The comparison of cocoa growth in different vegetation compositions

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Abstract. In general, the composition of cacao cropping in Indonesia is monoculture and polyculture. The different vegetation of shade trees in cacao cropping caused differences in the growth and productivity. This study was aimed to analyze the Leaf Mass Area (LMA), stem diameter, and the number of cocoa shade science leaves during rainy and dry seasons. This study was conducted more than 10 months to cacao cropping’s with many types of shade trees (polyculture), single shade tree (monoculture) and without shade tree. The result showed that the difference of vegetation composition of shade plants affected cocoa growth and productivity. Leaf mass area (LMA), ratio green and senescent leaves, flower and pods of cocoa on polyculture especially in cocoa with many types of trees were lower than polyculture patterns. Surprisingly, the polyculture cropping pattern with cocoa planting with many types of trees has almost no leaves of senescence in the early dry season. It shows a better adaptation to drought when planted with other tree species.

1. Introduction
Cocoa plays an important role for some farmers in Indonesia. Since 2008, in some areas of Central Java, Indonesia, there have been many farmers who began to plant their gardens with cocoa. This is because the results can be directly sold and the harvest can be rotated. Farmers generally combine it with some plants that have economic and ecological functions. The positive role of protective trees in cocoa cultivation is to reduce the adverse effects of environmental factors, such as wind damage, over-evapotranspiration and nutrient deficiencies [1], this may lead to microclimate stability supporting the sustainable cocoa production [2,3,4]. Nevertheless, some areas use single or monoculture cultivation systems are linked to increasing production [5,6].

Some factors, such as air temperature, RH, and precipitation are correlated and affect the microclimate conditions within the cocoa plantation [7] and the vegetation structure. If cocoa is cultivated in monoculture, it will be different microclimate situation, so it will affect the growth and productivity. Growth is an interaction generated by all processes in plants, such as photosynthesis, respiration, transportation, water relations and nutritional balance. Growth includes the addition of dry mass, volume, length or area of cells [8]. Crops grown under high trees receive more Photosynthetically Active Radiation (PAR) in the morning and afternoon because cocoa is very sensitive to the light availability, therefore a limited PAR during the day can affect its flowering [9]. In addition, shade trees can reduce cacao stress during evaporation and high light intensity.
Generally, farmers usually reduce the number of protective trees as the age of cocoa crops is supposed to increase production. In some areas cocoa garden are also found without protective trees. So far, there is not much information about the growth and productivity of cacao planted with other composition of trees. Therefore, this study seeks to observe growth, especially the Leaf Mass Area (LMA), stem diameter, number of cocoa green and senescence leaves and number of the flower and pod of cacao in different vegetation composition.

2. Methods

2.1. Determination and preparation of research plots
The selection of cocoa area is based on cocoa plant uniformity and difference of planting with the tree protector. In the Village Area Plan District of Somagede, there are three types of the cocoa garden with different planting pattern.

The cocoa garden I consists of 7-year-old cocoa plants planted among prehistoric plants, such as Gliricidia, Mahoni, Bangladesh, Langsa, Laban, Bayur, Sengon, and Albasia. The cocoa plantation II comprises a 7-year-old cocoa plant with no shade trees, and the third cocoa plantation consists of a 7-year-old cocoa plant with one shade tree located in the middle of the cocoa plant.

2.2. Measurement of environmental factors and weather factors
Environmental factors measured at the research sites are temperature and humidity of air, soil and light intensity. Temperature and air humidity are measured using thermohygrometer, the light intensity using lux meter, soil pH and temperature and humidity measured using soil tester.

2.3. Measurement of Leaf Mass Area (LMA)
Four mature leaves were taken from each tree. Determination of mature cacao leaves using a leaves color index. From these observations of mature cacao, leaves were spread, about 4 or 5 leaves on each branch. Leaves taken directly inserted into the plastic clip to avoid evaporation. Leaf measurements made in the laboratory by measuring the total area with millimeter paper, and then the leaves are dried in oven to get dry weight.

2.4. Measurement of cocoa tree diameter
The diameter of the tree was measured from the height of an adult’s chest, by installing the string rope. The tree diameter was observed at the beginning of the installation and the end of the study.

2.5. Analysis of Data
The data were analyzed using Analysis of Variance (ANOVA). If there is a significant difference, the result can be followed by Duncan Multiple Range Test (DMRT) at the 95% significance level.

3. Results
Geographically, the research location is at an altitude of 96 m above sea level, with the amount of rainfall mm per year, the average air humidity ranges of 47-80%, and the air temperature above the tree canopy average 30.4°C. Under the canopy, air temperature tree is lower at 29.7°C. Rainfall from December 2014 to August 2015 indicates a rainfall spreading of 200-300, which is not evenly distributed throughout the year.

The average light intensity, air temperature, relative air humidity, soil water content, soil temperature and soil pH at the study sites are shown in table 1 and table 2. From the weather measurements for ± 10 months, it shows that cocoa plots grown with many protective trees are less exposed to sunlight, have temperature beneath the lower canopy of trees with no protective trees and plots with one tree. However, poly cacao plots have higher air humidity (table1).
Table 1. Average light intensity, air temperature and air relative humidity (RH) at the study site.

| Plantation                              | Light intensity (x 1 Lux) | Air temperature (°C) | Air RH (%) |
|-----------------------------------------|----------------------------|----------------------|------------|
| Cocoa planting with many types of trees | 879                        | 28.8-29.1            | 79.3       |
| Cocoa with no shade trees               | 1379                       | 29-30.3              | 77.0       |
| Cocoa with one type of shade trees      | 1087                       | 29-30.2              | 78.2       |

Measurements of groundwater content, soil temperature, and soil pH are also visible. Plots of cacao grown with polyculture have more groundwater content and lower soil temperature than cocoa plots without protective trees (Table 2).

Table 2. Average soil water content, soil temperature and soil pH at the study site.

| Plantation                              | Soil water content(%) | Soil temperature(°C) | Soil pH |
|-----------------------------------------|-----------------------|----------------------|---------|
| Cocoa planting with many types of trees | 35-48                 | 24-25                | 6-7     |
| Cocoa with no shade trees               | 30-33                 | 25-27                | 6-7     |
| Cocoa with one type of shade trees      | 35-48                 | 25-26                | 6-7     |

The value of cocoa LMA in plots with many protective trees has lower LMA than cacao planted without protective trees. The lowest number of green leaves and leaves of senescence also occurs in cocoa on plots with many protective trees.

Table 3. The average Leaf Mass area, Number of green leaves and number of senescence leaves in different cacao plantation.

| Plantation                              | Leaf mass area (mg/cm²) | Number of Green leaves | Number of Senescence leaves |
|-----------------------------------------|-------------------------|------------------------|----------------------------|
| Cocoa planting with many types of trees | 5.90                    | 845.55                 | 1.55                       |
| Cocoa with no shade trees               | 8.20                    | 1410.00                | 9.60                       |
| Cocoa with one shade tree               | 7.30                    | 2505.11                | 15.00                      |

Table 4. The average of Leaf Mass area, Number of green leaves and number of senescence leaves in different cacao plantation.

| Plantation                              | Ratio green vs senescence leaves per tree (%) |
|-----------------------------------------|-----------------------------------------------|
| Cocoa planting with many types of trees | 0.183b                                        |
| Cocoa with no shade trees               | 0.68a                                         |
| Cocoa with one shade tree               | 0.59a                                         |
4. Discussion
In general, the difference between planting cocoa trees with and without unprotected trees causes differences in microclimates around the cocoa plants, either under the canopy or under subsidence (table 1 and table 2). Daily fluctuations in air temperature and humidity in the shade are smaller [10]. Higher relative humidity in cacao plant plots with many protective trees is due to the output of water vapor produced by higher transpiration rates where trees pump water from lower soil layers [11]. The shade plants affect microclimate fluctuations [10], such as reducing soil evaporation and coffee transpiration [12], thus resulting in lower drainage than in monocultures [13,14].

The low value of cocoa LMA in plots with many protective trees is seen in the relatively broader and thin leaf morphology. Cocoa in a plot without a protective tree have thicker and brighter green leaves. The activities of photosynthesis and leaf respiration in tropical trees, such as cocoa that live under shade, are affected by leaf age and light conditions. Several factors influence the leaf dynamics (production rate and abscission), water and light availability, and it also varies greatly between the site and planting systems [9]. Full light can also cause stomata closure, leading to a decrease in leaf water status, thereby reducing the activity of photosynthesis and growth [15].

Leaf senescence is grown more on cacao plants without protective trees (monoculture), followed by cocoa with a protective tree, and the last is the cultivation of cocoa planted with many protective trees. Several factors known in the process of senescence are genetic factors, N stress, radiation, temperature, drought, and pathogens [16,17]). The need for certain shade levels is also supported by the fact that cocoa growth and pod yields are reduced with high radiation intensity [9,18]. During dry season, cocoa in monoculture tends to release more leaves. Therefore, although cocoa in the plot with many protective trees is virtually nonexistent, it is important to regulate the amount of shade, because too much of it can produce a very moist microclimate conducive to higher fungi. Shade trees that are too thick can decrease the production of cocoa beans [9] due to the low photosynthesis and increasing diseases. The cocoa leaves had a shorter leaf age and earlier fallout when grown in the upper canopy with higher sun exposure [1]. Cocoa production in full sun planting can improve crop yields and economic benefits in a short time[6]. However, cocoa grown with shade can provide fewer economic benefits in the short term but will continue to produce in the future without the need for chemical input.

5. Conclusion
The difference of vegetation composition of shade plants affects cocoa growth and productivity. Leaf Mass Area (LMA), ratio green and senescence leaves, flower and pods of cocoa on polyculture, especially in cocoa with many types of trees which are lower than polyculture patterns. Surprisingly, the polyculture cropping pattern of cocoa planting using many types of trees has almost no senescence leaves in early dry season. It shows a better adaptation to drought when planted with other tree species.

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