sugarcane). Moreover, the 6-benzylaminopurine (BAP) used in this study was a synthetic cytokinin commercially available under the trade name 6-BAP.

Pruning was carried out at the beginning of the experiment (0 weeks) to maintain an average plant height of 153 cm above ground level (Rodrigues et al., 2017). The Arabica coffee plants used in this research were approximately three years old and were uniformly pruned within each experimental unit. The first foliar application was conducted immediately after pruning (0 weeks), followed by subsequent applications at 2, 6, 8, and 10 weeks after pruning. Foliar treatments involve using a hand sprayer, covering all parts of the plants, including the top and bottom parts of leaves. Spraying the leaves was conducted until they were evenly covered to ensure an even spread of the substance and its even absorption. Observed variables included the increased number of lateral branches, increased elongation of lateral branches, chlorophyll index, leaf area, width of the canopy, number of fruit clusters on the branch, number of fruit clusters on the plants, and the weight of the fruit.

Results and Discussion

Number of Lateral Branches. BAP treatment at 60 ppm, coupled with pruning, showed substantial improvement in lateral branches (Table 1). Based on Table 1, the application of liquid foliar treatments under different treatments did not significantly affect the development of lateral branches of arabica coffee plants at 2 to 6 weeks after treatments (WAT). However, a significant response began to appear at 8-12 WAT. At this point, the combination of BAP at 60 ppm and pruning gave a higher increase in the number of lateral branches than the other treatments. Although this increase was not significantly different from the 75% coconut water with pruning treatment and the 2 ml L^{-1} sugarcane molasses with pruning treatment, the combination of BAP at 60 ppm and pruning had the highest mean value.

This response is presumed to be related to the effect of pruning, which removes the apical growing point and alters the distribution of photosynthates within the plant. As a result, assimilates are redirected to other organs, particularly lateral branches (Muliasari et al., 2021). Physiologically, pruning stimulates the activation and extension of lateral branch growth. The change in the distribution of photosynthate allocation due to pruning means that there is more scope for the further development of lateral branches optimally. Damayanti et al. (2022) and Postma et al. (2020) found that reduction of vegetative parts could reduce competition of inner parts to get enough nutrients, enabling each branch to get enough nutrients. Besides, breaking of apical dominance is strongly related to a favourable condition for the induction of a lateral meristematic growth, which can also be triggered by chemical substances.

The impact of pruning with foliar treatments spraying has shown its efficiency to boost activity for the lateral meristem. This further activates cytokinin, a plant growth hormone present in BAP and coconut water, to effectively induce lateral branch development. The spraying of LPG, i.e., BAP, and coconut water, which is rich in cytokinin, is of significant importance in speeding up the division and differentiation of plant cells, which is a key factor towards photosynthesis, thus being essential to maintain healthy plants (Ikeda et al., 2021).

Table 1. Average increase in number of lateral branches of productive arabica coffee from 2 to 12 WAT in response to pruning and various liquid foliar treatments

Treatments	Increase in the Number of Lateral Branches					
	2 WAT	4 WAT	6 WAT	8 WAT	10 WAT	12 WAT
A	1.24	1.81	2.07	2.25 b	2.33 c	2.35 c
B	1.25	1.44	2.31	2.71 ab	3.05 ab	3.20 ab
C	1.11	1.53	2.52	2.80 ab	3.05 ab	3.17 ab
D	1.24	1.47	2.50	3.21 a	3.63 a	3.82 a
E	1.25	1.76	1.94	2.21 b	2.48 bc	2.55 bc
F	1.11	1.96	2.38	2.74 ab	2.97 abc	3.04 bc
G	1.38	1.52	2.13	2.43 b	2.67 bc	2.73 bc
CV	18.01%	18.05%	17.29%	15.83%	14.88%	14.72%

Note: WAT = Week after treatments. Means followed by different letters within the same column were significantly different based on Duncan multiple range test at the 5% level. Treatments were A= control without pruning and foliar treatments; B= 75% of coconut water (750 mL L^{-1} water) with pruning; C= 2 mL L^{-1} water sugarcane molasses with pruning; D= 60 ppm (0.06 mL L^{-1} water) liquid BAP with pruning; E= 75% of coconut water without pruning; F= 2 mL L^{-1} water sugarcane molasses without pruning; G= 60 ppm (0.06 mL L^{-1} water) liquid BAP without pruning.

The presence of sugarcane molasses acts as a source of phosphorus and nitrogen, which play a significant role in the improvement of plant metabolism. Higher chlorophyll content may improve photosynthetic efficiency, resulting in increased assimilate production, which is of critical importance for plant development, especially towards branch development (Busato et al., 2022).

Of all the treatments, 60 ppm BAP with pruning gave the best stimulation in terms of the elongation of the lateral branches and plant development. Such a result indicates that the suitable integration of pruning and cytokinin-based foliar treatments creates favourable physiological conditions for the development of lateral branches, thereby improving growth performance in arabica coffee plants.

Lateral Branch Length. The application of sugarcane molasses at a concentration of 2 ml L^{-1} showed a significant effect on the increase in lateral branch length of productive arabica coffee plants at 8 to 12 WAT (Table 2). Table 2 shows that the treatment of sugarcane molasses at 2 ml L^{-1} combined with pruning was significantly different from the treatments of 75% coconut water without pruning, BAP at 60 ppm without pruning, and the control. Meanwhile, the BAP treatment at 60 ppm without pruning did not differ significantly from the control during the observation period from 8 to 12 WAT. Among all treatments, sugarcane molasses at 2 mL L^{-1} combined with pruning resulted in the greatest increase in lateral branch length (Table 2).

The increase in branch length was strongly dependent on pruning treatment. Pruning influences the distribution of the pattern of photosynthates in the plant by diverting the focus of energy accumulation from the main shoot towards other organs, such as lateral branches, thereby giving these organs priority in growth. According to Muzaiyyanah et al. (2020), during the vegetative and generative growth phases, photosynthates are distributed and accumulated across various plant organs.

Photosynthates are essential for providing the energy required for the development of plant organs (Igamberdiev & Bykova, 2022). The allocation of photosynthetic products can be regulated by cutting the plant, enabling targeted allocation to organs known to be more actively developing, especially lateral branches (Yang et al., 2023; Zhong et al., 2024). Moreover, the sugarcane molasses used in this study contain macronutrients, including nitrogen (minimum 4%), phosphorus (minimum 10%), and potassium (minimum 8%), as well as micronutrients such as manganese (maximum 0.25%), zinc (maximum 0.25%), boron (maximum 0.125%), copper (maximum 0.25%), molybdenum (maximum 0.001%), and cobalt (maximum 0.0005%) which are important for plant growth (Stephen et al., 2024). Phosphorus and potassium in molasses fertilizer are significant in cell division and elongation in branch apical meristem tissues (Vinecky et al, 2017). These physiological processes are related to lateral branch development.

Table 2. Average increase in lateral branch length of productive arabica coffee from 2 to 12 WAT in response to pruning and various liquid foliar treatments

Treatments	Increase in Lateral Branch Length (cm)					
	2 WAT	4 WAT	6 WAT	8 WAT	10 WAT	12 WAT
A	1.29	1.63	2.46	1.86 bc	2.14 cd	2.19 c
B	1.26	1.62	2.61	2.02 ab	2.52 ab	2.83 b
C	1.49	1.89	3.43	2.30 a	2.84 a	3.33 a
D	1.63	1.74	2.64	2.00 ab	2.43 bc	2.72 b
E	1.33	1.52	2.69	1.49 c	2.11 cd	2.83 b
F	1.42	1.78	2.96	2.15 ab	2.63 ab	2.73 b
G	1.40	1.57	2.44	1.79 bc	1.85 d	1.87 c
CV	14.41%	19.02%	16.77%	12.19%	10.15%	10.70%

Note: WAT = Week after treatments. Means followed by different letters within the same column were significantly different based on Duncan multiple range test at the 5% level. Treatments were A= control without pruning and foliar treatments; B= 75% of coconut water (750 mL L^{-1} water) with pruning; C= 2 mL L^{-1} water sugarcane molasses with pruning; D= 60 ppm (0.06 mL L^{-1} water) liquid BAP with pruning; E= 75% of coconut water without pruning; F= 2 mL L^{-1} water sugarcane molasses without pruning; G= 60 ppm (0.06 mL L^{-1} water) liquid BAP without pruning.

Of all the treatments, sugarcane molasses solution at a concentration of 2 ml L^{-1}, when used in combination with pruning, was found to be the most effective for promoting the increase in lateral branch length. This finding suggests that combining pruning with foliar fertilization with a sugarcane molasses solution promotes specific physiological conditions. Pruning may enhance assimilate redistribution toward lateral branches as dominant sinks, allowing more efficient utilization of nutrients absorbed through foliar application to support their growth (Jing et al., 2018).

Leaf Chlorophyll Index. The results showed that no significant differences in chlorophyll index were observed among treatments at all observation times (Table 3). This indicates that the application of foliar treatments and pruning did not significantly influence chlorophyll content under the conditions of this study.

However, slight variations observed at early stages may be associated with the rapid absorption of nutrients through the stomata and cuticle, which can temporarily enhance physiological activity following treatments such as pruning. Over time, plant responses to foliar application may become less pronounced as plants enter a more stable physiological phase, reducing variation among treatments (Henningsen et al., 2022). In addition, chlorophyll content is influenced by environmental and physiological factors, including light availability within the canopy and leaf age. Increased light exposure after pruning may support chlorophyll synthesis, while older leaves tend to have a higher chlorophyll index due to physiological maturity (He et al., 2019). Coconut water contains natural plant growth regulators such as cytokinins and auxins, which are reported to support chlorophyll synthesis and delay leaf senescence (Hönig et al., 2018; Shayantavi et al., 2025). However, in this study, their application did not result in a statistically significant effect, suggesting that environmental factors or plant physiological conditions may have played a more dominant role.

Table 3. Average increase in leaf chlorophyll index of productive arabica coffee at 4, 8, and 12 WAT in response to pruning and various liquid foliar treatments

Treatments	Increase in Leaf Chlorophyll Index		
	4 WAT	8 WAT	12 WAT
A	55.2	58.9	64.2
B	53.6	60.1	70.9
C	55.3	60.0	71.1
D	57.0	64.5	70.5
E	52.2	58.1	65.5
F	52.8	56.6	60.2
G	54.5	59.9	66.8
CV	6.09%	5.96%	8.22%

Note: WAT = Week after treatments. Means followed by different letters within the same column were significantly different based on Duncan multiple range test at the 5% level. Treatments were A= control without pruning and foliar treatments; B= 75% of coconut water (750 mL L^{-1} water) with pruning; C= 2 mL L^{-1} water sugarcane molasses with pruning; D= 60 ppm (0.06 mL L^{-1} water) liquid BAP with pruning; E= 75% of coconut water without pruning; F= 2 mL L^{-1} water sugarcane molasses without pruning; G= 60 ppm (0.06 mL L^{-1} water) liquid BAP without pruning.

Table 4. Average increase in leaf area of productive arabica coffee from 2 to 12 WAT in response to pruning and various liquid foliar treatments

Treatments	Increase in Leaf Area (cm)					
	2 WAT	4 WAT	6 WAT	8 WAT	10 WAT	12 WAT
A	2.46	2.75	3.06	3.17 d	3.95 e	3.95 d
B	2.37	2.78	3.23	6.65 a	8.01 a	8.07 a
C	2.28	2.45	3.00	3.24 d	5.99 bc	6.95 b
D	2.59	3.30	3.82	5.03 b	6.28 b	6.54 b
E	2.28	2.78	3.66	4.23 bc	5.51 bcd	5.44 c
F	2.55	2.92	3.63	4.01 cd	4.76 de	4.94 cd
G	2.36	3.07	3.61	4.23 bc	5.20 cd	5.29 c
CV	15.91%	17.21%	16.56%	13.30%	12.54%	15.94%

Note: WAT = Week after treatments. Means followed by different letters within the same column were significantly different based on Duncan multiple range test at the 5% level. Treatments were A= control without pruning and foliar treatments; B= 75% of coconut water (750 mL L^{-1} water) with pruning; C= 2 mL L^{-1} water sugarcane molasses with pruning; D= 60 ppm (0.06 mL L^{-1} water) liquid BAP with pruning; E= 75% of coconut water without pruning; F= 2 mL L^{-1} water sugarcane molasses without pruning; G= 60 ppm (0.06 mL L^{-1} water) liquid BAP without pruning.

Table 5. Average increase in canopy width of productive arabica coffee from 2 to 12 WAT in response to pruning and various liquid foliar treatments

Treatments	Increase in Canopy Width (cm)					
	2 WAT	4 WAT	6 WAT	8 WAT	10 WAT	12 WAT
A	1.90	1.74	2.29 cd	2.47 c	3.10 c	3.15 c
B	1.61	1.80	2.61 bc	2.85 bc	3.71 b	4.12 b
C	1.93	1.68	3.43 a	3.71 a	4.65 a	5.05 a
D	1.79	1.46	3.06 ab	3.21 ab	3.87 b	4.23 b
E	1.68	1.25	1.70 d	1.85 d	2.99 c	4.00 b
F	1.69	1.32	3.12 ab	3.36 ab	4.11 ab	4.24 b
G	1.80	1.73	2.24 cd	2.54 c	2.80 c	2.84 c
CV	15.94%	17.73%	17.41%	11.95%	10.5%	10.0%

Note: WAT = Week after treatments. Means followed by different letters within the same column were significantly different based on Duncan multiple range test at the 5% level. Treatments were A= control without pruning and foliar treatments; B= 75% of coconut water (750 mL L^{-1} water) with pruning; C= 2 mL L^{-1} water sugarcane molasses with pruning; D= 60 ppm (0.06 mL L^{-1} water) liquid BAP with pruning; E= 75% of coconut water without pruning; F= 2 mL L^{-1} water sugarcane molasses without pruning; G= 60 ppm (0.06 mL L^{-1} water) liquid BAP without pruning.

Table 6. Average increase in fruit clusters per branch of productive arabica coffee from 2 to 12 WAT in response to pruning and various liquid foliar treatments

Treatments	Increase in Fruit Clusters per Branch					
	2 WAT	4 WAT	6 WAT	8 WAT	10 WAT	12 WAT
A	1.24 b	1.04 b	1.06 b	1.15 b	1.27 b	1.28 b
B	1.91 a	2.16 a	2.37 a	2.49 a	2.50 a	2.53 a
C	2.09 a	2.40 a	2.60 a	2.73 a	2.80 a	2.83 a
D	2.05 a	2.37 a	2.58 a	2.71 a	2.78 a	2.82 a
E	1.31 b	1.13 b	1.16 b	1.19 b	1.28 b	1.29 b
F	1.06 b	0.85 b	0.90 b	0.94 b	0.97 b	0.98 b
G	1.24 b	1.11 b	1.19 b	1.22 b	1.32 b	1.35 b
CV	10.16%	13.17%	12.58%	13.09%	12.59%	12.62%

Note: WAT = Week after treatments. Means followed by different letters within the same column were significantly different based on Duncan multiple range test at the 5% level. Treatments were A= control without pruning and foliar treatments; B= 75% of coconut water (750 mL L^{-1} water) with pruning; C= 2 mL L^{-1} water sugarcane molasses with pruning; D= 60 ppm (0.06 mL L^{-1} water) liquid BAP with pruning; E= 75% of coconut water without pruning; F= 2 mL L^{-1} water sugarcane molasses without pruning; G= 60 ppm (0.06 mL L^{-1} water) liquid BAP without pruning.

Leaf Area. The treatment with 75% coconut water and pruning elicited a significant increase in leaf area compared with other treatments at 8, 10, and 12 WAT (Table 4). The lack of significant effects observed during the early stages following the application of the foliar treatments, as well as the pruning treatment, at 2, 4, and 6 WAT may be attributed to the low growth rate of the lateral branches.

Pruning similarly promotes the growth of lateral branches that act as sources of new leaves, together with a better assimilate supply, i.e., greater concentration, towards these growing areas. Even though the number of leaves might decline with pruning, canopy measurement might increase in the medium term due to the growth of new leaves and lateral branches (Liang et al., 2020). The treatment on 75% coconut water with pruning was observed to be significant in increasing leaf area on coffee plants under the productive phase (Table 4). Coconut water has been found to have macronutrients, micronutrients, minerals, and organic plant growth regulators, with cytokinins known to be the most effective growth regulators (Mardhikasari et al, 2019; Shayanthavi et al, 2025). These components are known to increase plant growth rate by enhancing nutrient acquisition and cell division and expansion. This has also been reported in other plants, for example, cocoa, where the use of coconut water has been found to increase leaf area and dry matter (Rosniawaty et al., 2022; Irvandi & Nurbaiti, 2017). The increase in leaf area observed following the application of coconut water is also closely related to the presence of cytokines in coconut water, which promote cell enlargement and increased cell division, thereby contributing to the increase in leaf area (Wu et al., 2021).

Canopy Width. The treatment of sugarcane molasses at a concentration of 2 ml L^{-1} combined with pruning had a significant effect on increasing canopy width compared to other treatments from 6 to 12 WAT. In contrast, the BAP treatments at 60 ppm without pruning and the 75% coconut water treatment without pruning did not show significant differences from the control (Table 5). This result suggests that, under the conditions of this study, the use of liquid foliar treatments without pruning was insufficient to induce canopy expansion.

Canopy width in coffee plants is heavily dependent on pruning practices due to the important role that it plays in the distribution of photosynthates within plant tissues. By pruning, it reallocates energy from apical dominance at the main shoot to the lateral parts, promoting horizontal growth and subsequently contributing to canopy expansion. Muzaiyyanah et al. (2020) added that during both vegetative and generative growth phases, photosynthates were translocated and accumulated in target organs in accordance with physiological demand within a plant. Photosynthates represent the most active form as an energy source that is utilized for growth activities. Kumar et al. (2017) also showed that pruning regulates canopy development through modification in metabolite allocation toward vegetative growth.

Sugarcane molasses acts as a nutrient source, comprising macronutrients such as nitrogen (N), phosphorus (P), and potassium (K); micronutrients like zinc (Zn), boron (B), manganese (Mn), copper (Cu), molybdenum (Mo), and cobalt (Co); and organic carbon. Nitrogen serves as a precursor during the biosynthesis of amino acids and proteins, which are essential for cell division and growth, thus impacting canopy expansion. Phosphorus participates in energy transmission and photosynthesis, important processes in plant tissue formation and canopy development. Potassium is responsible for the closing and opening of stomata, affecting photosynthesis and transpiration and, thereby, canopy growth.

Fruit Clusters per Branch. This measure refers to the average fruit clusters that are developed on every lateral branch of the plant. Overall, this parameter pertains to the potential of fruiting development, particularly branching, of the coffee plants. Hence, FPP is also another important aspect of the growth and productivity of coffee plants. In terms of its actual influence, it appears that the 75% coconut water, sugarcane molasses at 2 ml L^{-1}, and BAP at 60 ppm in combination with pruning significantly enhanced the level of increase in the number of fruit clusters from 2 to 12 WAT compared to other treatments (Table 6). For its part, the treatment of coconut water, sugarcane molasses, and BAP without pruning did not show any significant difference from the control.

In addition, the results presented in Table 6 suggest that, between 2 and 12 WAT, all pruning treatments were associated with significantly higher numbers of fruit clusters than those of the control and treatment without pruning. In this sense, there is a need to emphasize the significance of pruning on the development of fruit clusters of Arabica coffee plants.

Arabica coffee plants bear fruit in clusters in the sense that they have an optimal number of effective branches to provide for the plants to flower and subsequently bear fruit. Pruning means removing the tip of the plants to direct resource allocation from growth to flowering and bearing fruit. Therefore, the plants are able to maximize the production of effective branches.

Siahaan et al. (2020) found that the effects of pruning, shading, and fertilizers interacted significantly for the purpose of influencing the parameters of coffee plant growth and the formation of cluster fruit. This study emphasized the importance of adding positive cultivation techniques for the productivity of coffee plants, especially the shaded plants.

In the same way, Karim et al. (2021) noted that because of the increased process of pruning in the cultivation of coffee plants under shaded conditions, there was an improvement in the production of fruits in arabica coffee varieties. This encouraged the coffee plants to grow new shoots, which eventually turned into successful branches, making them produce flowers and fruits. It is in this aspect that the process of pruning new shoots is important in the production of fruits in coffee plants.

In addition to pruning, the application of BAP, coconut water, and sugarcane molasses may have contributed to supporting fruit cluster development. BAP, as a cytokinin, is known to promote cell division and stimulate the growth of lateral buds, which can develop into productive branches (Maxiselly et al, 2025). Similarly, coconut water contains natural plant growth regulators such as cytokinins and auxins that may enhance vegetative and reproductive processes (Sosnowski et al., 2025). Meanwhile, sugarcane molasses provides essential nutrients that support metabolic activity and assimilate production (Ali et al., 2019). However, the application of these foliar treatments without pruning did not result in significant differences compared to the control, indicating that their effects are likely complementary rather than dominant. These findings suggest that while pruning serves as the primary driver of fruit cluster formation, the addition of BAP, coconut water, and molasses may support physiological processes that contribute to the development of reproductive structures.

Fruit Clusters per Plant. The fruit clusters per plant refer to the average total fruit clusters formed in each individual plant. This parameter reflects the general potential of fruit production and, therefore, it is an important indicator for the evaluation of the success of the generative growth phase in coffee plants. Statistical analysis showed that at a 95% confidence level, the treatments of 75% coconut water, sugarcane molasses at 2 ml L^{-1}, and BAP at 60 ppm combined with pruning were significantly different from the controls and the respective treatments without pruning within the period of 2-12 WAT (Table 7). The obtained data showed highly significant differences throughout the observation period. On the other hand, treatments without pruning, using the same materials, did not differ significantly from the controls during the same period.

Table 7. Average increase in fruit clusters per plant of productive arabica coffee from 2 to 12 WAT in response to pruning and various liquid foliar treatments

Treatments	Increase in Fruit Clusters per Plant					
	2 WAT	4 WAT	6 WAT	8 WAT	10 WAT	12 WAT
A	7.25 c	7.41 c	7.44 c	7.95 c	7.95 c	9.30 c
B	10.31 ab	11.51 ab	12.24 ab	12.52 ab	12.52 ab	13.42 ab
C	11.60 a	12.12 ab	12.46 ab	13.19 a	13.19 a	14.64 a
D	11.60 a	12.42 a	13.40 a	14.40 a	14.40 a	15.98 a
E	8.89 bc	9.46 bc	9.56 bc	9.91 bc	9.91 bc	10.94 bc
F	8.15 bc	8.27 c	8.43 c	8.88 c	8.88 c	10.27 bc
G	7.95 bc	8.14 c	8.20 c	8.54 c	8.54 c	9.66 c
CV	18.36%	17.96%	18.38%	19.43%	19.43%	19.42%

Note: WAT = Week after treatments. Means followed by different letters within the same column were significantly different based on Duncan multiple range test at the 5% level. Treatments were A= control without pruning and foliar treatments; B= 75% of coconut water (750 mL L^{-1} water) with pruning; C= 2 mL L^{-1} water sugarcane molasses with pruning; D= 60 ppm (0.06 mL L^{-1} water) liquid BAP with pruning; E= 75% of coconut water without pruning; F= 2 mL L^{-1} water sugarcane molasses without pruning; G= 60 ppm (0.06 mL L^{-1} water) liquid BAP without pruning.

Table 8. Average fruit weight of arabica coffee plants during the productive phase 2 to 12 WAT in response to pruning and different liquid foliar treatments

Treatments	Increase in Fruit Weight (g)					
	2 WAT	4 WAT	6 WAT	8 WAT	10 WAT	12 WAT
A	0.00	0.65	0.00	2.20	0.43	0.55
B	0.53	7.02	11.87	2.93	0.49	1.07
C	9.51	34.80	28.94	3.30	2.88	2.37
D	3.03	5.39	4.57	4.28	5.96	4.17
E	0.00	0.00	0.00	0.00	0.00	0.00
F	0.00	1.65	1.38	0.00	0.00	0.00
G	0.00	0.48	0.78	0.00	0.00	0.35

Note: WAT = Week after treatments. Means followed by different letters within the same column were significantly different based on Duncan multiple range test at the 5% level. Treatments were A= control without pruning and foliar treatments; B= 75% of coconut water (750 mL L^{-1} water) with pruning; C= 2 mL L^{-1} water sugarcane molasses with pruning; D= 60 ppm (0.06 mL L^{-1} water) liquid BAP with pruning; E= 75% of coconut water without pruning; F= 2 mL L^{-1} water sugarcane molasses without pruning; G= 60 ppm (0.06 mL L^{-1} water) liquid BAP without pruning.

The findings show that pruning significantly increases coffee plant productivity. In this case, treatments with coconut water, sugarcane molasses, and BAP, with accompanying pruning, produced more fruit clusters than the control and non-pruned groups. This further proves a point that the interaction of the two processes, this being the supply of yet another nutrient as well as pruning, is essential for the enhancement of plant productivity.

The application of BAP, coconut water, and sugarcane molasses may support this process by enhancing physiological functions. BAP may stimulate the formation of lateral branches, coconut water provides natural growth regulators, and molasses supplies essential nutrients that support assimilate production (Ali et al., 2019; Maxiselly et al, 2025; Sosnowski et al., 2025). However, their application without pruning did not significantly affect fruit cluster formation, indicating that their role is supportive rather than dominant in determining whole-plant productivity.

In arabica coffee, pruning of the shoot is important in enhancing the growth of fruitful branches, which bear flowers and fruits. During the fruiting stage, pruning also plays a facilitative role in ensuring plant nutrients are directed from the vegetative to the fruiting tissues. In this regard, Siahaan et al. (2020) reported that the application of proper pruning practices, alongside proper treatments and homogeneous shade conditions, was important in inducing fruit clusters. The interaction consequently enhanced fruitful branch development and increased coffee production.

In this line, Karim et al. (2021) also emphasized how pruning has helped increase fruiting in the arabica coffee plant. Pruning is very effective in bringing about new shoots, which soon develop into branches in the coffee plants, thus allowing for increased fruit and flower development. With the efficient use of its resources in coffee, the fruits now develop in a better way, allowing arabica coffee to achieve maximum production.

Fruit Weight. According to the data presented, none of the treatments caused a significant impact on the mass of arabica coffee fruits at 2-12 WAT. Although no significant differences were observed, the treatment with sugarcane molasses at 2 ml L^{-1}, combined with pruning, had the highest average fruit weight from 2 to 6 WAT (Table 8). In contrast, from 8 to 12 WAT, the highest average was recorded by the treatment in which BAP in concentrations of 60 ppm was used in combination with pruning.

Therefore, in general, it was seen that the data provided in Table 8 did not show significant effects of the application of pruning and liquid foliar treatments on coffee fruit weight. The condition is closely linked to the biological features of coffee as a perennial species. This means that in a coffee plant, there may be flowers, immature coffee fruits, semi-mature coffee fruits, and mature coffee fruits concurrently, with development at different stages and of different weights (López et al., 2021).

These differences in fruit developmental stages have important implications for resource distribution within the plant. However, it is not possible to homogeneously distribute water, nutrients, and photosynthates to all the fruits. Additionally, the fruits that develop early will enjoy better conditions for the supply of assimilates and nutrients, leading to optimum growth. On the contrary, fruits that develop later will not enjoy the best resources, impacting their weight and quality to some extent. This may be considered as the major factor for the potential effect of pruning and foliar application on coffee fruit weight, as indicated in the study by León-Burgos et al. (2024).

Previous studies have also indicated that in perennial crops, physiological factors are of more dominant importance compared to agronomic practices. This is due to the fact that the biological activities of plants, such as flowering and fruiting, are controlled by internal factors like genetics and environmental factors, which cannot be controlled in the short term. Studies on cocoa (Goudsmit et al., 2023) and tea (Zhang et al., 2022) crops revealed that flowering and fruiting were more important in determining the yield compared to any other factor.

Conclusion

Pruning treatment was identified as a significant treatment that increased all the growth parameters of the arabica coffee plants, namely the number of lateral branches, the length of lateral branches, leaf area, the width of the plant, the number of clusters of fruits per branch, and the number of clusters of fruits per plant. The findings of the study indicated that the application of pruning treatment in addition to the use of sugarcane molasses at a concentration of 2 mL L^{-1} improved the formation of lateral branches, leaf area, and the number of clusters of fruits per tree. The use of pruning, foliar fertilizer (coconut water and sugarcane molasses), and BAP was effective in supporting the optimal growth of coffee plants during the productive phase.

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