Physiology and early growth of introduced robusta coffee clones in wet climate drylands in Bacan, North Maluku

W Sulistiono1,2*, C Sugihono1,2, Y Hidayat1,2, M Assagafl,2, H L Abu1, B Brahmantio3, A Wahab1

1Assessment Institute of Agricultural Technology (AIAT) North Maluku, Indonesia
2Researcher at AIAT North Maluku, Kusu Agriculture complex No,1 North Oba District, Tidore Islands, North Maluku, Indonesia
3Livestock Research Institute, Bogor, Indonesia
*Corresponding author: tionojanah@gmail.com

Abstract. Climate change, such as a prolonged dry season, will greatly determine the physiological processes and growth of robusta coffee. To overcome this, suitable clonal planting and proper fertilization are required. This study aims to determine the physiological properties and early growth for the suitability of climatic conditions and cultivation treatments. The study was conducted in Latosol soil in the dry land of IP2TP (Instalasi Penelitian dan Pengkajian Teknologi Pertanian) Bacan South Halmahera, North Maluku, from September 2018 to November 2020. The study was arranged in a factorial randomized block design with three replications. The first factor consists of clones of coffee consisting of five clones, namely: BP42, BP409, BP936, BP93 and SA237. The second factor is the fertilizer dosage which consists of 3 levels, namely: (1) 100% chemical NPK (120kg ha-1), (2) 50% chemical NPK + 50% organic and (3) 100% organic. The results showed that the chlorophyll and proline content of leaf was determined by the interaction of clones and fertilization. 50% organic fertilization produced the highest leaf chlorophyll content in clones BP409 and BP936. 50% organic fertilization also produced the lowest leaf proline in clone BP42 which showed more tolerance to drought. Agronomic traits such as plant height are determined by the type of clone. The plant height of BP409 clone highest was significantly different from BP42 and BP936.

1. Introduction

Coffee is a plantation commodity crop that is very sensitive to progressive climate change [1]. Changes in climatic parameters such as temperature and rainfall are the limiting ecological factors that determine the physiological process of coffee and coffee production. Camargo [2] reported that there was a temperature increase of 1.1ºC to 6.4ºC and a 15% increase in rainfall had an impact on reducing coffee productivity in Brazil. Climate change mitigation strategies need to be carried out to reduce the vulnerability of agroecosystems and decrease coffee production, among others, replacing appropriate varieties, changing planting times and locations, increasing pest control, more intensive weeds and making good use of forecasts of seasonal climate elements [2, 3].

Robusta coffee in North Maluku is cultivated in West Halmahera, North Halmahera, South Halmahera, Sula, and East Halmahera districts and is recorded in statistical data as an important plantation commodity with a production of around 133 tonnes [4]. Robusta coffee plantations are smallholder crops, yards, and agroforestry systems with the introduction of various technology and production inputs as well as not optimal shade management.
The choice of robusta clones in coffee plantation development is important to optimize production. This is because selecting the right clones according to the agroecosystem will optimize growth and avoid the attack of dominant pests, thereby reducing production costs. Molina et al. [5] stated that the average temperature of the growing environment was related to production (R2 = 0.71, p = 0.10). In addition, environmental temperature greatly determines the development of pests such as coffee borer [6].

The type of robusta coffee plantation agroecosystem determines the cultivation system. This is like determining the need for shade trees and the percentage of shade [7]. Shade management is important in the cultivation of robusta coffee. It was reported that shade with a coverage rate of 35% improved leaf structures such as mesophyll cell structure and palisade tissue for optimal photosynthesis [7].

Therefore, in the current climate change conditions, it is necessary to study the nature of the early growth of robusta clones on the influence of the growing environment. This study aims to determine the varieties and treatments that are suitable for local climatic conditions and climate parameters that determine the physiological process of the early growth of robusta coffee. This information will underlie the assembly of specific cultivation location technologies into applied technology for robusta coffee cultivation in North Maluku.

2. Methods
The research was conducted in September 2019 to November 2020 in the dry land of IP2TP Bacan South Halmahera, Assessment Institute for Agriculture Technology (AIAT) of North Maluku. The soil type is classified as Latosol. Materials in this study was clones of coffee consisting namely: BP42, BP409, BP936, BP93 and SA237, organic fertilizer and NPK phonska fertilizer with 15% of nitrogen, phosphate and potassium contents for N, P and K. The experimental design was a factorial Randomized Block Design (RBD) arranged in a 5x3 factorial with 3 replications. The first factor consists of the clones of coffee consisting of five clones, namely: BP42, BP409, BP936, BP93 and SA237. The second factor was the fertilizer dosage which consists of 3 levels, namely: (1) 100% chemical NPK (120kg ha⁻¹), (2) 50% chemical NPK + 50% organic and (3) 100% organic. Observation variables were leaf chlorophyll (a, b and total), leaf proline, plant height, number of branches of plant, length of the first branch and number of internodes in the first branch.

Data analysis was used analysis of variance, if the significant effect continued with Duncan's Multiple Range Test at p ≤ 0.05. Climatic data were also observed such as average temperature, average humidity, rainfall, and length of exposure. Observations were made during the growth of plant data taken at a weather station (BMKG) in Labuha Bacan. The correlation between the observed parameters and the climatic elements is tested for the correlation data on physiology and growth traits as well as the climate elements obtained.

3. Result and discussion
3.1. The Climate conditions
The highest average air humidity occurred in the 1rd after transplanting, October, reaching 84.0 %. The lowest humidity was in the 2nd after transplanting, namely 74%. Humidity during the study showed 67-90%. The daily average temperature is in the range of 24.4 to 28.2°C. Temperatures were lowest in the months of transplanting reaching 25°C. The temperature increased at 1-4 month after transplanting 26-27°C (Figure 1). The Sunlight expose of 3 months after transplanting had a very significant positive correlation with leaf chlorophyll a, b and total namely r = 0.659**, 0.612**, 0.56 ** respectively (Table 1). These data indicate that the sunlight expose play an active role for physiology [8].
At planting and 1 months after transplanting be categorized as a humid month because of rainfall of 97.7 and 142.2 mm/month. During the dry season, the coffee plants are 2 months old. The third month after planting indicates the humid month (91.8mm/month).

### 3.2. Physiology parameters

#### 3.2.1. Leaf chlorophyl content
The clones interacted with the fertilization of chlorophyll (a, b and total) significantly (p<0.01) and increased the leave chlorophyll content. The dose of chemical fertilization mixed with 50% organic was increased the chlorophyll a (P <0.01), chlorophyll b (P <0.01), total chlorophyll (P <0.01) respectively (Table 1). The effect of interaction of clone and fertilization on increasing leave chlorophyll content is in line with the report of Sakiroh and Ibrahim [9] that leaf chlorophyll is affected by clone differences. Astuti et
also stated that the chlorophyll content of robusta coffee leaves was determined by the clone and the growing environmental conditions were related to fertilization.

### Table 1. Effect of clones and fertilization on chlorophyll and proline of coffee leaves.

| Clones   | Fertilization                        | Chlorophyll a (mg g\(^{-1}\)) | Chlorophyll b (mg g\(^{-1}\)) | Total chlorophyll (mg g\(^{-1}\)) | Prolin (μ mol g\(^{-1}\)) |
|----------|-------------------------------------|-------------------------------|-------------------------------|-----------------------------------|-----------------------------|
| BP42     | 100% chimical NPK (120kg/ha)        | 0.370g                        | 0.388h                        | 0.758g                            | 6.99c                       |
| BP42     | 50% chemical+50% organic            | 0.384ef                       | 0.417fg                       | 0.801ef                           | 4.31de                      |
| BP42     | 100% organic                        | 0.400cd                       | 0.483c-e                      | 0.884cd                           | 2.19ef                      |
| BP409    | 100% chimical NPK (120kg/ha)        | 0.397c-e                      | 0.491cd                       | 0.888cd                           | 14.14b                      |
| BP409    | 50% chemical+50% organic            | 0.462a                        | 0.521ab                       | 0.984a                            | 5.51cd                      |
| BP409    | 100% organic                        | 0.401cd                       | 0.498cd                       | 0.899cd                           | 0.11f                       |
| BP936    | 100% chimical NPK (120kg/ha)        | 0.411c                        | 0.501b-d                      | 0.912c                            | 1.04f                       |
| BP936    | 50% chemical+50% organic            | 0.440b                        | 0.506a-c                      | 0.945b                            | 14.97b                      |
| BP936    | 100% organic                        | 0.398cd                       | 0.499cd                       | 0.897cd                           | 39.48a                      |
| BP93     | 100% chimical NPK (120kg/ha)        | 0.391d-f                      | 0.431f                        | 0.821e                            | 1.67f                       |
| BP93     | 50% chemical+50% organic            | 0.404cd                       | 0.466e                        | 0.870d                            | 0.42f                       |
| BP93     | 100% organic                        | 0.404cd                       | 0.482de                       | 0.886cd                           | 39.25a                      |
| SA237    | 100% chimical NPK (120kg/ha)        | 0.382fg                       | 0.406gh                       | 0.789f                            | 16.20b                      |
| SA237    | 50% chemical+50% organic            | 0.464a                        | 0.525a                        | 0.990a                            | 4.75cd                      |
| SA237    | 100% organic                        | 0.351h                        | 0.343i                        | 0.693h                            | 3.95de                      |

Remarks: Different letters in same column represents significant differences by Duncan’s Multiple Range Test at 5 % level.

#### 3.2.2 Leaf prolin content.

The clones interacted with the fertilization application significantly increased (p<0.01) the prolin of leaf. Different clones had different responses to fertilization to produce leaf proline (Table 1). The lowest leaf proline content was produced from 100% organic fertilization on clone BP409 and 50% organic in clone BP93. This value is significantly different from several other treatment combinations. Low proline content indicates that plants have not been indicated to experience a physiological response against drought stress. This finding is in line with Tesfaye et al. [11] that the proline of robusta coffee leaves increases in drought-stressed land condition. Leaf proline in coffee showed genotic tolerance of the clones to drought stress [12].

### 3.3. Growth parameters

On the growth parameters, the clone effect (P <0.05) determined the height of the plants 3 months after planting (Table 2). BP409 clones had the best growth for plant height, which was significantly different from BP42 and BP936 (Table 3). The difference in clones or plants determining plant growth was also conveyed by Gomes et al. [13].

#### Table 2. Two-way ANOVA of growth parameters.

| Source        | DF | Plant height 3 mat | Number of branches of plant 3mat | Length of the first branch | Number of internodes first branch |
|---------------|----|-------------------|----------------------------------|-----------------------------|-----------------------------------|
| Clones        | 0.036* | 0.489ns          | 0.257ns                          | 0.107ns                     |
| Fertilization | 0.561 | 0.984ns           | 0.855ns                          | 0.292ns                     |
| Interaction   | 0.734 | 0.913ns           | 0.730ns                          | 0.428ns                     |
| CV            | 22.5 | 20.82             | 25.0                             | 25.95                       |

mat = month after transplanting
* = significantly different based on Duncan’s multiple distance test at p < 0.05
ns = non significant different based on Duncan’s multiple range test at p < 0.05

Plant performance in the form of plant height indicates a better adaptive ability of plants. This was because other growth components showed no significant difference between clones such as the number of branches per plant, length of the first branch and number of internodes of the first branch (Table 2).
### Table 3: Effect of fertilization methods and clones on plant height.

| Treatment                   | Plant height 3 mat |
|-----------------------------|--------------------|
| **Fertilization**           |                    |
| 100% chemical NPK (120kg/ha)| 63.20a             |
| 50% chemical + 50% organic  | 60.53a             |
| 100% organic                | 66.20a             |
| **Clones**                  |                    |
| BP42                        | 55.22bc            |
| BP409                       | 70.88a             |
| BP936                       | 53.66c             |
| BP93                        | 69.44ab            |
| SA237                       | 67.33a-c           |

*Remarks: Different letters in same column represents significant differences by Duncan’s Multiple Range Test at 5% level. mat = month after transplanting

### Table 4: Correlation of physiology-growth and climate elements.

| Chlor a | Chlor b | Chlor tot | Prolin | Plant height | Number of branches of plant | Length of the first branch | Number of internodes in the first branch | Sunlight expose of 3 mat |
|---------|---------|-----------|--------|--------------|-----------------------------|---------------------------|------------------------------------------|-------------------------|
| (a)     | (b)     | (c)       | (d)    | (e)          | (f)                         | (g)                       | (h)                                      | (l)                     |
| a 1.00  | 0.831** | 0.928**   | -0.098 | 0.426*       | 0.295                       | 0.052                     | 0.223                                    | 0.659**                 |
| b -     | 1.00    | 0.97**    | 0.071  | 0.50*        | 0.098                       | -0.013                    | -0.026                                   | 0.612**                 |
| c -     | -       | 1.00      | 0.022  | 0.486*       | 0.175                       | -0.0006                   | 0.055                                    | 0.656**                 |
| d -     | -       | -         | 1.00   | 0.302        | -0.202                      | 0.136                     | -0.292                                   | -0.104                  |
| e -     | -       | -         | -      | 1.00         | -0.099                      | 0.229                     | -0.051                                   | 0.141                   |
| f -     | -       | -         | -      | -            | 1.00                        | 0.553**                   | 0.678**                                  | 0.131                   |
| g -     | -       | -         | -      | -            | -                           | 1.00                      | 0.595**                                  | 0.097                   |
| h -     | -       | -         | -      | -            | -                           | -                         | 1.00                                    | 0.047                   |
| l -     | -       | -         | -      | -            | -                           | -                         | -                                       | 1.00                    |

#### 3.4. Correlation of physiology and growth parameters with climatic elements

Leaf chlorophyll content (a, b and total) had a significant positive correlation with plant height (0.486). Meanwhile, leaf chlorophyll content (a, b and total) was significantly positively correlated with long exposure to the sun (0.656) (Table 4). This indicates that the chlorophyll content significantly determines the process of plant growth. Chlorophyll plays a role in determining the process of capturing light and gas for photosynthesis in order to produce photosynthate. The presence of leaf chlorophyll is significantly positively correlated with long exposure to sunlight. This can be understood because one of the main factors of chlorophyll function is determined by sunlight. Chlorophyll will capture sunlight for the photosynthesis process, so long exposure to the sun will stimulate leaf chlorophyll content. These results are in line with the research of Plato et al. [14] that the chlorophyll content of robusta coffee is influenced by the shade or radiation received by plants.

#### 4. Conclusion

The physiological properties of robusta coffee such as chlorophyll and leaf proline at the early growth were determined jointly by the clone and the growing environment (fertilization). The selection of the type of clone planted also determines the height of the coffee plant at initial growth. Planting robusta coffee clones BP409 and BP936 with 50% chemical and organic fertilization technology can be applied as agronomic technology to mitigate climate change. Plant height has a positive correlation with leaf
chlorophyll content. The climatic parameter that determines the physiological process of coffee plants was the length of sunlight.

References
[1] DaMatta F M, Rahn E, Läderach P, Ghini R, Ramalho J C 2019 Why could the coffee crop endure climate change and global warming to a greater extent than previously estimated? J Climatic Change 152 167–178
[2] Camargo M B P 2010 The impact of climatic variability and climate change on arabic coffee crop in Brazil Bragantia Campinas 69(1) 239-247
[3] Andrade H J & Zapata P C 2019 Mitigation of climate change of coffee production systems in Cundinamarca, Colombia Floresta e Ambiente 26(3) 1-11
[4] North Maluku Province in Figures 2019 BPS-Statistics of Maluku Utara Province (Maluku Utara: BPS of Maluku Utara Province) pp 450
[5] Molina A L V, Peralta V P P, Orozco A B P, Iglesias M I O and Guerrero E G 2018 Calibration of the aquacrop model in special coffee (Coffea arabica) crops in the sierra nevada of Santa Marta, Colombia J. Agron. 17 (4) 241-250
[6] Jaramillo J, Chabi-Olaye A, Kamonjo C, Jaramillo A, Vega F E, Poehling H M, Borgemeister C 2009 Thermal tolerance of the coffee berry borer hypothenemus hampei: predictions of climate change impact on a tropical insect pest. PLoS ONE, 4(8) 1-11
[7] Baliza D P, Cunha R L, Castro E M, Barbosa, Pires M F, Gomes R A 2012 Gas exchange and adaptive structural characteristics of coffee plants grown in different levels of radiation Coffee Science, Lavras 7(3) 250-258
[8] Zervoudakis G, Salahas G,Kaspiris G, Konstantopoulou E 2012 Influence of light intensity on growth and physiological characteristics of common sage (Salvia officinalis L.) Braz. Arch. Biol. Technol 55(1) 89-95
[9] Sakiroh and Ibrahim M S D 2020 Karakterisasi morfologi, anatomi, dan fisiologi tujuh klon unggul kopi robusta. Jurnal Tanaman Industri dan Penyegar 7(2) 73-82
[10] Astutiy T M, Rahayu E, Santosa T N B, Putra D P, Solifudin A, Wijayanti Y and Pittkow M 2021 Study of agronomic characteristics of robusta coffee at coffee plantations in Temanggung, Indonesia E3S Web of Conferences 226 00051
[11] Tesfaye S G,Ismail M R, Ramlan M F, Marziah M and Kausar H 2013 Effect of soil drying on rate of stress development, leaf gas exchange and proline accumulation in robusta coffee (Coffea Canephora Pierre Ex Froehner) Clones Expl Agric 50(3) 458–479
[12] Tamirat W 2019 Review on role of proline on coffee under drought conditions Journal of Environment and Earth Science 9(10): 1-6
[13] Gomes T, Pereira J A, Ramalhosa E R, Casa S and Baptista P 2013 Effect Of Fresh And Composted Spent Coffee Grounds on Lettuce Growth, Photosynthetic Pigments And Mineral Composition VII Congreso Ibérico de Agroingenieria y Ciencias Horticolas (Madrid: SECH e SEAgIng) Ref. Nº P0424
[14] Piato K, Lefort F, Subia C, Caicedo C, Calderón D, Pico J, Norgrove L 2020 Effects of shade trees on robusta coffee growth, yield and quality A meta-analysis Agronomy For Sustainable Development 40(38) 1-13