Evaluating Biopore Technology For Sustaining Coffee Yield and Growth During El Nino Events in South Sumatra, Indonesia

by Mumarharun Mumarharun

Submission date: 25-Sep-2025 09:34AM (UTC+0700)
Submission ID: 2715666672
File name: and_Growth_During_El_Nino_Events_in_South_Sumatra,_Indonesia.pdf (762.06K)
Word count: 7034
Character count: 36694

EVALUATING BIOPORE TECHNOLOGY FOR SUSTAINING COFFEE YIELD AND GROWTH DURING EL NIÑO EVENTS IN SOUTH SUMATRA, INDONESIA

HARUN, M.U.[1*] – YAKUP[1] – IRSAN, C.[2] – KRISWANTORO, H.[3] – SEFRILA M.[1] – HABIBULLOH[1] – RAMADHANI, F.[1]

[1]*Agronomy, Agriculture Faculty, Universitas Sriwijaya, Inderalaya 30862, Indonesia*

[2]*Plant Protection, Agriculture Faculty, Universitas Sriwijaya, Inderalaya 30862, Indonesia*

[3]*Agrotechnology, Agriculture Faculty, Palembang University, Palembang 30139, Indonesia*

[*]*Corresponding author*
e-mail: mumarharun@unsri.ac.id; phone: +62-812-787-0243

(Received 29th Jun 2025; accepted 22nd Aug 2025)

Abstract. In order to mitigate the impact of El Niño on declining crop yields, local water management is necessary. The present study aimed to elucidate the impact of biopore application during the rainy season on the growth and yield of coffee plants in the dry season, which coincided with El Niño. In the context of ff coffee crops in Semendo, South Sumatra, the generative phase of the crop's development was characterised by the onset of flower production in April. The ripening of cherries occurred in July, while beans reached full maturity in August. A substantial discrepancy was observed in each of the variables, namely the leaf greenness index, the number of leaves, the number of flowers, and the number of seeds, following treatment. Biopore application showed to increase leaf water content by 1-2%, primary branch length by 3-18%, primary branch diameter by 1-8%, the number of plagiotropic branches by 53-62%, the number of flower clusters by 10-30%, the number of fruit clusters by 38-58%, and the number of fruits by 20-60%. The percentage of normal beans and the weight of the beans increased significantly along with the number of biopore holes.
Keywords: *climate change, homemade hole, production, perennial, robusta*

Introduction

El Niño is defined as a global climate phenomenon, characterised by elevated sea surface temperatures in the central and eastern Pacific Ocean. In Indonesia, El Niño has been observed to induce alterations in weather patterns, including a decrease in precipitation and the onset of drought conditions. Consequently, El Niño is considered a catalyst for climate change. The repercussions of climate change, encompassing rising temperatures and shifting rainfall patterns, are poised to present substantial challenges to coffee plantations in tropical regions in the forthcoming years. It is hypothesised that climate change can result in the transformation of coffee production centres into areas that are suboptimal for coffee cultivation. Consequently, a range of climate change adaptation technologies for coffee plants are being extensively researched in numerous countries, including Indonesia, a major coffee producer that has also suffered losses due to climate change. Extended periods of drought caused by climate change have led to a significant decrease in coffee bean production. This is due to the method's ability to interfere with the flowering process, causing a large number of flowers to fall off (Imbach et al., 2017). Climate change has been demonstrated to affect temperature and rainfall patterns around coffee plantations (Jones et al., 2021). Prolonged dry and rainy seasons have been shown to cause plants to grow and produce poorly (Patil et al., 2022). Drought

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2305_1034510357

reduces the amount of water in the soil, thereby stunting the growth of coffee plants (González-Robaina et al., 2017).

The quantity and duration of water availability around the rhizosphere is a prerequisite for coffee plant cultivation. Low soil water content affects plant water potential and cell turgor, which subsequently inhibits cell elongation and plant growth, greatly reducing bean yields (Malau et al., 2018). Furthermore, a water deficit slows organ growth and causes plant shoots to wilt and eventually die (Chemura et al., 2014; Prijono and Bana, 2015).

The two coffee genotypes cultivated were Robusta (*Coffea canephora*), which constituted 72.35% of the 2022 bean yield, and Arabica, which accounted for 27.65%. The majority of coffee plantations were located at medium altitudes ranging from 500 to 1,300 meters above sea level. The crops were cultivated under the canopy of *Leucaena glauca, Erythrina subumbrans,* and *Albizzia falcata.* Indonesia produced 0.62 tons of coffee per hectare, a low yield due to inappropriate use of coffee clones and poor plantation maintenance, as well as a lengthy dry season. In the highlands of West Lampung and South Sumatera, many coffee grafts from various clones were planted. Evizal et al. (2018) and Evizal and Prasmatiwi (2020) reported that coffee cultivation currently implements intraspecific and interspecific grafting techniques for coffee clones. In Semendo, intraspecific coffee cultivation (Robusta/Robust) is already widespread.

One method of water management is the use of biopores to control runoff and the water supply in the rhizosphere of plants during the rainy season. Biopores quickly restore rhizosphere water adequacy during the rainy season and release it after the dry season (Permatasari, 2015). The capacity of biopores with a diameter of 10 cm and a length of 100 cm was estimated to be 7.85 ℓ, equivalent to 7.854 cm^3. The utilisation of biopores within coffee plantations has been demonstrated to enhance coffee bean yield whilst concomitantly supporting elevated groundwater capacity (Bermúdez-Florez et al., 2018). The water present within the biopores is connected by micropores in the walls, thereby facilitating the absorption of water into the soil. As reported by Defrenet et al. (2016), the coffee root biomass was found to be approximately 92% at a depth of 1.5 m and around 8% at depths of up to 4 m. It was evident from the observations made that the root reach width of coffee crops ranges from approximately 0.4 to 0.6 m. Consequently, it was hypothesised that the coffee roots must be located at a depth between 0.1 and 2 m. Horizontally, the coffee root system extends to a depth of 0.5 m from the stem. It was estimated that the coffee rhizosphere encompasses an approximate volume of $0.5m^3$ for each individual coffee crop.

The results of the study by Tezara et al. (2024) showed significant differences in net photosynthesis rate and stomatal conductance among coffee genotypes when water efficiency decreased by 4-74%. Based on these findings, water deficits can occur during the dry season, impacting plant growth and yield. Robusta and arabica coffee plantations in Indonesia are located in the highlands or mountains, making it very difficult to supply water. Thus, farmers need a suitable method. Biopore was a simple technique that coffee farmers can easily apply. However, the precise placement and number of biopores for each crop was still unknown.

The coffee farmers were accustomed to using one biopore for each plant. However, there was no significant increase in plant growth or coffee crop yield. Therefore, the recommendation was to install more than one biopore per plant during the rainy season to store more water and release it during the long dry season. This study evaluated the optimal number of biopores needed to provide water to the rhizosphere for coffee plant

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2305_1034510357

growth during the long dry season. It also evaluated how the growth, flowering, and formation of coffee beans were affected by the number of biopores. Understanding how Robusta coffee crops respond to water supply from biopores is crucial for developing effective water management strategies to combat climate change.

Materials and methods

Methods

The research was carried out in Rantau Dadap, Segamit Village, Semendo, South Sumatra, Indonesia, located at (-4.201212, 103.447751) (*Figure 1*). The research period was from February through August 2019. The research area was located on a hilly slope with a 5% incline, at an elevation of 1,100 m above sea level. El Niño conditions were observed in South Sumatera from July to October 2019, as reported by the Meteorology and Geophysics Agency in Palembang during the present study (Meteorology and Geophysics Agency, Palembang 2020).

Figure 1. *Map of experimental site locations*

The coffee crops grown were of the revitalized intraspecific robusta variety, which was rejuvenated approximately five years ago using 20-year-old rootstocks and Garuda as the scion. The coffee crops were planted at a spacing of 3×3 m. Additionally, *Erythrina subumbrans* was planted as a shade tree with a spacing of 10×15 and 10×20 m. The plants were randomly selected.

This study did not use a design or non-design approach, as the land area was very limited (28 m x 15 m) and consisted of only 30 coffee trees but the plants were still randomly selected. Accordingly, the quantity of water that had undergone treatment was

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2305_1034510357

then measured, and the samples were isolated from one another. The number of treatments was five, with three replications, thus resulting in a total sample of 15 trees. The placement of treatment samples was conducted in a randomised manner. The treatments utilised were B0-Control (no biopores); B1 (1 biopore); B2 (2 biopores); B3 (3 biopores); and B4 (4 biopores).

The installation of the biopores was conducted in February, coinciding with the onset of the rainy season. The biopores had a diameter of 10 cm, a depth of 1 metre, and were installed at a distance of approximately 0.5 m from the coffee crop. The pores were perpendicular to the surface at a 90-degree angle. Each coffee crop was fertilised with 500 g of NPK (16:16:16), which was broadcast at a distance of 40 cm from the crop and placed approximately 5 cm into the soil. Throughout the study, the biopore was maintained at a depth of one metre, and weekly soil samples were obtained from the hole. From early July until the conclusion of the study (i.e. the dry season), 2.4 kg of compost were administered to all biopore holes with the aim of controlling water evaporation.

Two secondary branches were selected from each sample crop for the purpose of collecting data on generative organs and leaf water content. The water content of the leaves was measured based on turgid leaf weight (*Equation 1*). The leaves were then subjected to an oven-based drying process at a temperature of 80°C for a period of 24 hours. The leaf water content (LWC) was calculated according to the following formula:

$$\text{LWC (\%)} = [(\text{FW-DW}) / (\text{TW-DW})] \times 100 \quad \text{(Eq.1)}$$

where, FW – fresh weight, TW – turgid weight, and DW – dry weight (Ye et al., 2022).

Measurements were taken on a monthly basis. The measurement of the Leaf Green Index was conducted by means of a SPAD Chlorophyll Meter (model SPAD-502 Plus) on three fully mature leaves during the flowering period. The SPAD (Soil Plant Analysis Development) leaf greenness was assessed using the SPAD-502 Plus measuring instrument (Konica Minolta, Inc, Japan). The instrument was clamped in the middle of each leaf between 10 am and 12 pm. The results were expressed in non-metric SPAD units ranging from 0 to 200. The readings were recorded and averaged (Zarzecka et al., 2021). The length of the secondary branch was measured in cm from the branch union at the base to the terminal bud. The quantity of plagiotropic branches was determined for all branches bearing flower clusters. The production data comprised the number of flower clusters, fruit clusters, and beans produced. The Meteorology and Geophysics Agency of Palembang City was responsible for the procurement of local rainfall and weather data. The following text was intended to provide a concise summary of the key points.

The analysis of the data from each variable obtained was displayed in tabulation. The data was obtained by calculating the mean value and standard deviation. The data were then subjected to a comparison using the Least Significant Difference (LSD 0.05). Should the discrepancy between the two treatments exceed the LSD value, it is declared to be significantly different.

Results

The availability of water in the soil was crucial to supporting the growth and development of coffee crops. From February to April, rainfall was high, providing the crops with water. However, rainfall decreased from May to August 2019. Rainfall at an elevation of 1,100 meters also impacted environmental temperature. The interaction

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2305_1034510357

between coffee crops, groundwater, and environmental temperature creates growth in the vegetative and generative organs and fruit of coffee crops (*Table 1*). The data was obtained using AAWS (Automatic Agroclimate and Weather Station) provided by the Meteorology and Geophysics Agency, Palembang.

Table 1. *Performance of vegetative and generative growth of coffee crops and weather in Semendo*

Variables	2019						
	Feb	**March**	**April**	**May**	**June**	**July**	**August**
Precipitation (mm)	480	355	536	188	189	89	41
Rain Days (day)	21	19	20	13	13	3	3
Temp (°C)	27,6	27,1	27,8	28	27,8	27,3	28
Humidity (%)	12	7	5	11	13	30	66
Phase of Crops	..……..Vegetative……….			…...Flowering….		…Cherry...	…Bean...

Note: Meteorology and Geophysics Agency, Palembang (2020)

The period of relatively normal rainfall from February to May greatly helps coffee crops enter the flowering phase. In June, the optimal temperature for coffee flowers is around 28°C, and almost all robusta coffee crops flowered at the research location. Thus, the coffee crop enters the generative phase. The formation of coffee flowers marks the beginning of cherry and coffee bean formation.

The Relative leaf water content was measured monthly on coffee crops, showing that the value followed rainfall. There was an increase in leaf water content in April, followed by a drastic decrease in August (*Figure 2*). Leaf water content increased rapidly after the application of biopores following rainfall for all biopore treatment numbers. In April, leaf water content reached its peak, and then decreased again during the dry season. Generally, the highest leaf water content was found in B4, followed by B3, B2, and B1. Coffee crops not treated with biopores had the lowest leaf water content values from beginning to end of the study. Applying biopores during the rainy season increases the amount of water entering the soil and, at the same time, increases the relative water content of the leaves.

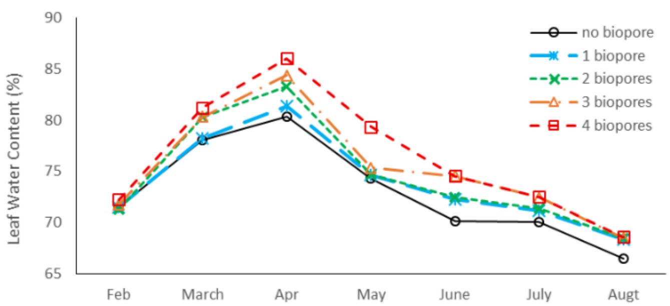


Figure 2. *Leaf Water Content (LWC) recorded along the course of the research as affected by different number of biopores imposed in each coffee crop*

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2305_1034510357

By the end of the study, the leaf green index revealed significant differences between the treatments applied with and without biopores, as well as between the biopore applications (*Figure 3*). The leaf green index reflects the leaves' chlorophyll content, and it appears that there was no significant difference between the three biopore treatments, while the non-biopore application was significantly different from all biopore treatments. Therefore, it was thought that the application of biopores could maintain the chlorophyll content of coffee leaves.

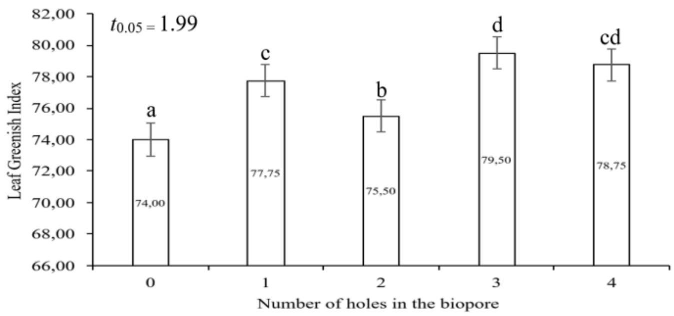


Figure 3. *Leaf greenish index showed improvement with the increase in biopore number built in per crop. Note: Means followed with the same letters within columns are not significantly different based on the LSD at p ≤ 0.05*

It has been observed that a significant proportion of coffee plant leaves undergo defoliation when the seed formation phase begins. Based on the research results, the use of biopores produces a relatively greater number of leaves compared to non-biopore applications. It is known that, in general, the sample branches had a total of more than 400 leaves at the start of the study. By the end of the study, the number of leaves had decreased to approximately 300. As shown in *Figure 4*, the number of leaves in the three biopore treatments differed significantly from the other treatments. The non-biopore treatment had 112 leaves, which differed significantly from all biopore treatments.

A significant differences in branch length, branch diameter, and the number of plagiotropics was observed in coffee crops treated with biopores in comparison to non-biopore applications (*Table 2*). The maximum increase in branch length was observed in coffee crops treated with four biopores, reaching around 26 cm. This outcome was found to be statistically significant in comparison to all other treatment groups. The smallest increase in branch length from the non-biopore application was 8 cm. This study reported that the diameter of coffee branches increased by approximately 0.26 cm over six months in plants treated with three or four biopores, which was significantly different from other treatments. In general, there was also an increase of about three plagiotropics in plants treated with three or four biopores. The increase in branch length, branch diameter, and plagiotropics from four biopores appears to be greater than from other treatments and non-biopores.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2305_1034510357

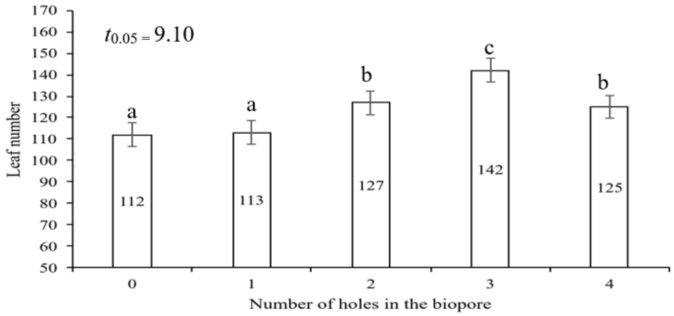


Figure 4. *Number of leaves on plagiotroph branch of coffee trees as affected by number of biopores furnished. Note: Means followed with the same letters within columns are not significantly different based on the LSD at p ≤ 0.05*

Table 2. *Branch length (cm), branch diameter (cm), and plagiotroph branch number of robusta coffee trees recorded as treated by different number of biopores invested in each tree*

Biopore numbers	**Branch length (cm)**		**Branch diameter (cm)**		**Plagiotroph branch number**	
	------------------------------------ Rate		**--**			
0	98.00 ± 2.16	a	3.11 ± 0.17	a	4.00 ± 0.82	a
1	101.50 ± 5.74	b	3.15 ± 0.10	ab	6.50 ± 1.00	b
2	107.25 ± 5.85	c	3.21 ± 0.15	b	6.75 ± 1.50	bc
3	112.50 ± 4.20	d	3.38 ± 0.05	c	7.00 ± 1.41	bc
4	116.50 ± 4.73	e	3.38 ± 0.05	c	7.50 ± 0.96	c
	$t_{0.05}$ = 3.50		$t_{0.05}$ = 0.06		$t_{0.05}$ = 0.91	

Note: Numbers when followed by the same alphabets in the same columns indicated non-significant difference at LSD 5% (p<0,05)

The response of coffee crop growth from the application of biopores during the rainy season until the production of beans during the dry season was interesting to study. Therefore, we compared the number of leaves, leaf greenness index, and leaf water content at the beginning and end of the study. The final data from the study were important because they describe the effect of biopores on coffee crops. Initially, almost all measured variables showed the same value; however, by the end of the study, there was a significant difference between the variables of each treatment. Furthermore, it was reported that the number of coffee leaves decreased by the end of the study. It seems that the more fruit clusters there are, the fewer leaves there are on the branches. A comparison between the vegetative and generative phases of coffee plants shows that the application of biopores increases the number of leaves, leaf green index, and leaf water content (LWC), indicating higher quality coffee leaves.

There were significant differences in the number of coffee flowers, coffee cherries, average number of cherries, and beans per plagiotropic between non-biopore and biopore applications. Information suggests that biopore applications can increase the number of

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2305_1034510357

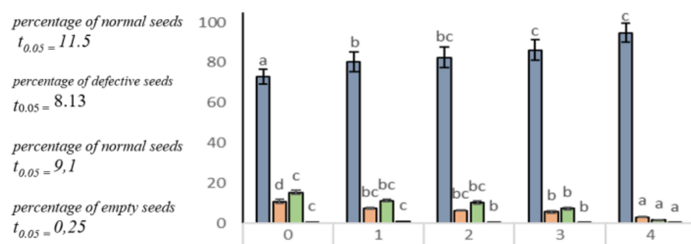
flowers and seeds in coffee crops (*Table 3*). Applying B4 to coffee crops showed significant differences compared to applying biopores.

Table 3. *Effects of different biopore numbers built in sround the coffee trees yield variables Including flower clusters, number of fruit clusters, average fruit and number of bean per branch*

Biopore	Flower (cluster/branch)		Fruit/cherry (cluster/branch)		Average fruit (Fruit/cluster)		Bean (bean/branch)	
0	9 ± 0.92	a	5 ± 0.15	a	12,3 ± 0.16	a	70 ± 8.21	a
1	10 ± 0,31	ab	8 ± 0.82	ab	13,5 ± 1.21	a	87 ± 3.49	a
2	12 ± 0.49	bc	9 ± 0.31	bc	14,1 ± 0.07	ab	120 ± 9.03	b
3	12 ± 0.28	bc	10 ± 0.64	bc	14,6 ± 0.13	b	130 ± 8.62	b
4	13 ± 0.11	c	12 ± 0.99	c	16,7 ± 0.02	c	180 ± 9.11	c
	$t_{0.05}$ = 2.22		$t_{0.05}$ = 2.57		$t_{0.05}$ = 1.99		$t_{0.05}$ = 36.38	

Note: Numbers followed by the same alphabet in the same columns indicated non-significant difference at LSD 5% ($p<0,05$)

The percentage of flowers to cherries was between 7 and 56%, and the percentage of cherries to beans was between 7 and 71%, depending on the amount of biopore applied to robusta coffee. Biopore B4 increased the percentage of cherry formation and reduced abnormal seeds (*Figure 5*). Based on this research, it was concluded that, without water management efforts, there was a decrease in cherry formation and an increase in abnormal seeds (defective, empty, and triage).



	0	1	2	3	4
percentage of normal seeds	73	80,4	82,6	86,3	94,8
Percentage of defective	11,0	7,4	6,5	5,9	3,2
Percentage of empty	15,5	11,3	10,4	7,5	1,9
Percentage of triage	0,5	0,9	0,5	0,3	0,1

Figure 5. *Percentage of normal seed, defective, empty and tiage of coffee seed as affected by number of biopores furnished. Note: Means followed with the same letters within columns are not significantly different based on the LSD at p ≤ 0.05*

The number of beans formed by applying four biopores was significantly different compared to not using biopores. The beans were relatively heavy, resulting in a greater weight compared to other treatments (*Figure 6*). The average weight of the beans ranged from 0.3 g.bean^{-1} for non biopore to 0.34 g.bean^{-1} for four biopore.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2305_1034510357

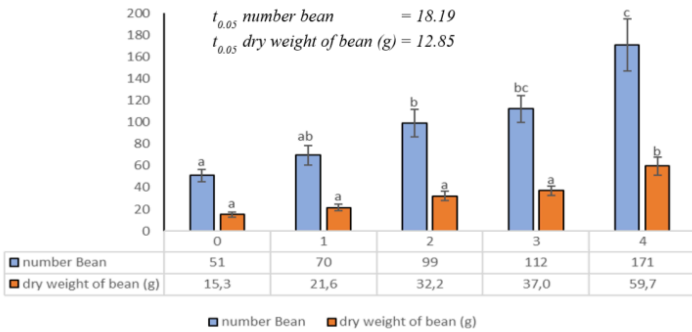


***Figure 6.** Number and dry weight of coffee bean as affected by number of biopores furnished.*
Note: Means followed with the same letters within columns are not significantly different based on the LSD at $p \leq 0.05$

Discussions

The phenomenon observed in robusta coffee crops based on rainfall includes the vegetative phase and the generative phase, which includes flowering, fruit formation, and coffee bean formation. This phenomenon is similar to that observed by Dinh et al. (2022) in Vietnam. Three months before the end of the rainy season, the dominant vegetative phase produces new shoots and leaves. At the beginning of the dry season, the generative phase begins. At the end of the rainy season, all coffee crops enter the generative phase of flowering. Apart from water, coffee flowering is strongly influenced by temperature (Kath et al., 2020). In July of the dry season, coffee berries begin to form. By the end of August, coffee beans have formed. The growth and seed formation phenomena that occurred in Semendo were somewhat similar to those reported by Kath et al. (2023) in Vietnam, in that the process from vegetative growth to seed formation takes about four months. Based on the obtained data, the percentage of flowers that became coffee berries was between 30 and 35%.

The relative leaf water content increased by nearly 86% from the B4 level in April, followed by the B3, B2, B1, and non-biopore levels. This increase was thought to be due to the accumulation of rainfall during the rainy season. The difference in the number of biopores appears to greatly affect the accumulation of water in the rhizosphere. The continuous decrease in the relative water content of coffee leaves from May to August was also related to rainfall. Coffee crops do not thrive in heavy rainfall during flowering; during this phase, the water content of coffee crop leaves ranges from 74% to 79.3% (Ronchi and Miranda, 2020; Molina and Rivera, 2022). The relative leaf water content drops to 70%-72% during fruit formation. Nevertheless, non-biopores still had lower leaf water content than biopore applications.

All analyzed vegetative and generative variables showed a significant effect of biopores on coffee crops (*Table 2*). These results demonstrate that water availability from rainfall plays a significant role in controlling the growth, development, and production of coffee beans (Evizal et al., 2020). Furthermore, the significant effect on all variables indicates that biopores play a significant role in providing water to the coffee rhizosphere.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2305_1034510357

Syakir and Surmaini (2017) reported that biopores provide benefits such as water storage and land conservation during droughts, controlling surface water flow, preventing erosion, and protecting soil chemical fertility from leaching. Therefore, applying biopores can increase water levels in the rhizosphere, providing water for a longer period to support crop growth and development. Thus, the number of biopores significantly affected all variables.

The decreasing pattern of monthly rainfall will affect the increase in temperature and the decrease in humidity. Therefore, the water deficit in the rhizosphere, coupled with increasing temperatures and decreasing humidity, will impact the metabolism of coffee crops (Sarvina et al., 2020; Merga and Beksisa, 2023). Previous studies have shown that the amount of water in the rhizosphere and the relative water content in different leaves stimulate significant differences in all vegetative and generative variables of coffee crops.

Ultimately, the green leaf index revealed significant differences between treatments with (77.88) and without (74.00) biopores. According to Tamirat (2019), water stress due to the dry season can reduce leaf chlorophyll. The combination of a water deficit and high temperatures can change the color of leaves from green to greenish. Additionally, it was suggested that the decrease in green leaf index may be due to photosynthates being sent from the leaves to the generative organs of the coffee crop (Mohammed et al., 2021). Therefore, the difference in the green leaf index of coffee crops during the dry season is caused by relative leaf water content, the presence of water in the rhizosphere, metabolism, and weather.

Many coffee crop leaves fall after entering the flower and fruit formation phase, a common phenomenon. This was due to the dry season as well as the breakdown of assimilates in the leaves for flower and seed growth. The application of biopores has been shown to increase the availability of water and nutrients for coffee crops, reducing leaf fall compared to non-biopore applications. Sufficient water availability in the leaves due to biopores was thought to maintain leaves on the tree.

This study reported an increase in the diameter of coffee branches and plagiotropic branches, as well as an increase in branch length, for six months in coffee crops. The coffee crops were treated with biopores 3 and 4, which produced significantly different results than other treatments. The increase in all vegetative variables in B3 and B4 was thought to be due to sufficient water availability, enabling the crops to carry out photosynthesis and organ growth. According to Izzah et al. (2019), sufficient water can increase the growth of crop organs.

By the end of May, all Robusta coffee crops had begun to flower. According to Da Matta and Ramalho (2006), coffee crops flower when temperature increases and rainfall decreases. Therefore, Boreux et al. (2016) suggested irrigating coffee plantations to stimulate flowering. Thus, a sufficient water supply in the rhizosphere and an increased temperature can stimulate the emergence of coffee crop flowers. The number of flower and fruit clusters and the average number of fruits need to be considered and maintained. These three variables depend on the water supply from rain or irrigation, pollinating insects, and temperatures suitable for fruit and seed development (Evizal et al., 2020). We believe that B1 biopores, which are commonly used by farmers, produced lower results than 3-4 biopores.

An increase in leaf water content due to biopores increases the percentage of flowers that become fruit. On coffee crops without biopores, flowers and fruit fell by more than 50%, resulting in fewer fruits than on coffee crops where biopores were applied (*Table 3*). In general, Arabica coffee experiences flower drop of up to 40% (Tarno et al., 2018).

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2305_1034510357

The indicators of freshness and health of the crop were the leaves (color, quantity, and relative water content). We compared the condition of the leaves between the rainy and dry seasons at each level of biopore application to learn about the relationship between the three variables. Crops with 3 or 4 biopores had consistently higher values than crops with fewer applications. Furthermore, increasing metabolic processes in coffee crops with biopore holes positively affected the growth of vegetative organs, such as primary branch length, branch diameter, and the number of plagiotrophs. These results are somewhat similar to Randriani et al.'s (2014) research that determined the robusta coffee yield was dependent on the number of plagiotropes. With more and longer plagiotropes than B3 or B4, the number of seeds was greater than with other treatments.

In tropical areas, the emergence of coffee flowers is more influenced by photoperiodism, or light intensity and duration of exposure (Yuliasmara, 2020). The relatively low percentage of flowers that become cherries indicates a strong influence of temperature and water availability in the rhizosphere (Takeno, 2016; Kath et al., 2023). This study's results show that the biopore treatment has a greater number of flowers and produces more cherries than the non-biopore treatment due to optimal temperature and water availability. Furthermore, abnormal beans from the non-biopore treatment have high levels of B0 due to suboptimal photosynthesis. Photosynthesis is important for forming normal coffee beans (Da Matta et al., 1997).

The number of biopores around a coffee tree affects the number of flower and fruit clusters, as well as the average number of fruits and seeds per branch. These generative organs appear to be more strongly influenced by the presence of optimal water in the rhizosphere. Izzah et al. (2019) and Kath et al. (2023) also stated that water is closely related to the growth of coffee generative organs.

Furthermore, the percentage of normal, defective, empty, and sorted coffee beans is influenced by the number of biopores applied around the coffee tree. Coffee bean quality is greatly influenced by photosynthates and water from the soil (Halupi, 2020). The number and weight of coffee beans are influenced by the number of biopores applied. This study found that the number and weight of B4 beans were significantly different from B2, B1, and B0 beans. However, B3 could be the optimal choice for economic and efficiency reasons. Therefore, it is believed that optimal water availability during the dry season is very important for coffee plants.

Conclusions

The vulnerability of coffee plants to agroclimatic changes affects the process of flower and fruit formation, especially when exposed to drought stress. The installation of biopores during the rainy season has been proven to increase water content in coffee plant leaves, leaf chlorophyll, and reproductive organs during the dry season. This activity can be carried out as a climate change mitigation effort through soil and water conservation by enhancing water absorption into the soil. Additionally, a 23.32% increase in coffee bean yield was observed compared to trees without biopores.

Acknowledgements. We would like to thank the review team for their valuable feedback, and express our gratitude to the funders of PT. Supren Energy Geothermal and Universitas Sriwijaya.

REFERENCES

[1] Bermúdez-Florez, L. N., Cartagena-Valenzuela, J. R., Ramírez-Builes, V. H. (2018): Soil humidity and evapotranspiration under three coffee (*Coffea arabica* L.) planting densities at Naranjal experimental station (Chinchiná, Caldas, Colombia). – Acta Agronomica 67(3): 402-413. https://doi.org/10.15446/acag.v67n3.67377.

[2] Boreux, V., Vaast, P., Madappa, L. P., Cheppudira, K. G., Garcia, C., Ghazoul, J. (2016): Agroforestry coffee production increased by native shade trees, irrigation, and liming. – Agronomy for Sustainable Development 36(3). https://doi.org/10.1007/s13593-016-0377-7.

[3] BPS-Statistics Indonesia. (2022): Statistical Yearbook of Indonesia 2022. – In BPS-Statistics Indonesia (Vol. 1101001). https://www.bps.go.id/publication/2020/04/29/e9011b3155d45d70823c141f/statistik-indonesia-2020.html.

[4] Chemura, A., Mahoya, C., Chidoko, P., Kutywayo, D. (2014): Effect of Soil Moisture Deficit Stress on Biomass Accumulation of Four Coffee (*Coffea arabica*) Varieties in Zimbabwe. – ISRN Agronomy 2014(February): 1-10. https://doi.org/10.1155/2014/767312.

[5] Defrenet, E., Roupsard, O., Van Den Meersche, K., Charbonnier, F., Pérez-Molina, J. P., Khac, E., Prieto, I., Stokes, A., Roumet, C., Rapidel, B., De Melo Virginio Filho, E., Vargas, V. J., Robelo, D., Barquero, A., Jourdan, C. (2016): Part of a special issue on root biology: Root biomass, turnover and net primary productivity of a coffee agroforestry system in Costa Rica: Effects of soil depth, shade trees, distance to row and coffee age. – Annals of Botany 118(4): 833-851. https://doi.org/10.1093/aob/mcw153.

[6] Dinh, T. L. A., Aires, F., Rahn, E. (2022): Statistical Analysis of the Weather Impact on Robusta Coffee Yield in Vietnam. – Frontiers in Environmental Science 10(June): 1-15. https://doi.org/10.3389/fenvs.2022.820916.

[7] Evizal, R., Sugiatno, S., Dwi Utomo, S., Pujisiswanto, H., Widagdo, S., Erry Prasmatiwi, F., Dwi Stiawan, A. (2018): Growth Performance of Mature Trees Resulted from Intra and Inter-specific Grafting on Robusta Coffee. – Planta Tropika: Journal of Agro Science 6(2). https://doi.org/10.18196/pt.2018.083.77-83.

[8] Evizal, R., Prasmatiwi, F. E. (2020): Grafting Coffee Agrotechnology for Increased Production. – Jurnal Agrotek Tropika 8(3): 423. https://doi.org/10.23960/jat.v8i3.4088.

[9] Evizal, R., Prasmatiwi, F. E., Widagdo, S., Novpriansyah, H. (2020): Ethno-Agronomy of Coffee Cultivation Tolerant of Rainfall Variability. – Jurnal Agro Industri Perkebunan 8(1): 49. https://doi.org/10.25181/jaip.v8i1.1392.

[10] González-Robaina, F., Cisneros Zayas, E., Montilla, E. (2017): The coffee tree (*Coffea arabica* L.) response to water deficit in different development phases. – Revista Ciencias Técnicas Agropecuarias 26(3): 4-11. https://www.redalyc.org/articulo.oa?id=93252908001.

[11] Imbach, P., Fung, E., Hannah, L., Navarro-Racines, C. E., Roubik, D. W., Ricketts, T. H., Harvey, C. A., Donatti, C. I., Läderach, P., Locatelli, B., Roehrdanz, P. R. (2017): Coupling of pollination services and coffee suitability under climate change. – Proceedings of the National Academy of Sciences of the United States of America 114(39): 10438-10442. https://doi.org/10.1073/pnas.1617940114.

[12] Izzah, N. K., Pranowo, D., Wardiana, E. (2019): The production and tolerance level of 22 accessions of Sukabumi robusta coffee to water stress. – IOP Conference Series: Earth and Environmental Science 418(1): 012019. https://doi.org/10.1088/1755-1315/418/1/012019.

[13] Kath, J., Byrareddy, V. M., Craparo, A., Nguyen-Huy, T., Mushtaq, S., Cao, L., Bossolasco, L. (2020): Not so robust: Robusta coffee production is highly sensitive to temperature. – Global Change Biology 26(6): 3677-3688. https://doi.org/10.1111/gcb.15097.

[14] Kath, J., Byrareddy, V. M., Reardon-Smith, K., Mushtaq, S. (2023): Early flowering changes robusta coffee yield responses to climate stress and management. – Science of The Total Environment 856: 158836. https://doi.org/10.1016/j.scitotenv.2022.158836.

[15] Malau, S., Siagian, A., Sirait, B., Ambarita, H. (2018): Plant growth of genotypes of Arabica coffee on water stress. – IOP Conference Series: Materials Science and Engineering 420(1). https://doi.org/10.1088/1757-899X/420/1/012066.

[16] Merga, D., Beksisa, L. (2023): Mechanisms of Drought Tolerance in Coffee: Implication for Genetic Improvement Program: Review. – American Journal of BioScience 11(3): 63-70. https://doi.org/10.11648/j.ajbio.20231103.12.

[17] Mohammed, M., Shimbir, T., Meskelu, E. (2021): Evaluation of Coffee Genotypes for Drought Tolerance in South Ethiopia. – Irrigation and Drainage Systems Engineering 10(6).

[18] Molina, D., Rivera, R. M. (2022): Identifying Coffee genotypes tolerant to water deficit. – Coffee Science 17. https://doi.org/10.25186/.v17i.1994.

[19] Patil, S., Devasia, J., Daniel, G., Rao, N. S. P. (2022): Influence of elevation and rainfall on leaf growth, bean characteristics and yield components of arabica and robusta coffee under changing climatic conditions in Karnataka state, India. – Journal of Plantation Crops 50(2): 78-84. https://doi.org/10.25081/jpc.2022.v50.i2.7981.

[20] Permatasari, L. (2015): Biopore Infiltration Hole: "One Day for Biopore" As an Alternative Prevent Flood. – International Journal of Advances in Science Engineering and Technology 3: 2321-9009.

[21] Prijono, S., Bana, S. (2015): Study of Soil Moisture on Coffee Plantation in Dry Land Using Neutron Probe in Malang, East Java. – Bulletin of Environment, Pharmacology and Life Sciences [BEPLS] 4(2): 135-143. https://bepls.com/jan2015/25.pdf.

[22] Randriani, E., Dani, D., Tresniawati, C., Syafaruddin, S. (2014): Relationship Between Vegetative Characters, Yield Components, and Yield Power of Robusta Coffee from Plagiotropic Grafting. – Jurnal Tanaman Industri Dan Penyegar 1(2): 109. https://doi.org/10.21082/jtidp.v1n2.2014.p109-116.

[23] Ronchi, C. P., Miranda, F. R. (2020): Flowering percentage in arabica coffee crops depends on the water deficit level applied during the pre-flowering stage. – Revista Caatinga 33(1): 195-204. https://doi.org/10.1590/1983-21252020v33n121rc.

[24] Sarvina, Y., June, T., Surmaini, E., Nurmalina, R., Hadi, S. S. (2020): Coffee Productivity Improvement Strategy and Adaptation to Climate Variability and Change through Cultivation Calendar. – Jurnal Sumberdaya Lahan 14(2): 65. https://doi.org/10.21082/jsdl.v14n2.2020.65-78.

[25] Syakir, M., Surmaini, E. (2017): Climate Change in the Contex of Production System and Coffee Development in Indonesia. – Jurnal Penelitian Dan Pengembangan Pertanian 36(2): 77. https://doi.org/10.21082/jp3.v36n2.2017.p77-90.

[26] Tamirat, W. (2019): Review on Role of Proline on Coffee Under Drought Conditions. – Journal of Environment and Earth Science 9(10): 1-6. https://doi.org/10.7176/jees/9-10-01.

[27] Tarno, H., Wicaksono, K. P., Begliomini, E. (2018): Floral stimulation and behavior of insect pollinators affected by pyraclostrobin on Arabica coffee. – Agrivita 40(1): 161-167. https://doi.org/10.17503/agrivita.v40i1.1719.

[28] Tezara, W., Loyaga, D. W., Reynel Chila, V. H., Herrera, A. (2024): Photosynthetic Limitations and Growth Traits of Four Arabica Coffee (*Coffea arabica* L.) Genotypes under Water Deficit. – Agronomy 14(8):1-17. https://doi.org/10.3390/agronomy14081713.

[29] Ye, Q., Wang, H., Li, H. (2022): Arbuscular Mycorrhizal Fungi Improve Growth, Photosynthetic Activity, and Chlorophyll Fluorescence of *Vitis vinifera* L. cv. Ecolly under Drought Stress. – Agronomy 12(7). https://doi.org/10.3390/agronomy12071563.

[30] Zarzecka, K., Gugała, M., Mystkowska, I., Sikorska, A. (2021): The Leaf Greenness Index SPAD and Selected Features of Potato Following an Application of Herbicides and Biostimulants. – Journal of Ecological Engineering 22(8): 54-63. https://doi.org/10.12911/22998993/140330.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2305_1034510357

Evaluating Biopore Technology For Sustaining Coffee Yield and Growth During El Nino Events in South Sumatra, Indonesia

ORIGINALITY REPORT

8%	8%	3%	6%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to Xianjiatong-Liverpool University Student Paper	6%
2	www.cropj.com Internet Source	1%
3	www.mdpi.com Internet Source	1%
4	ojs.unud.ac.id Internet Source	1%

Exclude quotes Off
Exclude bibliography On
Exclude matches < 1%