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ARABICA COFFEE GROWTH PERFORMANCE BEFORE AND AFTER REJUVENATION IN AGROFORESTRY SYSTEM

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ABSTRACT

Coffee plants are generally shade-grown and most varieties are naturally intolerant of direct sunlight (shade loving). At the research site, Arabica coffee pine agroforestry management is divided into four groups, ranging from least to most intensive: Low Coffee (LC), Medium Coffee (MC), High Coffee (HC), and Best Management Practice (BMP). In LC, MC, and HC, the density of pine as a shade tree is almost twice higher than in BMP. In addition, in LC, HC and MC management, coffee plants are not pruned well. Prunning however conducted in 2021 by leaving 50 cm of main stem (full stumping) in LC, MC and HC. The research aim to determine which is better on growth and yield of Arabica coffee between BMP, HC, MC and LC in pre- and post-rejuvenation. The research set in Randomly Block Desain with agroforestry management is the factor to compare. In each agroforestry, observations were made on three replications with an area of 4 m x 5 m, each replication consist of four Arabica coffee plants. The result of this research are BMP show the best growth of Arabica coffee Lini S-795 under pre-rejuvenation conditions. After being rejuvenated for 3 years, HC produced the best growth compared to MC and LC. In general, HC post rejuvenation has achieved a growth of about 49.42% when compared to BMP. HC is capable of producing 40.93% of the number of productive branches, 51.74% of the number of productive nodes, 63.73% of the number of fruit bunches per node, and 41.28% of the number of fruits per branch compared to the results obtained by BMP management. By knowing the components that most influence Arabica coffee yields through PCA, correlation and regression analysis, the variables secondary branch length, secondary internode length, number of secondary nodes, number of productive branches and number of productive nodes should be concerned by agroforestry managers to increase yields. Its also inform us that the coffee pine agroforestry system is able to support the regrowth of full stumping pruned coffee with shade cover of 54-72% in LC, MC and HC. The best growth and yield of Arabica coffee is produced by the most intensively managed agroforestry, BMP (before rejuvenation) and HC (after rejuvenation).

Keywords: Arabica, Agroforestry, Pine, Rejuvenation, Stumping

INTRODUCTION

Coffee cultivation with agroforestry management is expected to support increased coffee production and improved forest management. Land suitability for coffee cultivation affects plant growth, especially the microclimatic conditions around coffee plants. Shade plants can reduce extreme conditions for coffee growth such as high soil or air temperature and humidity. Coffee plants are generally shade-grown and most varieties are naturally intolerant of direct sunlight and require a canopy of shade trees that can reduce the intensity of sunlight (shade loving). Coffee and shade trees also contribute to ecological conservation such as creating an environment for the conservation of certain bird species (Alemu, 2015). Coffee shade trees also require maintenance to prevent the light intensity received by the coffee from being too low. Low sunlight intensity can result in etiolation, which causes the number of nodes on the coffee branch, which is the growing point of the fruit bunch, to decrease.

At the research site in the forest of Universitas Brawijaya (UB), Arabica coffee cultivation is carried out with agroforestry management using pine (*Pinus merkusii*) as a shade tree. The land area used for coffee cultivation is 125 hectares (Dikdayan and Ariffin, 2022). The agroforestry management model applied in the UB forest is a type of land-sharing agricultural landscape because pine and Arabica coffee are planted on the same land area, not separated by location. There are two models of landscape arrangement that are useful for improving eco-management services and biodiversity conservation: land sharing and land sparing. According to Grass *et al*. (2019), land sharing is a wildlife-friendly agricultural management landscape arrangement that focuses on improving eco-management services in the farm environment, resulting in environmentally friendly production. Meanwhile, land sparing involves the division of agricultural landscapes between intensive agricultural cultivation and natural habitats, focusing on species conservation. This research observation is focused on the production of Arabica coffee produced from land sharing agricultural landscapes.

Coffee pine agroforestry management is divided into four groups, ranging from least to most intensive: Low Coffee Management (LC), Medium Coffee Management (MC), High Coffee Management (HC), and Best Management Practice (BMP). In LC, MC, and HC management, the density of pine as a shade tree is almost twice as high as in BMP. This means that Arabica coffee plants are in an environment with a high level of shade. Thinning of pine trees is not allowed by the Indonesian Ministry of Environment and Forestry as a forest conservation effort. Furthermore, in LC and MC management, coffee plants are not pruned to remove non-productive branches. As a result, Arabica coffee plants grow too tall with a small number of lateral branches. Lateral branches are an important parameter in coffee because cherries grow on these branches. In 2021, UB forest managers carried out full stumping pruning by leaving 50 cm of the main stem of Arabica coffee plants in LC, MC, and HC management (Rowe *et al*., 2022). Pruning returns the plant to the vegetative phase so that plant management can be carried out better. Rejuvenation pruning has never been done by farmers because, during the post-rejuvenation period and the following two years, coffee is not able to produce, which affects the farmer's income.As a study of Arabica coffee rejuvenation pruning, the research aimed to determine which coffee pine agroforestry management resulted in the best pre- and post-rejuvenation growth of Arabica coffee plants.

MATERIALS AND METHODS

This study was conducted from February to May 2024 in agroforest ry land-use system dominated by pine and arabica coffee in Brawijaya University (UB) Forest, Boro Sumbersari hamlet, Tawangargo village, Karangploso district, Malang regency. UB Forest is located on the slopes of Mount Arjuna with a height of 1,200 meters above sea level and an average temperature 16-26 ^{0}C.

We observe vegetative and generative variables of Arabica coffee also the plant density of Arabica coffee (*Coffea arabica*, Lini S-795) and pine (*Pinus merkusii*) as components of agroforestry. The research set in Randomly Block Desain withagroforestry management is the factorto compare.The agroforestry management observed in this study are LC (Low Coffee Management), MC (Medium Coffee Management), HC (High Coffee Management), and BMP (Best Management Practice). In each agroforestry, observations were made on three replications with an area of 4 m x 5 m, each replication consist of four Arabica coffee plants. In each management type (LC, MC, HC, BMP), there were three replications for unrejuvenated coffee and three replications for rejuvenated coffee.

Morphological observations include plant length, number of leaves, leaf area, plant canopy width, number of primary and secondary branches, primary and secondary branch length, number of nodes in primary and secondary branch, internode length in primary and secondary branch and also chlorophyll content. Generative observations include the number of productive branches, number of productive nodes, number of fruit bunches per node, and number of green fruits per branch. Maturation and cherry fruit have not been observed because they are still in the process of ripening. Vegetative and generative observations were made on representative branches in each part of the upper, middle, and lower canopy of Arabica coffee.

Leaf area per plant was calculated using the Average Leaf Area (ALA) method by multiplying the number of leaves by the average leaf area per leaf (Widaryanto *et al*., 2019). The average leaf area per leaf is obtained from the average leaf area of the upper, middle, and lower canopy. The average leaf area per leaf (cm²) in each agroforestry management for non-rejuvenated Arabica coffee plants is 76.48 (BMP), 93.6 (HC), 84.0 (MC), and 92.1 (LC). The average leaf area per leaf (cm²) in each agroforestry management for rejuvenated Arabica coffee plants is 98.6 (HC), 84.4 (MC), and 71.1 (LC).

Chlorophyll was analyzed by weighing 2 g of the leaves sample then mashed with a mortar and pestle. The leaf paste was put into a film bottle (30 ml) then mixed with 10 ml of PA acetone (Pro Analyst) then closed. The solution was stored for 24 hours in the refrigerator. After 24 hours, the solution was filtered with Whatsman 42 paper. The filtered results were then pipetted as much as 1 ml and put into a test tube for dilution. Dilution was done by adding 9 ml of acetone and homogenized. The extract solution obtained was then put into a cuvette and its absorbance level was measured in a spectrophotometer with a wavelength of 645 nm, 663 nm.

Changes in Arabica coffee growth after rejuvenation were assessed by comparing the values of the observation variables between before rejuvenation and after rejuvenation coffee using the formula:

$$Percent\ Gap\ (\%) = ((AR - BR)/BR)\ x\ 100\%$$

Notes:

BR = Value of arabica coffee observation variable before rejuvenation
AR = Value of arabica coffee observation variable after rejuvenation

Data analysis involved the use of the ANOVA table at a 5% significance level. If significant results were observed in the processed data, the Honest Significantly Different (HSD) test (5%) was used to assess treatment differences. Additionally, correlation tests and PCA were performed to explore the relationships between research variables while regression analysis to model and understand relationships between variables. Analyses were performed using SPSS and R-Studio statistical software.

RESULTS AND DISCUSSION

The presence of shade trees in coffee plantation modified the microclimate, the coffee growth and yield. The density of pine plants as shade tree in BMP is lower by around 40-50% compared to LC, MC, and HC agroforestry management (Table 1). This difference in the density of shade plants results in varying intensities of sunlight received by Arabica coffee. The intensity of light received in BMP management is higher than in the other three agroforestry management types, with a shade cover of 30%.

Table 1. Light conditions in four agroforestry management

Agroforestry Management	% Pine density	% Arabica coffee density	Light intensity (lux)	% Shade cover
LC	0.34	0.66	1199	54
MC	0.31	0.69	564	72
HC	0.23	0.77	565	72
BMP	0.14	0.86	1804	30

Note: BMP: Best Management Practice, HC: High Coffee Management, MC: Medium Coffee Management, LC: Low Coffee Management.

Arabica coffee rejuvenation is carried out in LC, MC, and HC management. In BMP management, rejuvenation is not carried out because the length of Arabica coffee plants was in accordance with the SOP (Standard Operating Procedure). The length of coffee plants in BMP is lower than in the other three management types, at 136.73 cm (Figure 1). The standard coffee plant length is no more than 170 cm to simplify maintenance and harvesting (Khayati *et al*., 2020). The length of Arabica coffee plants in LC and MC management ishighest because shaping was not done (Table 2). Plant length after rejuvenation is not significantly different between LC, MC, and HC management. Plant height ranged from 206-224 cm due to no pruning after rejuvenation. The height of the coffee plant after rejuvenation has exceeded the SOP so it should be pruned so that more productive branches can be formed. Pruning has a very significant effect on plant height at the age of 2 to 6 month after application in Arabica coffee (Muliasari *et al*., 2021). Pruning treatment produced the lowest plant height and achieved optimal production.

The number and leaf area of Arabica coffee leaves before rejuvenation were highest in BMP management (Table 2). After rejuvenation, HC management produced a higher number of leaves and greater leaf area compared to LC and MC management. HC management includes annual fertilization and more routine weeding. In MC management, fertilization is only applied at the beginning of planting with infrequent weeding. In LC management, fertilization and weeding are very infrequent, based on interviews with managing farmers. Maintenance of coffee plants stimulates the formation of new branches and leaves. The total leaf area and leaf number of Arabica coffee increased with increasing nitrogen levels in the growing medium (Gonthier *et al*., 2011). The increase of leaf number and leaf area enhances the photosynthetic ability of coffee plants, which positively affects their growth (Siahaan *et al*., 2019).

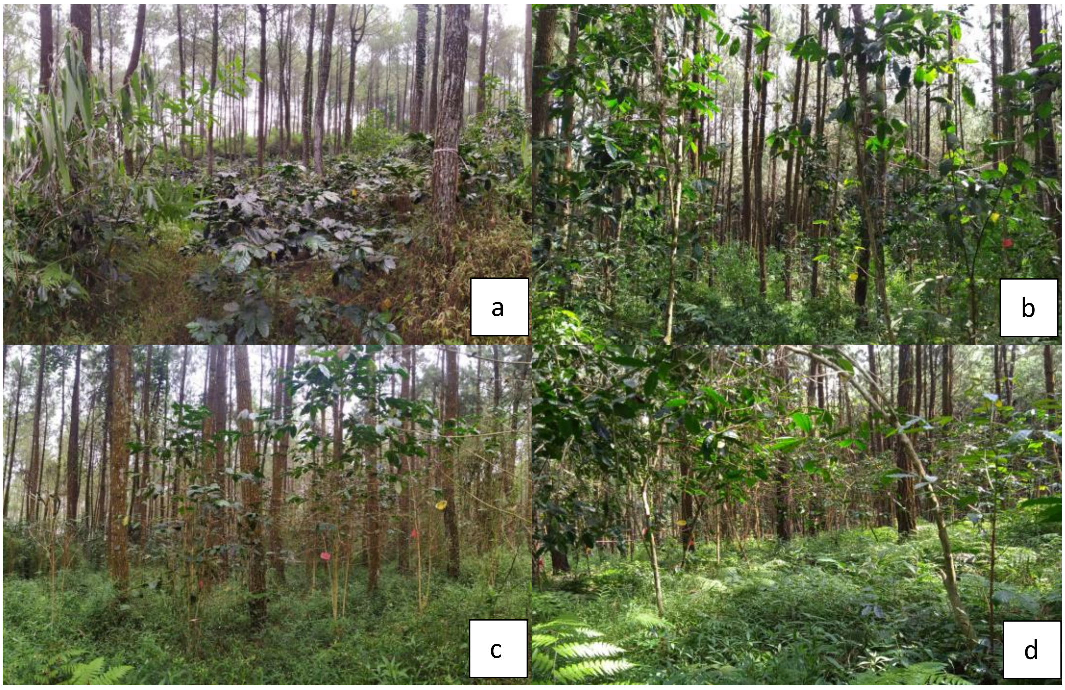


Figure 1. Agroforestry management landscape of pine and Arabica coffee before rejuvenation: (a) BMP, (b) HC, (c) MC, (d) LC (BMP: Best Management Practice, HC: High Coffee Management, MC: Medium Coffee Management, LC: Low Coffee Management).

BMP management resulted in the highest number of primary and secondary branches in Arabica coffee (Table 2). Shaping and pruning are considered mandatory technical measures to give coffee trees a balanced canopy, fully utilizing each tree's unique space. Shaping and pruning were well performed in BMP. According to Helena Coffee Vietnam (2023), during shaping, excess shoots should be removed regularly and promptly to avoid unnecessary nutrient consumption. The purpose of annual pruning and shaping is to facilitate the development of reserve branches and bring the fruit position closer to the central stem axis for high yields and better bean quality. Plants need to be pruned of useless branches, dead and dry branches, pest-infested branches, also weak and overgrown secondary branches at the top of the canopy. Rejuvenation carried out in LC, MC, and HC management resulted in the same number of primary and secondary branches in Arabica coffee. Uniformity in the number of primary and secondary branches in rejuvenated plants (LC, MC and HC) should be followed by further pruning by farmers to increase the number of productive branches.

The length of primary and secondary branches in BMP management is lower than in the other three agroforestry management types due to shaping and pruning, as well as greater light intensity received, so the plants did not experience etiolation (Table 2). The length of secondary branches correlated with internode length per secondary branch, with a correlation value of 0.953 (Table 3). In addition to branch length, the number of nodes on the branches was also calculated. The number of nodes on the secondary branches showed a correlation with the number of productive nodes (0.993) and the number of fruits per node (0.966) (Table 3). Rejuvenation resulted in similar primary and secondary branch lengths, primary and secondary branch internode lengths, and the number of nodes on primary branches of Arabica coffee under LC, MC, and HC management. Pruning and fertilization are the main factors that cause an increase in the number of productive branches and nodes in coffee plants due to good nutrient redistribution in plants (Dufour *et al*., 2019).

The level of intensification in agroforestry management and light intensity conditions influence the formation of chlorophyll in Arabica coffee leaves. Chlorophyll a content in BMP management are similar with HC and MC in unrejuvenated, while in rejuvenated Arabica coffee plants, chlorophyll a content in HC and MC higher than LC (Table 2). Chlorophyll b content in unrejuvenated show that BMP, HC and MC higher than LC, while after rejuvenation, HC management produced the highest chlorophyll b content. Total chlorophyll contentof BMP, HC and MC higher than LC before rejuvenation and after rejuvenation HC and MC is higher than LC. Chlorophyll levels are influenced by nutrient availability and light acquisition factors. In a study conducted in Southern Manabí, Ecuador, the highest chlorophyll levels in Arabica coffee plants within an agroforestry system were obtained from S2 shade conditions (31-50%) compared to S1 (0-30%) or S3 (50-70%) conditions (Corzo-Bacallao *et al*., 2023). Under S1 light conditions with lower shade, there is no increase in chlorophyll, likely due to the shade-adapted characteristics of coffee, which has a homeostatic mechanism to mitigate the negative impact of excessive light intensity (Chaves *et al*., 2008; Moraes *et al*., 2010). The chlorophyll contentin the BMP system (30% shade) align with these findings. Additionally, the chlorophyll contentin LC with 54% shade were lower than i HC and MC with 72% shade.This is affected by the intensity of cultivation, where maintenance and fertilizer application in LC are lower than in HC and MC. An application of nitrogen fertilizer with a foliar spray of 20 mM on Arabica coffee seedlings undergoing low-temperature stress in Japan showed an increase in total chlorophyll to 9 mg g^{-1} (Acidri *et al*., 2020).After rejuvenation, the highest total chlorophyll content is obtained from HC and MC. This indicates that the intensification of agroforestry management affects the chlorophyll a, b, and total chlorophyll content of Arabica coffee leaves. Chlorophyll content in Arabica coffee plants rejuvenated without the application of inorganic and organic fertilizers is smaller than in fertilized plants (Rohani *et al*., 2024).

Rejuvenation conducted on Arabica coffee Lini S-795 in Arabica coffee pine agroforestry management resulted in relatively similar growth of vegetative variables in the three agroforestry management systems (LC, MC, HC). Variables such as leaf number, leaf area, number of nodes on secondary branches, and chlorophyll b content in rejuvenated plants in HC management showed better results than in LC and MC management (Table 2). While chlorophyll a and total chlorophyll content of HC management were similar to MC and higher than LC in rejuvenated Arabica coffee plants. This indicates that although the light intensity in LC (Table 1) is higher than in MC and HC, management intensification affects chlorophyll formation. HC agroforestry management in rejuvenated Arabica coffee plants showed relatively better regrowth than LC and MC.

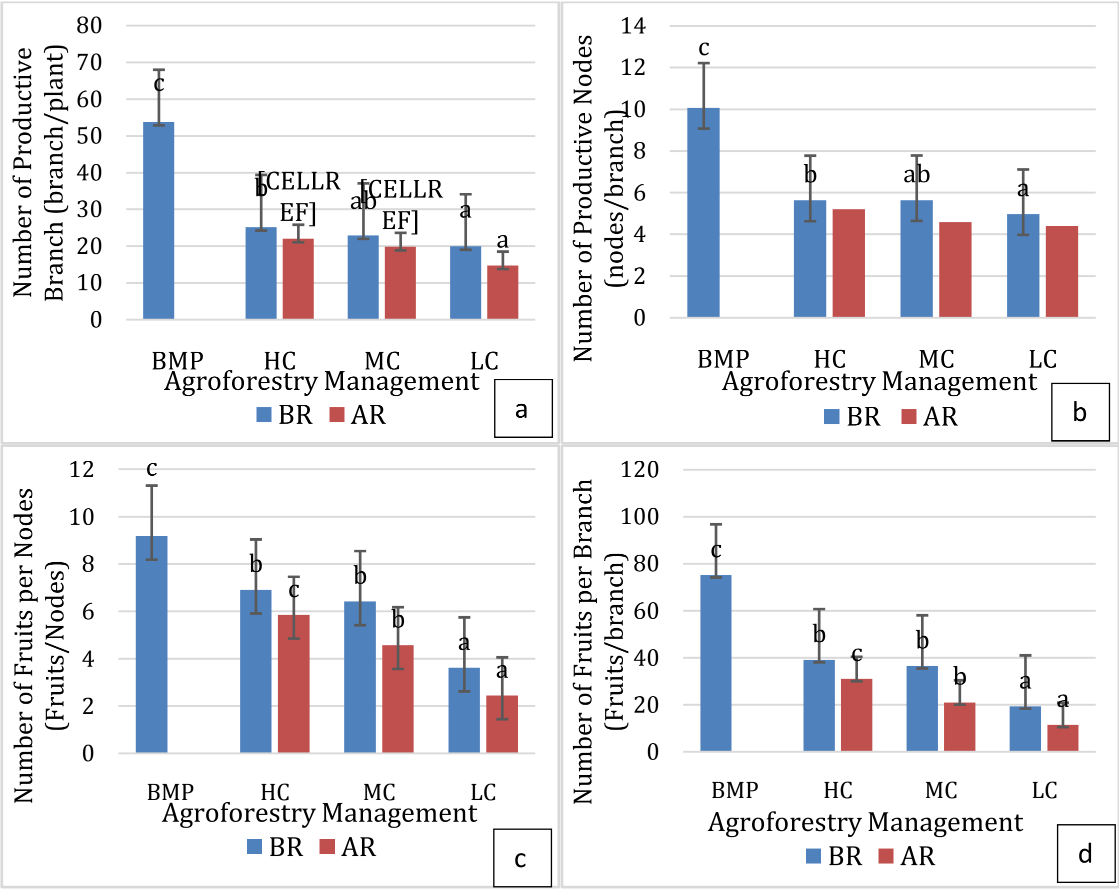
Tabel 2. Parameters of vegetative development per coffee plant in pine and arabica coffee agroforestry system

Agroforestry Management		BMP	HC	MC	LC	HSD (5%)
Plant Length (cm)	BR	136.73 a	235.47 b	246.69 bc	282.73 c	47.42
	AR		224.35	206.36	212.97	ns
	%Gap		-0.05	-0.16	-0.25	
Number of Leaf (Leaves/plant)	BR	678.63 c	274.37 b	149.64 a	130.27 a	56.69
	AR		254.37 b	160.20 a	142.39 a	20.76
	%Gap		-0.07	0.07	0.09	
Leaf Area (cm^2)	BR	50425.70 c	25484.55 b	12275.87 a	13027.55 a	4353.19
	AR		26820.20 b	12987.05 a	10375.75 a	5744.33
	%Gap		0.05	0.06	-0.20	
Number of Primary Branch (branch)	BR	4.90 b	2.42 a	2.40 a	2.37 a	0.3
	AR		2.45	2.51	2.33	ns
	%Gap		0.01	0.05	-0.02	
Number of Secondary Branch (branch)	BR	17.77 a	30.23 b	29.10 b	27.23 b	4.87
	AR		28.63	27.47	26.97	ns
	%Gap		-0.05	-0.06	-0.010	
Primary Branch Length (cm)	BR	13.31 a	210.00 b	201.31 b	265.75 c	52.84
	AR		167.65 a	155.33 a	169.29 a	35.86
	%Gap		-0.20	-0.23	-0.36	
Secondary Branch Length (cm)	BR	36.90 a	60.70 b	60.56 b	74.70 b	52.84
	AR		165.08 a	166.36 a	164.27 a	13.11
	%Gap		1.72	1.75	1.20	
Number of Primary Nodes (node/branch)	BR	5.27 a	22.83 c	19.83 b	20.93 bc	2.6
	AR		17.87 a	16.97 a	16.47 a	1.96
	%Gap		-0.22	-0.14	-0.21	
Number of Secondary Nodes (node/branch)	BR	10.3 b	7.30 a	6.79 a	6.58 a	1.45
	AR		6.52 b	5.63 a	6.47 b	0.37
	%Gap		-0.11	-0.17	-0.02	
Primary Branch Internode Length (cm)	BR	5.42 a	8.69 b	10.42 c	11.74 d	1,25
	AR		9.34 a	9.63 ab	11.03 b	1.77
	%Gap		0.07	-0.08	-0.06	
Secondary Branch Internode Length (cm)	BR	4.72 a	7.95 b	9.50 c	10.31 c	21,12
	AR		8.35 a	8.89 a	9.52 a	1.46
	%Gap		0.05	-0.06	-0.08	
Chlorophyll A	BR	145.77 b	142.21 b	143.07 b	134.78 a	5.75
	AR		143.00 b	141.93 b	120.03 a	12.41
	%Gap		0.0027	0.0027	0.0027	
Chlorophyll B	BR	85.94 ab	95.49 ab	122.34 b	62.20 a	37.00
	AR		142.30 c	117.87 b	63.63 a	13.99
	%Gap		0.69	0.69	0.69	
Total Chlorophyll	BR	241.33 b	238.93 b	265.42 b	197.19 a	41.44
	AR		260.37 b	258.90 b	193.07 a	34.56
	%Gap		0.15	0.15	0.06	

Note: ns (non-significant), significant differences within a row at $P < 0.05$ or $P < 0.01$, respectively, in response to the treatment; BR= arabica coffee Before Rejuvenation; AR=

arabica coffee After Rejuvenation; BMP: Best Management Practice; HC: High Coffee Management; MC: Medium Coffee Management; LC: Low Coffee Management.

BMP management produced 2.1-2.3 times the highest number of productive branches compared to HC or MC management and up to 2.7 times compared to LC management under unrejuvenated arabica coffee conditions (Figure 2). While in rejuvenated coffee, in 2024 (3 years after rejuvenation, 2021) HC and MC management produced a higher number of productive branches (34.6-49.6%) than LC. The number of productive branches correlated with the number of productive nodes at 0.998 (Table 3). The number of productive nodes in BMP is 2.03-1.79 times higher than LC, MC, and HC.



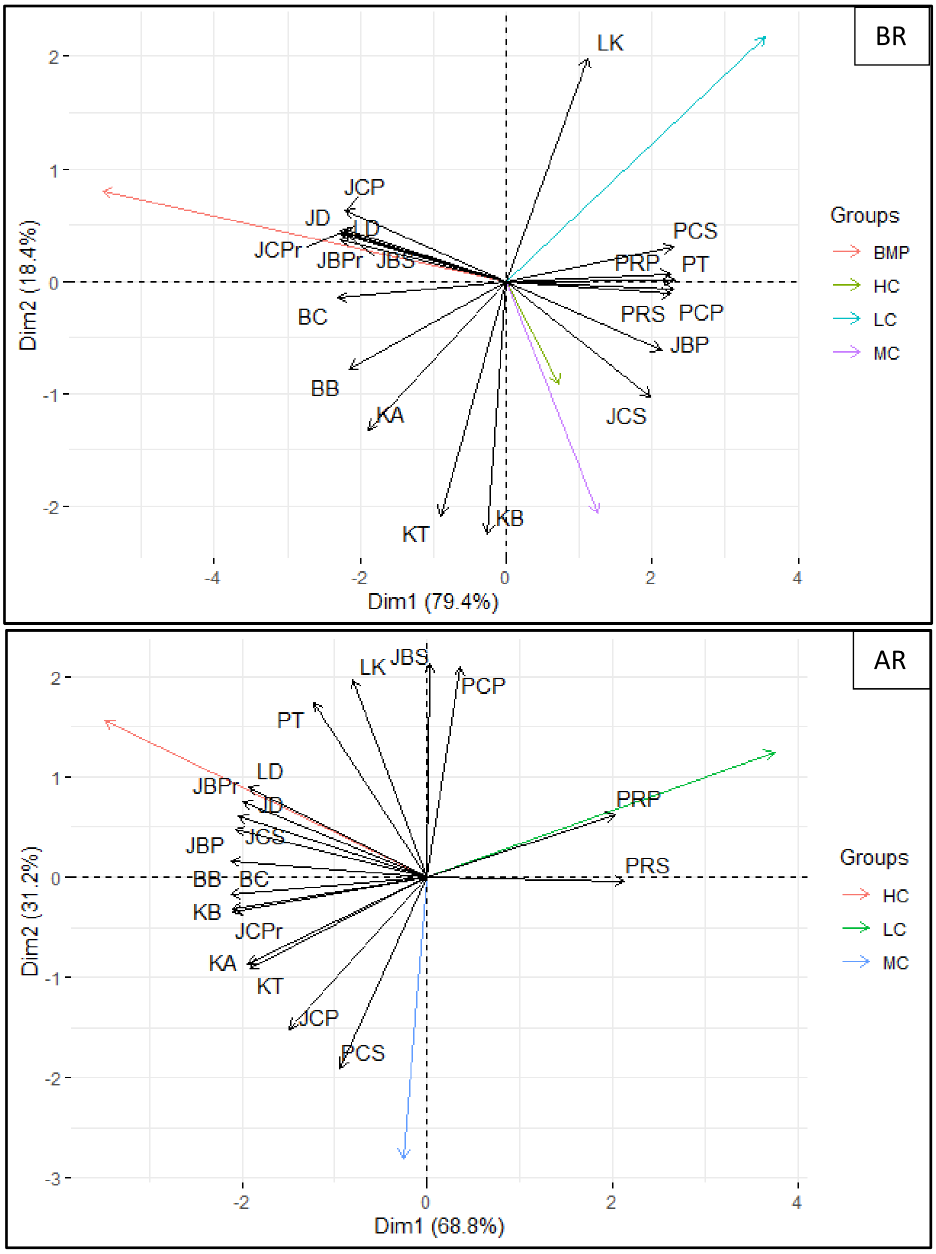
Note: BR: Before Rejuvenation; AR: After Rejuvenation; BMP: Best Management Practice; HC: High Coffee Management; MC: Medium Coffee Management; LC: Low Coffee Management.

Figure 2. (a) number of productive branch, (b) number of productive nodes, (c) number of fruit bunch per nodes, (d) number of fruit (green berries) per branch

The number of productive branches and nodes in BMP management correlated with the number of fruit bunches and the number of fruits per branch (Figure 2). The number of fruit bunches per node correlated with the number of fruits per branch with a value of 0.954 (Table 3). In the rejuvenated Arabica coffee plants, HC management produced 1.28-2.38 more fruit bunches per node than MC and LC management. The number of fruits per branch under HC management is 1.47-2.70 times more than under LC management. In general, HC management also produced better generative variables than LC and MC after 3 years of rejuvenated Arabica coffee Lini S-795 in coffee pine agroforestry management. Research about the effect of fertilization on yield and quality of Arabica coffee grown on mountain terraces in southwestern Saudi Arabia showed that by 1.5 chemical fertilizer dose applied in 2022 and 2023 (1365 g $tree^{-1}$ $year^{-1}$) give higher flower density (number of flowers per branch) than 1 or 0.5 dose (Khemira *et al*., 2023). Flower density in 1.5 chemical fertilizer dose is 68± 18 flower $branch^{-1}$.

Observations of vegetative and generative parameters in unrejuvenated Arabica coffee plantations of Lini S-795 showed that BMP management is better than the other three agroforestry management (LC, MC, and HC). BMP management isbetter in the number of primary branches, number and leaf area of leaves, number of secondary branch nodes, number of productive branches and nodes, number of fruit bunches per node, and number of fruits per branch (Figure 3a). HC and MC management produced better growth in the number of nodes on primary branches and the number of secondary branches. LC management had a higher plant length, canopy width, secondary branch lenght also primary and secondary internode length.

Meanwhile, the vegetative and generative parameters of Arabica coffee Lini S-795 with 3 years of age after rejuvenation showed that HC management produced better growth than MC and LC. After rejuvenation, HC management give better result in the variables of plant length, number and area of leaves, number of secondary branches, number of primary branch nodes, chlorophyll a, b, and total content, number of productive branches and nodes, and the number of fruits bunch per node and fruit per branch (Figure 3b). While MC management after rejuvenation excelled in the parameter of the number of primary branches and secondary branch lenght.LC management excelled in the parameters of thelength of primary and secondary branch internodes. In general, after rejuvenation, HC management produce better generative parameters than MC and LC.



Note: BR: Before Rejuvenation; AR: After Rejuvenation. BMP: Best Management Practice, HC: High Coffee Management, MC: Medium Coffee Management, LC: Low Coffee Management. PT: Plant Length, JD: Number of Leaf, LD: Leaf Area, LK: Canopy Area, JCP: Number of Primary Branch , JCS: Number of Secondary Branch , PCP: Primary Branch Length , PCS: Secondary Branch Length, JBP: Number of Primary Nodes, JBS: Number of Secondary Nodes, KA: Chlorophyll A, KB: Chlorophyll B, KT: Total Chlorophyll, PRP: Length of Primary Branch Internode, PRS: Length of Secondary Branch Internode, JCPr: Number of Productive Branch, JBPr: Number of Productive Nodes, BB: Number of Fruits per Nodes, BC: Number of Fruits per Branch

Figure 3. Multi-colinearity plot between coffee plant morpho-physiology and agroforestry managementbefore rejuvenation and after rejuvenation

Table 3. Pearson correlation matrix among arabica coffee vegetatif and generatif components of four management pine coffee agroforestry before rejuvenation

	PT	JD	LD	LK	JCP	JCS	PCP	PCS	JBP	JBS	KA	KB	KT	PRP	PRS	JCPr	JBPr	BB	BC
PT	1	**-.978***	**-.961***	0.489	**-.952***	0.854	**.993****	**.990****	0.917	**-.981***	-0.821	-0.105	-0.385	**.979***	**.983***	**-.981***	**-.980***	-0.935	**-.998****
JD	**-.978***	1	**.994****	-0.328	**.972***	-0.898	**-.967***	-0.940	-0.923	**.996****	0.696	-0.098	0.190	**-.970***	**-.986***	**.989***	**.979***	0.861	**.964***
LD	**-.961***	**.994****	1	-0.323	0.945	-0.862	-0.938	-0.917	-0.880	**.982***	0.674	-0.136	0.150	**-.973***	**-.988***	**.969***	**.952***	0.851	0.944
LK	0.489	-0.328	-0.323	1	-0.208	-0.006	0.441	0.590	0.174	-0.310	-0.893	-0.855	-0.936	0.532	0.465	-0.310	-0.323	-0.763	-0.540
JCP	**-.952***	**.972***	0.945	-0.208	1	**-.972***	**-.969***	-0.912	**-.987***	**.987***	0.623	-0.138	0.143	-0.897	-0.924	**.993****	**.993****	0.783	0.934
JCS	0.854	-0.898	-0.862	-0.006	**-.972***	1	0.893	0.799	**.981***	-0.926	-0.443	0.288	0.025	0.771	0.814	-0.937	-0.940	-0.620	-0.827
PCP	**.993****	**-.967***	-0.938	0.441	**-.969***	0.893	1	**.984***	**.953***	**-.980***	-0.796	-0.099	-0.376	0.948	**.956***	**-.986***	**-.992****	-0.905	**-.990***
PCS	**.990****	-0.940	-0.917	0.590	-0.912	0.799	**.984***	1	0.886	-0.945	-0.887	-0.241	-0.508	**.964***	**.959***	-0.949	**-.954***	**-.966***	**-.997****
JBP	0.917	-0.923	-0.880	0.174	**-.987***	**.981***	**.953***	0.886	1	**-.952***	-0.597	0.101	-0.167	0.831	0.861	**-.967***	**-.976***	-0.736	-0.901
JBS	**-.981***	**.996****	**.982***	-0.310	**.987***	-0.926	**-.980***	-0.945	**-.952***	1	0.693	-0.087	0.200	**-.955***	**-.973***	**.998****	**.993****	0.851	**.966***
KA	-0.821	0.696	0.674	-0.893	0.623	-0.443	-0.796	-0.887	-0.597	0.693	1	0.639	0.830	-0.821	-0.780	0.698	0.711	**.961***	0.855
KB	-0.105	-0.098	-0.136	-0.855	-0.138	0.288	-0.099	-0.241	0.101	-0.087	0.639	1	**.958***	-0.087	-0.018	-0.065	-0.029	0.403	0.169
KT	-0.385	0.190	0.150	-0.936	0.143	0.025	-0.376	-0.508	-0.167	0.200	0.830	**.958***	1	-0.364	-0.300	0.221	0.254	0.644	0.443
PRP	**.979***	**-.970***	**-.973***	0.532	-0.897	0.771	0.948	**.964***	0.831	**-.955***	-0.821	-0.087	-0.364	1	**.997****	-0.943	-0.931	-0.947	**-.977***
PRS	**.983***	**-.986***	**-.988***	0.465	-0.924	0.814	**.956***	**.959***	0.861	**-.973***	-0.780	-0.018	-0.300	**.997****	1	**-.962***	-0.950	-0.922	**-.976***
JCPr	**-.981***	**.989***	**.969***	-0.310	**.993****	-0.937	**-.986***	-0.949	**-.967***	**.998****	0.698	-0.065	0.221	-0.943	**-.962***	1	**.998****	0.848	**.967***
JBPr	**-.980***	**.979***	**.952***	-0.323	**.993****	-0.940	**-.992****	**-.954***	**-.976***	**.993****	0.711	-0.029	0.254	-0.931	-0.950	**.998****	1	0.850	**.969***
BB	-0.935	0.861	0.851	-0.763	0.783	-0.620	-0.905	**-.966***	-0.736	0.851	**.961***	0.403	0.644	-0.947	-0.922	0.848	0.850	1	**.954***
BC	**-.998****	**.964***	0.944	-0.540	0.934	-0.827	**-.990***	**-.997****	-0.901	**.966***	0.855	0.169	0.443	**-.977***	**-.976***	**.967***	**.969***	**.954***	1

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Coefficients in bold type are statistically significant at $P < 0.05$. Notes: PT: Plant Length, JD: Number of Leaf, LD: Leaf Area, LK: Canopy Area, JCP: Number of Primary Branch , JCS: Number of Secondary Branch , PCP: Primary Branch Length , PCS: Secondary Branch Length, JBP: Number of Primary Nodes, JBS: Number of Secondary Nodes, KA: Chlorophyll A, KB: Chlorophyll B, KT: Total Chlorophyll,PRP: Length of Primary Branch Internode, PRS: Length of Secondary Branch Internode , JCPr: Number of Productive Branch, JBPr: Number of Productive Nodes, BB: Number of Fruits per Nodes, BC: Number of Fruits per Branch.

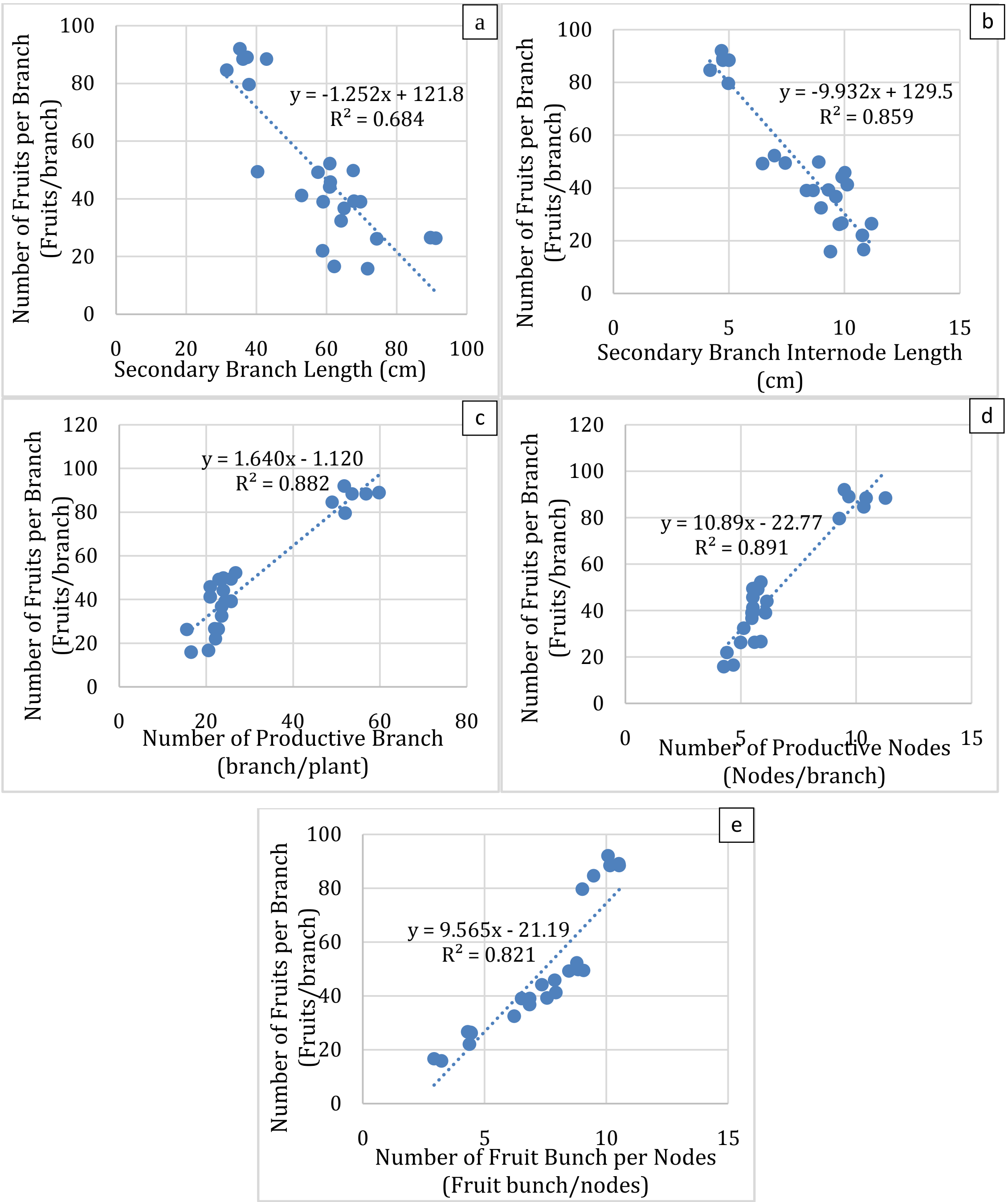


Figure 4. Linear regression in Arabica coffe before rejuvenation between number of fruits per branch and secondary branch length (a);secondary branch internode length (b);number of productive branch (c); number of productive nodes (d); and number of fruit bunch per nodes (e)

Coffee fruits was appeared from secondary branches to tertiary branches. Based on the results of the study, it was identified that the yield of Arabica coffee plants is influenced by several components. The components that affect the number of fruits per branch were analyzed by regression to determine the relationship model between the two variables (Figure 4). The shorter the secondary branch internodes, the higher the number of fruits per branch. Short secondary branch internodes will also decrease the length of secondary branches. Thus, based on the regression curve, the number of fruits per branch increases with shorter secondary branches (R^2 = 0.6842) or shorter secondary branch internodes (R^2 = 0.8595). In addition, the number of fruits per branch will increase as the number of productive branches increases (R^2 = 0.8827), the number of productive nodes (R^2 = 0.8917), and the number of fruit bunches per node (R^2 = 0.8216).The length of secondary branches and the number of productive branches are influenced by pruning. Pruning is an important cultural activity in management coffee plantation. This helps create a good and healthy tree canopy structure thereby providinggood results in productive age without producing alternate results orbiannual production (Waldemariam *et al*., 2016). In addition, a balanced ratio of leaves and fruit will increase photosynthate translocation.

CONCLUSION

The best growth of Arabica coffee Lini S-795 before rejuvenation show in Best Management Practice (BMP) management. After being rejuvenated for 3 years, Arabica coffee growth show that HC management produce the best growth compared to MC and LC. HC management, in general, has achieved a growth of about 49.42% when compared to BMP. HC is capable of producing 40.93% of the number of productive branches, 51.74% of the number of productive books, 63.73% of the number of fruit bunches per node, and 41.28% of the number of fruits per branch compared to the results obtained by BMP management.

The components that most influence Arabica coffee yields are secondary branch length, secondary internode length, number of secondary nodes, number of productive branches and number of productive nodes. It should be concerned by agroforestry farmers to increase yields. It also informs us that the coffee pine agroforestry system is able to support the regrowth of full stumping pruned coffee with shade cover of 54-72% in LC, MC and HC. The best growth and yield of Arabica coffee is produced by the most intensively managed agroforestry, BMP (before rejuvenation) and HC (after rejuvenation).

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