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16

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ORGANIZADA PELA ALIANÇA DOS PAISES PRODUTORES DE CACAU (COPAL) EM COLABORAÇÃO COM O GOVERNO DA INDONESIA

ORGANIZADA POR LA ALIANZA DE PAISES PRODUCTORES DE CACAO (COPAL) EN COLABORACIÓN CON EL GOBIERNO DE INDONESIA

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ANATOMICAL AND PHYSIOLOGICAL CHARACTERISTICS AS WELL AS YIELD OF SOME FINE FLAVOUR AND BULK COCOA CLONES IN INDONESIA

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SUMMARY

Growth and yield of cocoa are affected by some anatomical properties and physiological activities. Cocoa is a C3 plant that has a photosynthetic saturation at a certain light intensity. To know some anatomical and physiological characteristics that affect growth and yield of cocoa, two experiments have done at the Indonesian Coffee and Cocoa Research Institute. At the first experiment, fully expanded leaves of eight clones have been measured on their photosynthetic rate; stomata conductance, transpiration rate, and intercellular carbon dioxide concentration were measured using portable gas exchange system Li-6400 (LI-COR Inc., Lincoln, NE). Clones measured were grouped to two groups, i.e. fine flavour cocoa and bulk cocoa. The fine flavor cocoa clones were DR 1, DR 2, DR 38 and DRC 16; whereas the bulk one was ICCRI 03, KKM 22, KW 165 and TSH 858. Measurement was done at Kaliwining Experimental Station, Jember, Indonesia, at the altitude of 50 m above sea level. Measurement was stressed to describe the dynamic light response curve model and to correlate photosynthetic rate to other parameters. The results of that measurements showed that when photosynthetic active radiation (PAR) was increased; the photosynthetic rate, stomata conductance as well as transpiration rate were increased exponentially; but intercellular carbon dioxide concentration was decreased. The light saturation points of eight cocoa clones were took place in the surround of PAR 1000 $\mu mol.m^{-2}.s^{-1}$. There were positively correlation between the photosynthetic rate and stomata conductance, and between photosynthetic rate and transpiration rate. Conversely, there was a negatively correlation between photosynthetic rate and intercellular carbon dioxide concentration. The measurements also showed that the photosynthetic rate, stomatal conductance as well as respiration rate of bulk cocoa was higher than those of fine flavor cocoa. The second experiment was to know the relationship of chlorophyll, stomata and palisade towards the yield of cocoa clones. Fully expanded leaves of fourteen clones have been measured on their chlorophyll content, stomata density and palisade index. Leaves were taken from collection garden of the Indonesian Coffee and Cocoa Research Institute. Chlorophyll content was measured by using spectrophotometer, stomata density was observed by using light microscope, and palisade index was observed by using binocular microscope. The differences among parameters were tested by variance analysis and Duncan's Multiple Range Test. The relationship between yield and those observed parameters was done to illustrate a role of those parameters to yield. The results showed that there were significantly differences among parameters of cocoa clones tested. There were positive correlations between yield and chlorophyll content as well as stomata density.

Keyword: cocoa, clone, physiological characteristic, chlorophyll, stomata, palisade, yield.

CARACTERISTIQUES ANATOMIQUES ET PHYSIOLOGIQUES ET RENDEMENT CERTAINS CLONES DE CACAOYERS ORDINAIRES ET AROMATIQUES EN INDONESIE

RESUME

La croissance et le rendement du cacaoyer sont influencés par certaines propriétés anatomiques et certaines activités physiologiques. Le cacao est une plante de type C3, qui atteint un point de saturation photosynthétique à une certaine intensité lumineuse. Pour connaître certaines caractéristiques anatomiques et physiologiques qui affectent la croissance et le rendement du cacaoyer, deux expériences ont été menées à l'Indonesian Coffee and Cocoa Research Institute. Dans la première expérience, les feuilles entièrement déployées le huit clones ont fait l'objet de mesures du rendement photosynthétique, de la conductance stomatique, du coefficient de transpiration et de la concentration intercellulaire en dioxyde de carbone par un dispositif portatif d'étude de la photosynthèse LICOR Li-6800. Les clones mesurés ont été réunis en deux groupes, à savoir les cacaoyers aromatiques d'une part et les cacaoyers ordinaires d'autre part. Les clones de cacaoyers aromatiques étaient de type DR 1, DR2, DR 38 et DRC 16 ; et les clones de cacaoyer ordinaire étaient de type ICCRI 03, KKM 22, KW 165 et TSH 858. La mesure a été faite à la station expérimentale de Kaliwining, Jember, en Indonésie, à une altitude de 50 m. Les mesures ont été orientées de façon à décrire le modèle de courbe de réponse dynamique à la lumière et à faire la corrélation entre le rendement photosynthétique et d'autres paramètres. Les résultats de ces mesures ont montré que lorsque le rayonnement photosynthétique actif augmentait, le rendement photosynthétique, la conductance stomatique ainsi que le coefficient de transpiration augmentaient de façon exponentielle, mais que la concentration de dioxyde de carbone intercellulaire était diminuée. Les points de saturation à la lumière de huit clones de cacaoyers se sont situés aux alentours de 1000 $\mu mol.m^{-2}.s^{-2}$ de rayonnement photosynthétique actif. On a pu observer une corrélation positive entre le rendement photosynthétique et la conductance stomatique, et entre le rendement photosynthétique et le coefficient de transpiration. Inversement, on a pu observer une corrélation négative entre le rendement photosynthétique et la concentration en dioxyde de carbone intercellulaire. Les mesures ont également montré que le rendement photosynthétique, la conductance stomatique ainsi que la fréquence respiratoire du cacaoyer ordinaire étaient supérieurs à ceux du cacaoyer aromatique. La deuxième expérience visait à connaître la relation entre la chlorophylle, les stomates et la couche palissadique par rapport au rendement des clones de cacaoyers. Les feuilles entièrement déployées de quatorze clones ont été mesurées pour examiner leur teneur en chlorophylle, leur densité stomatale et leur indice de palissade. Les feuilles ont été prélevées dans le jardin botanique de la collection de l'Indonesian Coffee and Cocoa Research Institute. La teneur en chlorophylle a été mesurée à l'aide d'un spectrophotomètre, la densité stomatique à l'aide de microscope optique, et l'indice de palissade sous microscope binoculaire. La différence entre ces paramètres a été testée par analyse de variance et par un Multiple Range Test de Duncan. La relation entre le rendement et les paramètres observés a permis d'illustrer le rôle de ces paramètres sur le rendement. Les résultats ont montré qu'il existe des différences significatives entre les paramètres des clones de cacaoyers testés. Une corrélation positive a été constatée entre rendement et contenu chlorophyllien ainsi que densité stomatale.

Mots-clés: cacao, clone, caractéristique physiologique, chlorophylle, stomate, palissade, rendement.

CARACTERÍSTICAS ANATÓMICAS E FISIOLÓGICAS BEM COMO O RETORNO DE ALGUNS CLONES DE CACAU DE SABOR FINO E A GRANEL NA INDONÉSIA

RESUMO

O crescimento e retorno do cacau são afectados por algumas propriedades anatómicas e actividades fisiológicas. O cacau é uma planta C3 que tem uma saturação fotossintética a uma certa intensidade da luz. Para conhecer algumas características anatómicas e fisiológicas que afectam o crescimento e o retorno do cacau, foram realizados dois ensaios no Instituto Indonésio de Investigação do Cacau e do Café.

No primeiro ensaio, mediram-se folhas totalmente expandidas de oito clones quanto à sua taxa fotossintética, condutância estomatal, taxa de transpiração, e concentração intercelular de dióxido de carbono através de aparato de sistema portátil de fotossíntese LICOR Li-6800. Os clones medidos foram agrupados em dois grupos, i.e. cacau de sabor fino e cacau a granel. Os clones do cacau de sabor fino foram DR 1, DR 2, DR 38 e DRC 16; enquanto que os do a granel foram ICCRI 03, KKM 22, KW 165 e TSH 858. As medições foram feitas na Estação Experimental de Kaliwining, Jember, Indonésia, a uma altitude de 50 m acima do nível do mar. As medições alargadas para descrever o modelo de reacção da luz dinâmica de curva e para correlacionar a taxa fotossintética com outros parâmetros. Os resultados dessas medições mostraram que quando a radiação activa fotossintética (PAR) foi aumentada; a taxa fotossintética, a condutância estomatal bem como a taxa de transpiração subiram exponencialmente; mas a concentração intercelular de dióxido de carbono desceu. Os pontos de saturação da luz de oito clones do cacau deram-se em redor de PAR 1000 $\mu mol.m^{-2}.s^{-1}$. Existiu uma correlação positiva entre a taxa fotossintética e a condutância estomatal, e entre a taxa fotossintética e a taxa de transpiração. Pelo contrário, existiu uma correlação negativa entre a taxa fotossintética e a concentração intercelular de dióxido de carbono. As medições também mostraram que a taxa fotossintética, a condutância estomatal bem como a taxa de respiração de cacau a granel eram mais altas do que as de cacau de sabor fino. O segundo ensaio realizou-se para conhecer o relacionamento entre fotossíntese da clorofila, a estomata e a palissada em relação ao retorno dos clones do cacau. Folhas totalmente abertas de catorze clones foram medidas quanto ao seu teor de clorofila, densidade estomatal e índice de palissada. Tiraram-se folhas do jardim de colecções do Instituto Indonésio de Investigação do Cacau e do Café. O teor de clorofila foi medido usando um espectrofotómetro, observou-se a densidade estomatal usando um microscópio de luz, e o índice de palissada foi observado usando um microscópio binocular. A diferença entre os parâmetros foi testada através de análise de variâncias e do Teste Múltiplo de Médias de Duncan (Duncan's Multiple Range Test). A relação entre retorno e os parâmetros observados foi feita para ilustrar o papel desses parâmetros para o retorno. Os resultados demonstraram que existiam diferenças significativas entre os parâmetros dos clones do cacau testados. Existiu uma correlação positiva entre o retorno e o teor de clorofila bem como da densidade estomatal.

Palavras-chave: cacau, clone, característica fisiológica, clorofila, estomata, palissada, retorno.

CARACTERÍSTICAS ANATÓMICAS Y FISIOLÓGICAS, Y RENDIMIENTO DE ALGUNOS CLONES DE CACAO FINO AROMÁTICO Y DE CACAO BÁSICO DE INDONESIA

RESUMEN

Algunas propiedades anatómicas y actividades fisiológicas afectan el crecimiento y el rendimiento del cacao. El cacao es una planta C3 que experimenta una saturación fotosintética a cierta intensidad de la luz. A fin de conocer algunas características anatómicas y fisiológicas que afectan el crecimiento y el rendimiento del cacao, se han llevado a cabo dos experimentos en el Instituto Indonesio de Investigaciones del Café y del Cacao. En el primer experimento se midieron las hojas completamente abiertas de ocho clones, con un equipo portátil de medición de fotosíntesis, LICOR Li-6800, para determinar la tasa de fotosíntesis, la conductancia estomática, la tasa de transpiración, y la concentración intercelular de dióxido de carbono de las mismas. Los clones estudiados fueron clasificados en dos grupos, a saber: cacao fino aromático y cacao básico. Los clones de cacao fino aromático estudiados fueron DR 1, DR 2, DR 38 y DRC 16; mientras que los de cacao básicos fueron ICCRI 03, KKM 22, KW 165 y TSH 858. Las mediciones fueron realizadas en la Estación Experimental de Kaliwining, Jember, Indonesia, a una altitud de 50 m sobre el nivel del mar. Se hizo énfasis en las mediciones con el fin describir el modelo dinámico de la curva de respuesta a la luz, así como para establecer una correlación entre la tasa de fotosíntesis y otros parámetros. Los resultados de dichas mediciones demostraron que, cuando aumentaba la radiación fotosintéticamente activa (PAR), la tasa de fotosíntesis, la conductancia estomática y la tasa de transpiración aumentaban exponencialmente, pero la concentración intercelular de dióxido de carbono disminuía. Los puntos de saturación de luz de ocho clones de cacao se produjeron cuando la PAR llegó a alrededor de los 1000 $\mu mol.m^{-2}.s^{-1}$. Se observó una correlación positiva entre la tasa de fotosíntesis y la conductancia estomática, y entre la tasa de fotosíntesis y la tasa de transpiración. En cambio, se observó una correlación negativa entre la tasa de fotosíntesis y la concentración intercelular de dióxido de carbono. Las mediciones también demostraron que la tasa de fotosíntesis, la conductancia estomática y la tasa de respiración del cacao básico eran superiores a las del cacao fino aromático. El objetivo del segundo experimento era conocer la relación entre la clorofila, los estomas y la empalizada, y el rendimiento de los clones de cacao. Se midieron las hojas completamente abiertas de catorce clones, para establecer su contenido de clorofila, densidad estomática e índice de empalizada. Las hojas fueron tomadas de la colección del vivero del Instituto Indonesio de Investigaciones del Café y del Cacao. El contenido de clorofila se midió usando un espectrofotómetro, la densidad estomática mediante un microscopio óptico, y el índice de empalizada por medio de un microscopio binocular. La diferencia entre los parámetros se contrastó por análisis de varianza y el test de rangos múltiples de Duncan. La relación entre el rendimiento y los parámetros analizados se estableció para ilustrar el papel de dichos parámetros con respecto al rendimiento. Los resultados demostraron que había diferencias significativas entre los parámetros de los clones de cacao analizados. Se observó una correlación positiva entre el rendimiento y el contenido de clorofila, así como la densidad estomática.

Palabras clave: cacao, clon, características fisiológicas, clorofila, estomas, empalizada, rendimiento.

INTRODUCTION

Cocoa is one of estate commodities that have a high economic value and as an important income source for Indonesia. Many of smallholders' cocoa plantations in Indonesia are bulk cocoa, but there a little part of government plantation is fine flavour cocoa. Clones of bulk cocoa are grouped in Forastero, whereas the fine flavour one is Trinitario or Criollo; those are relatively different in their anatomical and physiological characteristic. Their difference in those characteristic might cause a different yield.

Cocoa is a C3 photosynthetic pathway crop, it means that for optimum growth need only 70% of sunlight and their saturated photosynthesis active radiation (PAR) is around 1000 $\mu mol.m^{-2}.s^{-1}$. Usually PAR of Criollo and Trinitario were lower than that of Forastero.

To explore anatomical and physiological characteristics and then to relate to their yield, two series of experiment were conducted at Kaliwining Experimental Station, Indonesian Coffee and Cocoa Research Institute (ICCRI). The specific objective of the first experiment were (1) to describe a dynamic model for photosynthesis rate (P), stomata conductance (gs), transpiration rate (E) and intercellular CO_2 concentration (Ci) among varies cocoa clones in varying light intensity, (2) to investigate the relationships between photosynthesis rate (P) and other physiological parameters such as E, gs, and Ci. The second experiment was to know the relationship of chlorophyll, stomata and palisade towards the yield of cocoa clones. Results of those experiments were presented below.

MATERIALS AND METHODS

Two series experiments conducted at the Indonesian Coffee and Cocoa Research Institute. At the first experiment, fully expanded leaves of eight clones have been measured on their photosynthetic rate, stomata conductance, transpiration rate, and intercellular carbon dioxide concentration were measured using portable gas exchange system Li-6400 (LI-COR Inc., Lincoln, NE).. Clones measured were grouped to two groups, i.e fine flavor cocoa and bulk cocoa. The fine flavor cocoa clones were DR 1, DR 2, DR 38 and DRC 16; whereas the bulk one was ICCRI 03, KKM 22, KW 165 and TSH 858.

In second experiment, fully expanded leaves of fourteen clones have been measured on their chlorophyll content, stomata density and palisade index. Clones were Sca 12, DRC 15, DR 1, DR 38, KW 165, ICS 60, DRC 16, TSH 858, Sca 6, DR 2, KKM 22, ICCRI 04, ICCRI 03, and KW 162. Leaves were taken from collection garden of the Indonesian Coffee and Cocoa Research Institute. Chlorophyll content was measured by using spectrophotometer, stomata density was observed by using light microscope, and palisade index was observed by using binocular microscope. The data collected analyzed with variance analysis. The difference among parameters was tested by Duncan's Multiple Range Test at the 0.05 probability level. Using *DSAASTAT ((Dipartimento di Scienze Agrarie en Ambientali (DSAA) Statistic ver.1.0192))* excel program. The relationship between yield and those observed parameters was done to illustrate a role of those parameters to yield.

RESULTS

There was an exponential relationship between photosynthetic active radiation *(PAR)* and photosynthetic rate (*P*), stomata conductance, transpiration rate, and carbon dioxide intercellular of cocoa clones.

Table 1: The relationship between photosynthetic active radiation (PAR) and photosynthetic rate (*P*) of cocoa clones

Cocoa clones	Equations
Fine flavour	
DR 1	$P = 5(1\text{-exp}(-0.001 \times PAR/5))$; $R^2 = 0.67$
DR 2	$P = 5(1\text{-exp}(-0.15 \times PAR/5))$; $R^2 = 0.826$
DR 38	$P = 6.4(1\text{-exp}(-0.0169 \times PAR/6.4))$; $R^2 = 0.980$
DRC 16	$P = 7.8(1\text{-exp}(-0.03 \times PAR/7.8))$; $R^2 = 0.875$
Bulk	
ICCRI 03	$P = 8.4(1\text{-exp}(-0.02 \times PAR/8.4))$; $R^2 = 0.915$
KKM 22	$P = 8.2(1\text{-exp}(-0.03 \times PAR/8.2))$; $R^2 = 0.960$
KW 165	$P = 8.1(1\text{-exp}(-0.0289 \times PAR/8.1))$; $R^2 = 0.982$
TSH 858	$P = 9(1\text{-exp}(-0.0263 \times PAR/9))$; $R^2 = 0.963$

For example, the positive exponential relationship between PAR and photosynthetic rate of DR 1 clone is presented as Figure 1.

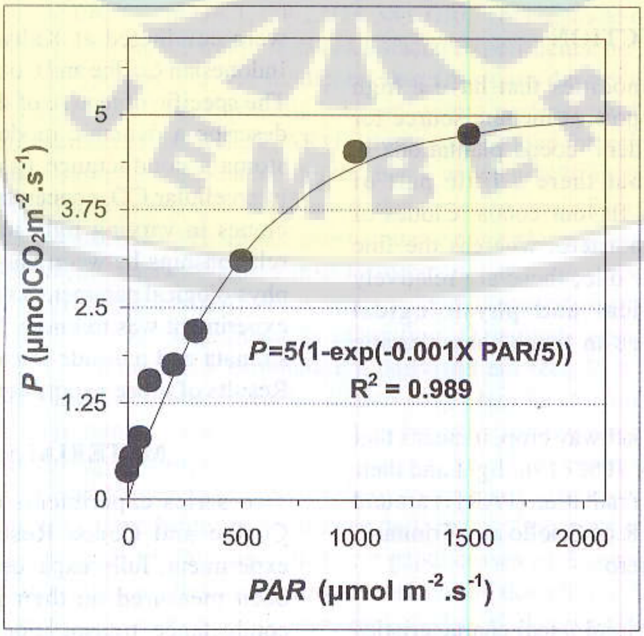

Figure 1: Graph of relationship between PAR and photosynthetic rate (P) of DR 1 clone.

Table 2: The relationship between photosynthetic active radiation (PAR) and stomata conductance (*gs*) of cocoa clones

Cocoa clones	Equations
Fine flavour	
DR 1	gs = 0,09(1-0.4 exp(-0,0002 X PAR/0.09)); R^2 = 0.91
DR 2	gs = 0.13(1-0.87 exp0.0002 X PAR/0.13)); R^2 = 0.889
DR 38	gs = 0.086(1-0.41exp0.0002 X PAR/0.086)); R^2 = 0.911
DRC 16	*gs* = 0.15(1-0.4 exp(-00001 X PAR/0.15)); R^2 = 0.912
Bulk	
ICCRI 03	gs = 0.13(1-0.48 exp(-0,0002 X PAR/0.13)); R^2= 0,824
KKM 22	gs = 0.15(1-0.37exp0,0002 X PAR/0.15)); R^2= 0.659
KW 165	gs = 0.085(1-0.32exp0.0004 X PAR/0.085)); R^2= 0.902
TSH 858	gs = 0.145(1-0.37exp0.0002 X PAR/0.145)); R^2 = 0.875

The positive exponential relationship between PAR and stomata conductance (*gs*) of DR 1 clone is presented as Figure 2.

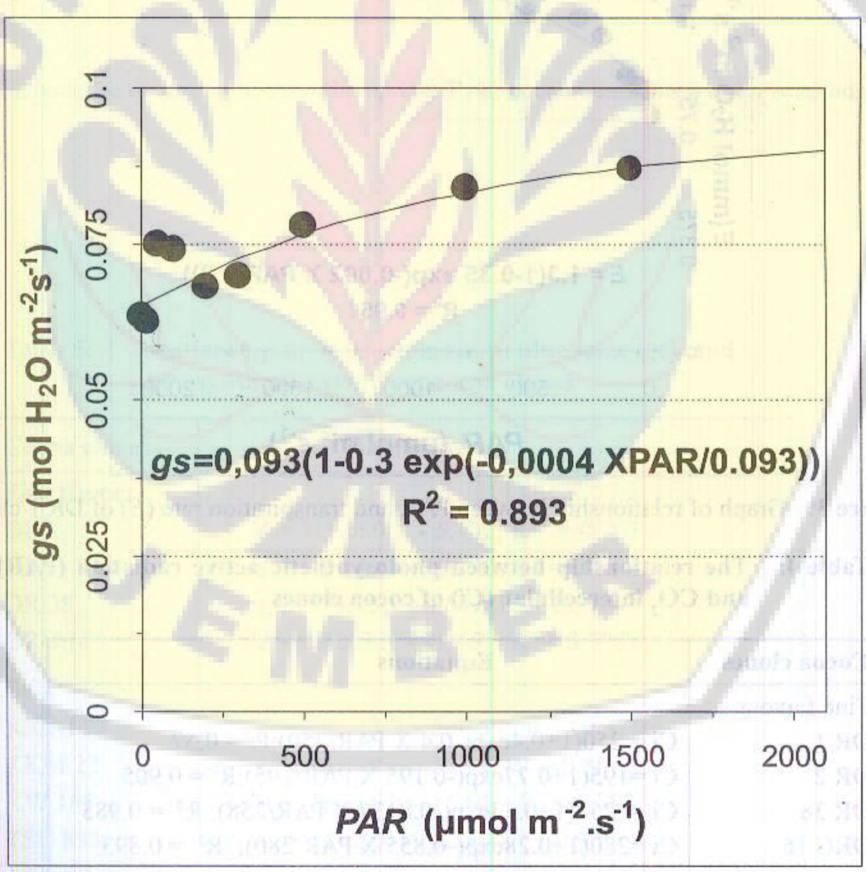

Figure 2: Graph of relationship between PAR and stomata conductance (*gs*) of DR 1 clone.

Table 3: The relationship between photosynthetic active radiation (PAR) and transpiration rate (*E*) of cocoa clones

Cocoa clones	Equations
Fine flavour	
DR 1	$E = 1.3(1\text{-}0.35\exp(-0,002 \text{ X PAR}/1.3))$; $R^2 = 0.93$
DR 2	$E = 2.6(1\text{-}0.82\exp(-0.0036 \text{ X PAR}/2.6))$; $R^2 = 0.91$
DR 38	$E = 1.9(1\text{-}0.82\exp(-0.0041 \text{ X PAR}/1.9))$; $R^2 = 0.976$
DRC 16	$E = 2.85(1\text{-}0.4\exp(-0.0063 \text{ X PAR}/2.85))$; $R^2 = 0.791$
Bulk	
ICCRI 03	$E = 2.9(1\text{-}0.51\exp(-0.0053 \text{ X PAR}/2.9))$; $R^2 = 0.919$
KKM 22	$E = 4.3(1\text{-}0.8\exp(-0,0108 \text{ X PAR}/4.3))$; $R^2 = 0.896$
KW 165	$E = 2.05(1\text{-}0.5\exp(-0.0042 \text{ X PAR}/2.05))$; $R^2 = 0.763$
TSH 858	$E = 2.6(1\text{-}0.6\exp(-0.0067 \text{ X PAR}/2.6))$; $R^2 = 0.858$

The positive exponential relationship between PAR and transpiration rate (*E*) of DR 1 clone is presented as Figure 3.

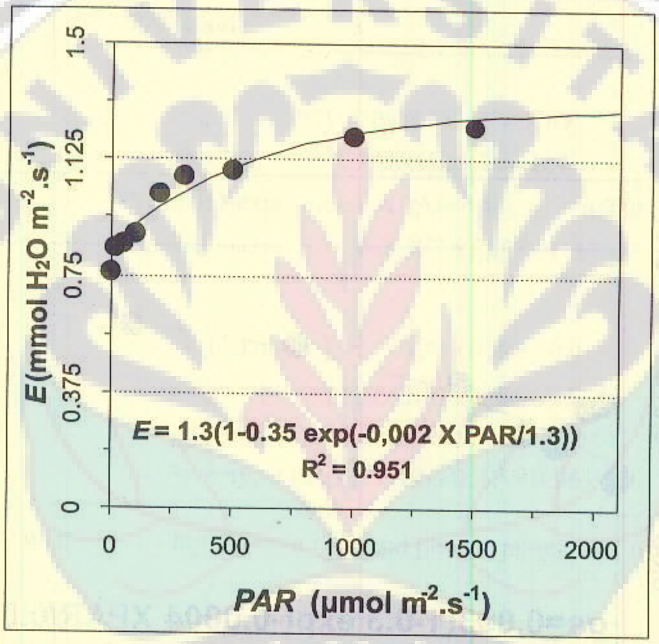

Figure 3: Graph of relationship between PAR and transpiration rate (*E*) of DR 1 clone.

Table 4: The relationship between photosynthetic active radiation (PAR) and CO_2 intercellular (*Ci*) of cocoa clones

Cocoa clones	Equations
Fine flavour	
DR 1	$Ci = 250(1+0.4\exp(-0.4 \text{ X PAR}/250)$;$R^2 = 0.57$
DR 2	$Ci = 195(1+0.77\exp(-0.195 \text{ X PAR}/195)$;$R^2 = 0.905$
DR 38	$Ci = 258(1+0.53\exp(-0.8137 \text{ X PAR}/258)$; $R^2 = 0.983$
DRC 16	$Ci = 280(1+0.28\exp(-0.855 \text{ X PAR}/280)$; $R^2 = 0.893$
Bulk	
ICCRI 03	$Ci = 263(1+0.27\exp(-0.729 \text{ X PAR}/263)$; $R^2 = 0.816$
KKM 22	$Ci = 265(1+0.27\exp(-0.677 \text{ X PAR}/265))$; $R^2 = 0.659$
KW 165	$Ci = 200(1+0.4\exp(-0.5 \text{ X PAR}/200))$; $R^2 = 0.564$
TSH 858	$Ci = 267(1+0.35\exp(-0.695 \text{ X PAR}/267))$; $R^2 = 0.612$

Difference with three graphs above, the relationship between PAR and CO_2 intercellular (*Ci*) of DR 1 clone is negatively exponential as presented in Figure 4.

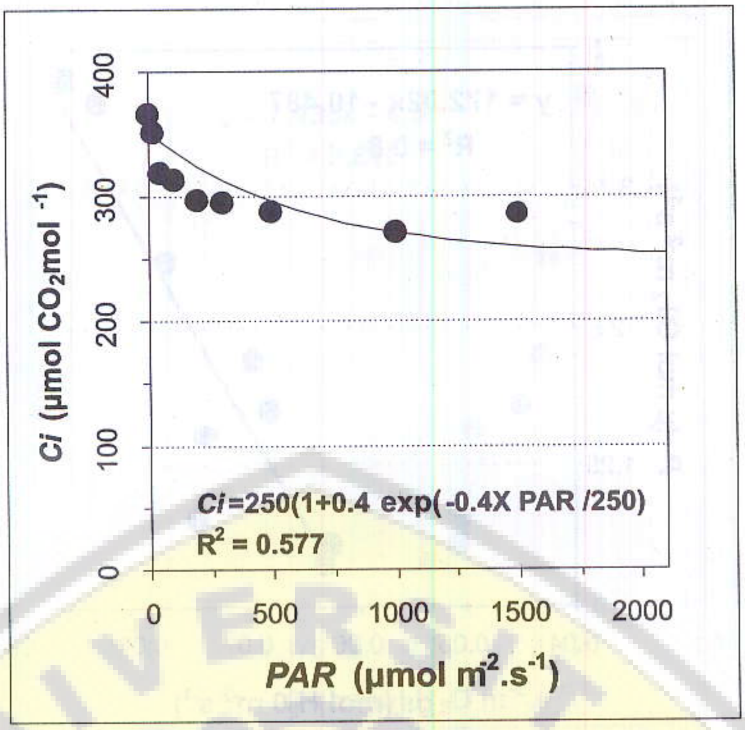

Figure 4: Graph of relationship between PAR and CO_2 intercellular (*Ci*) of DR 1 clone.

Between stomata conductance (gs) and photosynthetic rate (P) of cocoa there was a linier relationship (Table 5).

Table 5: Relationship between stomata conductance (*gs*) and photosynthetic rate (*P*) of cocoa clones

Cocoa clones	Equations
Fine flavour	
DR 1	Y = 115.560 X - 5.432; R^2 = 0.767
DR 2	Y = 33.142 X + 0.920; R2 = 0.984
DR 38	Y = 175.15X - 8.647; R^2 = 0.970
DRC 16	Y = 150.13 X - 11.651; R^2 = 0.706
Bulk	
ICCRI 03	Y = 108.23 X - 5.6359; R^2 = 0.8256
KKM 22	Y = 168.09 X - 14.44; R^2 = 0.86
KW 165	Y = 286.15 X - 15.646; R^2 = 0.783
TSH 858	Y = 181.5 X - 15.75; R^2 = 0.945

Between stomata conductance and photosynthetic rate there is a positive linier relationship, as presented in Figure 5 for DR 1 clone.

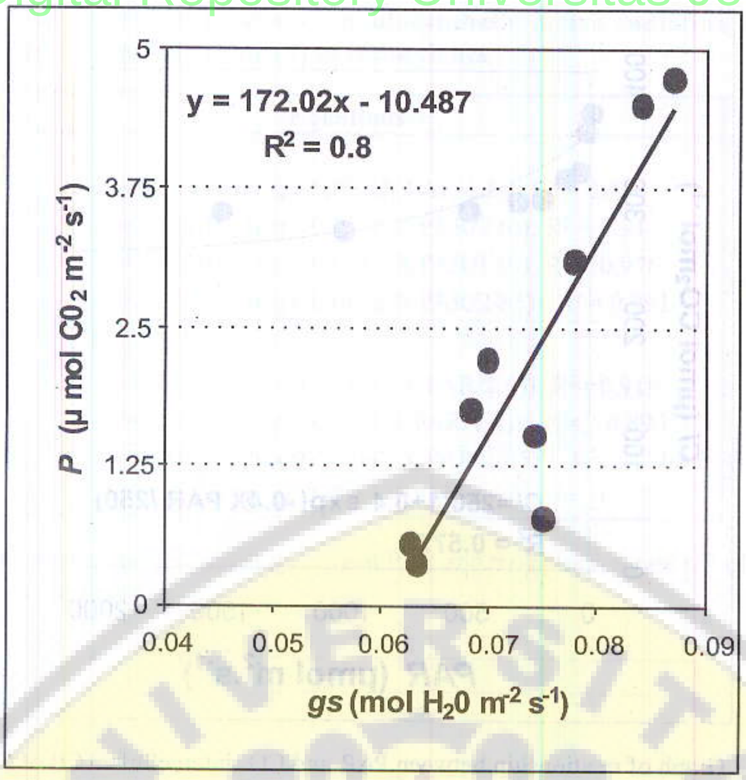

Figure 5: Graph of relationship between stomata conductance (gs) and photosynthetic rate (P) of DR 1clone.

There was a linier relationship of transpiration rate (*E*) and photosynthetic rate (*P*).

Table 6: Relationship between transpiration rate (*E*) and photosynthetic rate (*P*) of cocoa clones

Cocoa clones	Equations
Fine flavour	
DR 1	Y = 7.435 X - 4.50; R^2 = 0.815
DR 2	Y = 2.201 X - 0.004; R^2 = 0.786
DR 38	Y = 4.510 X - 1.776; R^2 = 0.969
DRC 16	Y = 6.484 X - 9.897 ; R^2 = 0.923
Bulk	
ICCRI 03	Y = 4.773 X - 5.989; R^2 = 0.891
KKM 22	Y = 1.895 X - 0.7355; R^2 = 0.46
KW 165	Y = 8.257 X - 7.065; R^2 = 0.768
TSH 858	Y = 7.171 X - 8.141; R^2 = 0.926

There was a positive linier relationship of transpiration rate (*E*) and photosynthetic rate (*P*) of DR 1 clone.

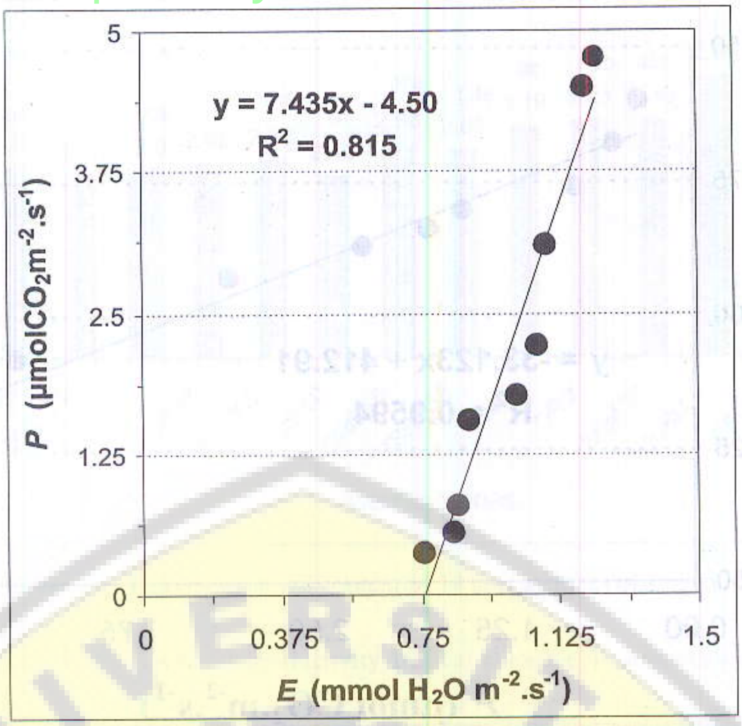

Figure 6: Graph of relationship between transpiration rates (*E*) and photosynthetic rate (*P*) of DR 1 clone.

The relationship between CO_2 intercellular (*Ci*) and photosynthetic rate (*P*) was linier (Table 7).

Table 7: Relationship between photosynthetic rate (*P*) and CO_2 intercellular (*Ci*) of cocoa clones.

Cocoa clones	Equations
Fine flavour	
DR 1	Y = - 33.123 X + 419.12 ; R^2 = 0.959
DR 2	Y = - 30.624X + 390.57; R^2 = 0.825
DR 38	Y = - 20.920X + 390.57; R^2 = 0.910
DRC 16	Y = -12.13X + 373.77; R^2 = 0.942
Bulk	
ICCRI 03	Y = - 8.595 X + 334.74; R^2= 0.793
KKM 22	Y = - 11.929X + 357.65; R^2= 0.896
KW 165	Y = - 16.45 X + 326.71; R^2= 0.787
TSH 858	Y = - 9.673 X + 355.78; R^2= 0.937

There was a negative linier relationship of photosynthetic rate (*P*) and CO_2 intercellular (*Ci*) of DR 1 clone.

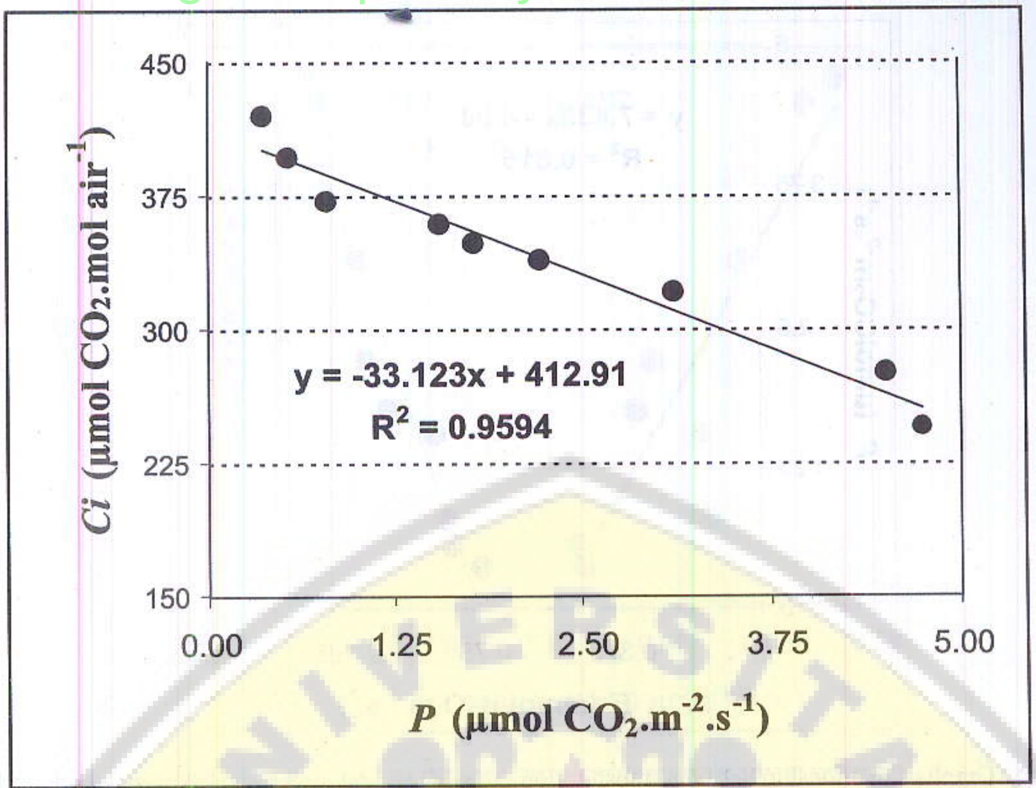

Figure 7: Graph of relationship between photosynthetic rate (*P*) and CO_2 intercellular (*Ci*) of DR 1 clone.

Data of second experiment showed that productivity of Sca 12 clone was the lowest, whereas KW 162 was the highest among fourteen clones observed.

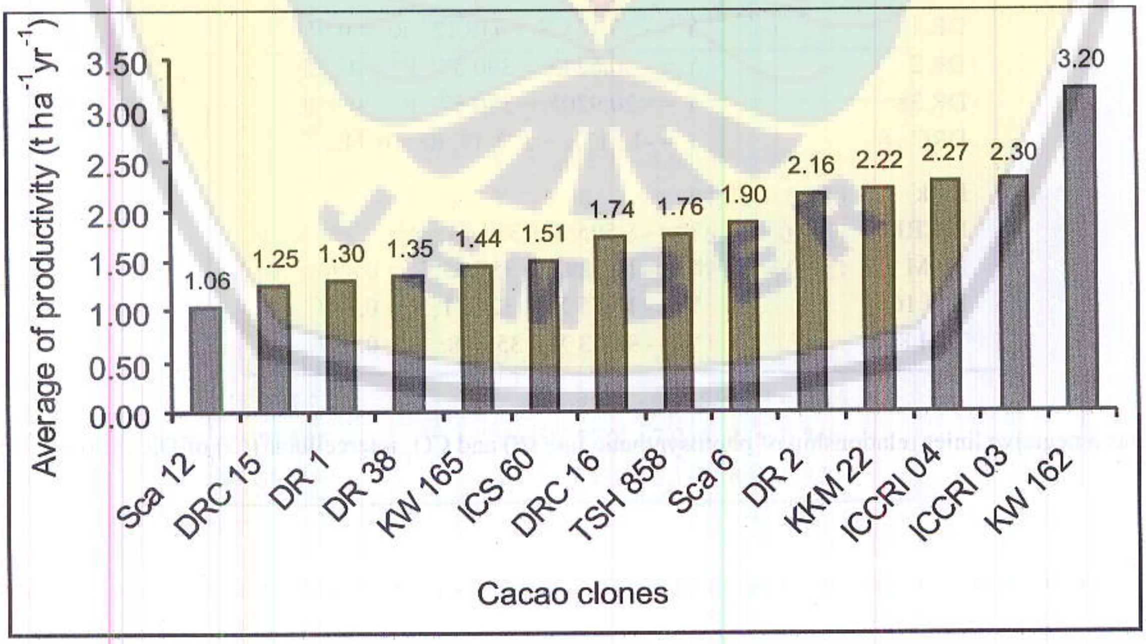

Figure 8: Average productivity of 14 cocoa clones observed.

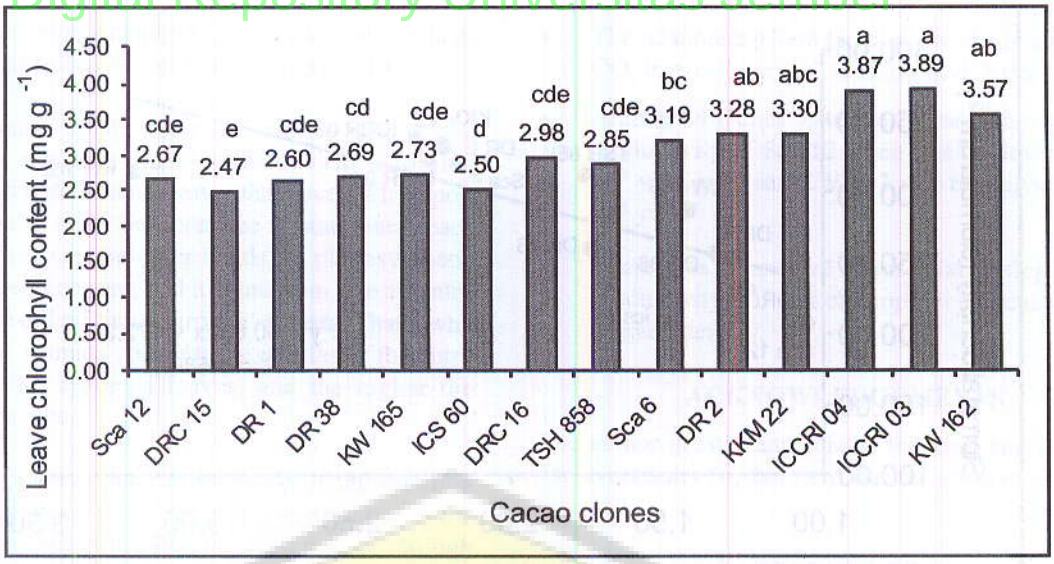

Figure 9: Leaf chlorophyll content of 14 cocoa clones observed.

There was a positive linier relationship between productivity and leaf chlorophyll content among cocoa clones tested.

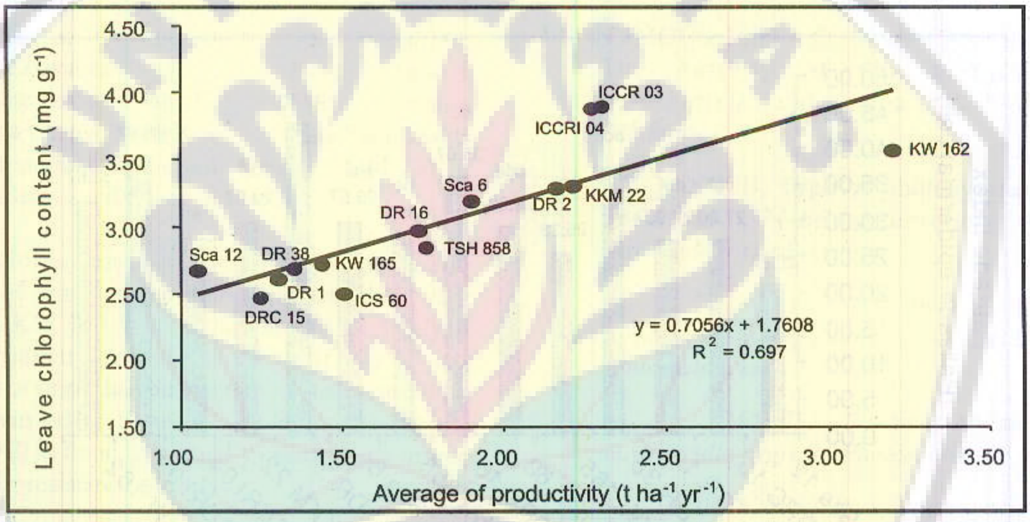

Figure 10: The graph of relationship between productivity and chlorophyll content of 14 cocoa clones observed.

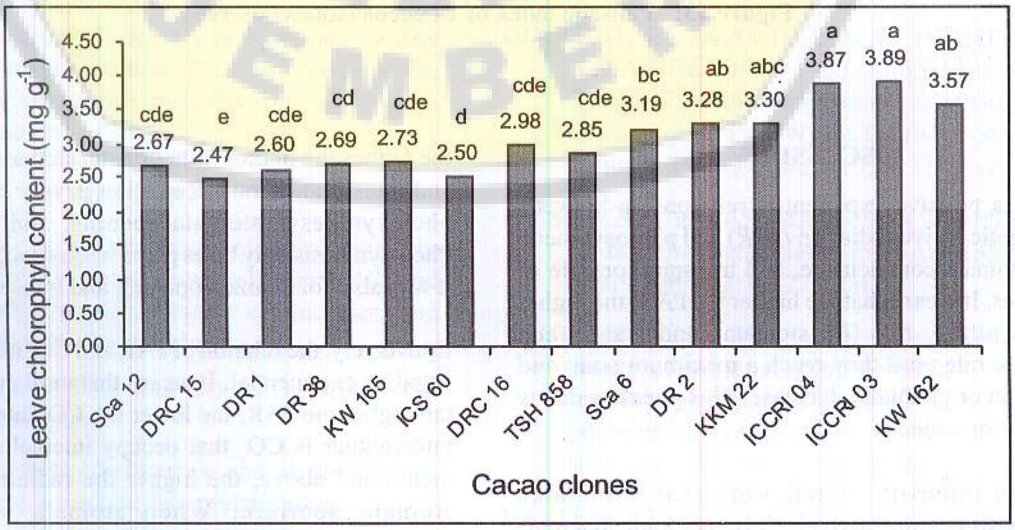

Figure 11: Stomata density of 14 cocoa clones observed.

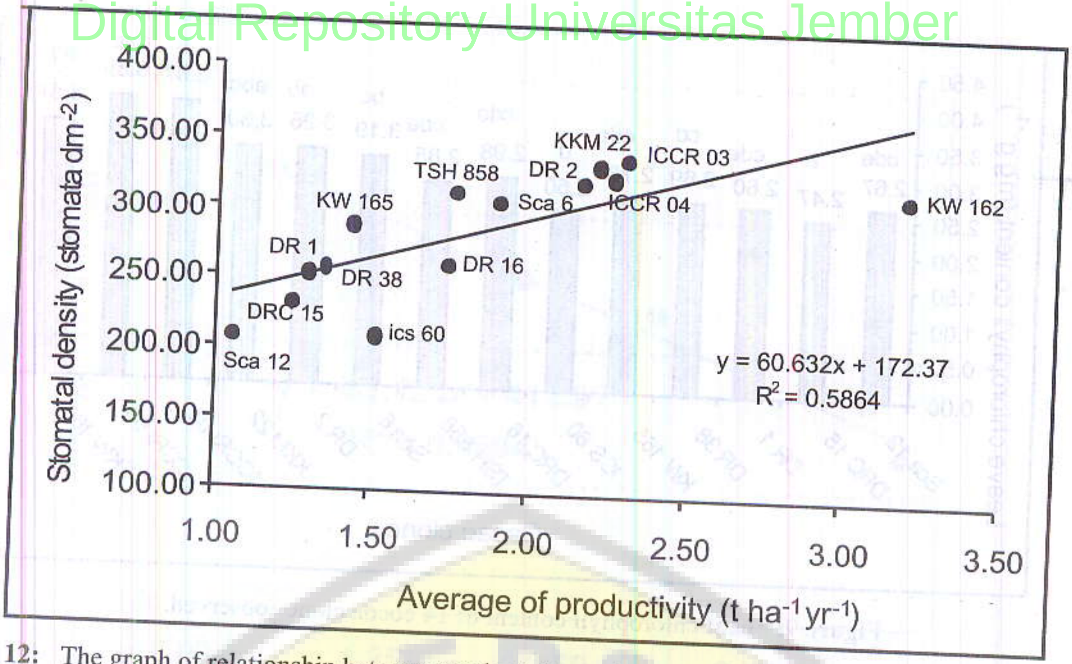

Figure 12: The graph of relationship between productivity and stomata density of 14 cocoa clones observed.

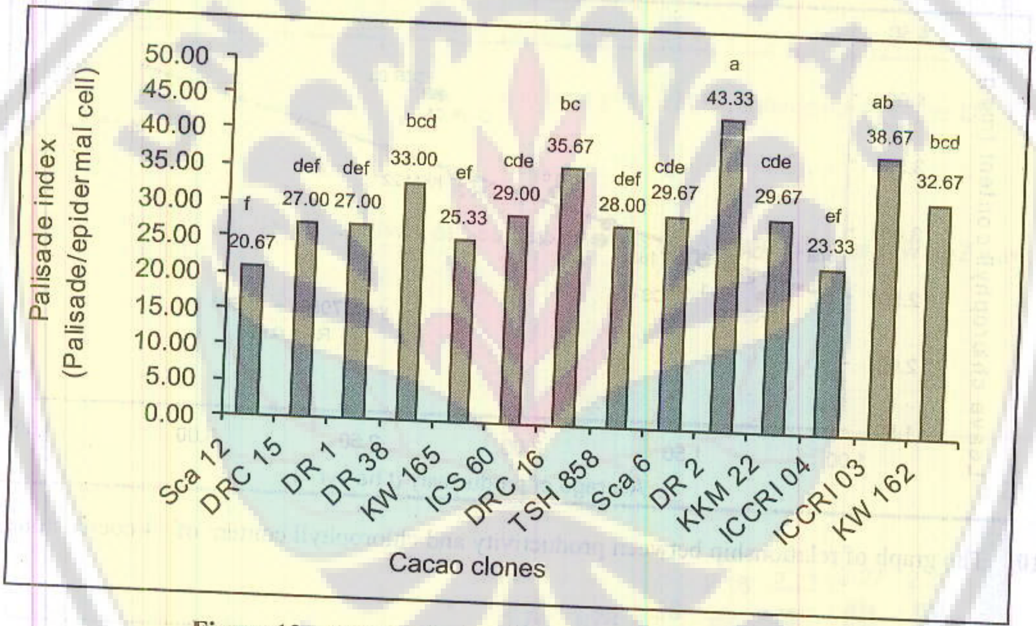

Figure 13: Palisade index of 14 cocoa clones observed.

DISCUSSION

There was a positive exponential relationship between photosynthetic active radiation *(PAR)* and photosynthetic rate (*P*), stomata conductance, and transpiration rate of cocoa clones. It means that the higher the PAR, the higher the photosynthetic rate (*P*), stomata conductance, and transpiration rate until they reach a maximum point and then constant or gradually decrease. This phenomenon is usual for living objects.

PAR is the intensity of radiation that stimulates photosynthesis reaction actively. It is very logic that until an optimum level, the higher the intensity of radiation, the higher the photosynthetic rate, stomata conductance, and transpiration rate. Radiation is very close related to photosynthesis, stomata opening, and transpiration. Photosynthesis only takes place when sunlight is presence; it was also for stomata opening and transpiration.

Conversely, the relation of PAR and CO_2 intercellular was negative exponential. It means that until minimum point, the higher the PAR, the lower the CO_2 intercellular. CO_2 intercellular is CO_2 that occupy intercellular space. As mentioned above, the higher the radiation, the wider stomata aperture. When stomata open widely, translocation of air between intercellular space and open air is very easy. At that condition, all gases in intercellular space of leaves will flow out freely, including CO_2.

Between stomata conductance and photosynthetic rate there was a positive linier relationship. Stomata conductance is a character of leaves that govern a transport of gas and water vapor between free air and inner space in leaves tissue. On the other hands, in photosynthetic process, CO_2 was needed, and it come from free air entry to inner space of leaf tissue through stomata. That's why the higher the stomata conductance, the faster the entry of CO_2 to inner space of leaves, and the higher the photosynthetic rate.

There was a positive linier relationship of transpiration rate (E) and photosynthetic rate (P). Transpiration is the loss of water vapor from plant tissue to free air through stomata. It caused an up-flow of water from soil solution enter roots and then transported to leaves. In leaves, water and CO_2 are the main materials in photosynthetic process. So, the more water in leaves that govern by transpiration rate, the higher the rate of photosynthesis.

The relationship between photosynthetic rate (P) and CO_2 intercellular (Ci) was negative linier. As mentioned above that CO_2 is the main raw material for photosynthetic process. When photosynthesis runs intensively, it needs CO_2 in much amount. It is causing the stock of CO_2 in pore space of leaves will be decreased.

Among 14 clones tested in the second experiment, productivity of Sca 12 clone was the lowest (1.08 t/ha/yr), whereas KW 162 was the highest (3.20 t/ha/yr). Although productivity and bean size of Sca 12 are relatively low or small than other clones, it has many better properties than other clones, i.e. tolerant to disease, drought, as well as flood. It is usually used as gene source in breeding for resistance activity.

There was a positive linier relationship between productivity and leaf chlorophyll content as well as stomata density among cocoa clones tested. It is very logic that chlorophyll content and stomata density affect the productivity. Chlorophyll content and stomata density govern photosynthetic reaction. The more intensive the photosynthetic reaction, logically the higher the productivity of plants.

CONCLUSIONS

- There was a positive exponential relationship between photosynthetic active radiation *(PAR)* and photosynthetic rate (P), stomata conductance, and transpiration rate of cocoa clones.
- The relation of PAR and CO_2 intercellular was negative exponential.
- Between stomata conductance and photosynthetic rate there was a positive linier relationship.
- There was a positive linier relationship of transpiration rate (E) and photosynthetic rate (P).
- The relationship between photosynthetic rate (P) and CO_2 intercellular (Ci) was negative linier.
- Among 14 clones tested in the second experiment, productivity of Sca 12 clone was the lowest (1.08 t ha^{-1} yr^{-1}), whereas KW 162 was the highest (3.20 t ha^{-1} yr^{-1}).
- There was a positive linier relationship between productivity and leaf chlorophyll content as well as stomata density.

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