Analysis of limiting factors of RGL citrus fruit productivity
(study case in Pal VII Village, Bermani Ulu Raya Subdistrict, Rejang Lebong District)

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Abstract. Environmental factors, especially climate, soil and pest attack, are limiting factors in citrus production. The purpose of this study was to determine the limiting factors on RGL citrus productivity. This research was carried out in 2019 in Pal VII Village, Bermani Ulu Raya District, Rejang Lebong Regency, Bengkulu Province with seven farmers at the research location. Data was collected from primary and secondary data consist of 10 years climate data, soil characteristics and citrus pest and diseases identification, which are then analyzed descriptively. The results showed that the productivity of RGL citrus in the research location was influenced by high rainfall during the fruiting period. Another limiting factor is the relatively low soil nutrient content because farmers generally do not apply fertilization technology that based on crop needs. Pests and diseases that had been potential reduced the productivity and quality of citrus fruits were fruit borers, fruit flies and scurvy, and climate factors also influenced the quality.

1. Introduction

Indonesia is a country that produces a variety of fruit commodities and one of the fruits that is widely consumed by the Indonesian people is oranges [1]. Based on the Central Bureau of Statistics (2018) in 2018 the production of tangerines and siem was recorded at 2.1 million tons. However, the large domestic demand for oranges has resulted in Indonesia still importing oranges. Indonesia is the second largest citrus importer country in ASEAN after Malaysia [2]. According to [3], the government in the context of import substitution has a program to develop yellow tangerines through area extensification or expansion.

One type of local citrus developed in Bengkulu Province is the RGL orange which is able to adapt well to an altitude of 650 m asl. It has competitive advantages i.e. having yellow-orange fruit, fruiting all year round, have large and stiff leaf size, thick fruit skin, sweet, sour, fresh taste with fruit weight up to 250 to 300 g, relatively high fruit juice content and have a fairly good market potential [4].

The leading commodities of each potential region need specific technology innovations. Currently, the production of RGL citrus is not optimal and the technology used is still minimal. It is assumed that the plants have not been able to adapt well to climate change. Citrus plants need an ideal climate to grow with rainfall between 1,000 to 3,000 mm year⁻¹, average temperature 13 to 35°C, and humidity of 70 to 95% [5]. Meanwhile, fertilization is an important cultivation technique for citrus plants. The implementation must pay attention to the principle of effectiveness and efficiency, considering that...
fertilization costs are quite high, namely 40 to 60% of the maintenance costs or 15 to 20% of production costs [6]. Besides that, another limiting factor is the attack of pests and diseases in citrus plants. The high and low number of population and the level of citrus pest attack are influenced by the availability of these pests, plant age, rainfall and improper cultivation techniques. The purpose of this study was to determine several limiting factors on the productivity of RGL citrus plants in Pal VII Village, Bermani Ulu Raya District, Rejang Lebong Regency, Bengkulu Province.

2. Materials and methods
The research location was Pal VII Village, Rejang Lebong Regency, Bengkulu Province, Indonesia which is the center for the development of RGL oranges. Activities were carried out in 2019 by determining the main limiting factors of productivity, namely soil and leaf nutrients. Soil sampling was carried out in a composite manner on 7 cooperator farmers lands to be analyzed for nutrient content at the BPTP Bengkulu Soil Laboratory.

Furthermore, after harvesting leaf samples, three-four adult leaves were taken from each tree that were from the upper third of the branches. These leaves were then analyzed to determine the concentration of N, P and K nutrients using the Kjeldahl semi-micro method for N, Spectrophotometer UV-VIS for P and Flamephotometer for K. The next limiting factor that was observed was the rainfall (mm) in Bermani Ulu Raya District. The data were obtained from The Bureau of Meteorology, Climatology and Geophysic (BMKG). Direct field observations of pests and plant diseases were also carried out on 7 citrus cooperator farmer fields. Data were collected through direct in-depth interviews with 7 respondents, which is 7 citrus cooperator farmers with 7 ha of total land of citrus plantation. These data was then analyzed descriptively.

3. Results and discussion

3.1. Land Potential
Rejang Lebong Regency is one of the 10 districts or cities in Bengkulu Province and is located along the slopes of the Bukit Barisan Mountains with an area of 151,576 ha which is divided into 15 districts. Its location in a hilly area causes the elevation of Rejang Lebong Regency to vary greatly from flat to mountainous, dominated by moderate to high plains covering an area of 105,014 ha (69.28%). The height above sea level determines the temperature and intensity of light received by plants, the higher a place, the lower the temperature, as well as the decreasing sun intensity.

There are 5 districts as citrus development areas in Rejang Lebong Regency sequent Bermani Ulu, Bermani Ulu Raya, Selupu Rejang, Sindang Kelingi, and Sindang Dataran. Based on the results of field identification through interviews and field observations, the citrus plantation area in the development area in the 5 sub-districts is estimated to be 286.5 ha (figure 1).

However, Bermani Ulu Raya District has established citrus area in Rejang Lebong Regency with a planted area of about 240 ha (figure 2).

The PAL 7 study site is potential for citrus development, located at an altitude of 900 to 1200 m above sea level. Oranges have wide adaptability, however, RGL oranges (which are one type of tangerine) when grown in the highlands have a more optimal production than those grown in the lowlands. This is in line with observations in the field that RGL oranges grown in the lowlands have rough skin quality and low fruit juice content.
Figure 1. Citrus plantation area in five sub-districts of the development area in Rejang Lebong Regency, Bengkulu Province, Indonesia.

Figure 2. Citrus plantation area in Bermani Ulu raya District, Rejang Lebong Regency.

3.2. Climate
Climate is a very determining factor for productivity and product quality. Each type of plant requires a climate element with a certain range in each phase of its growth. Pal VII Village, Bermani Ulu Raya District is located at latitude 03° 22’ 43.3" South latitude and 102° 28’ 34.2" East Longitude. Monthly rainfall and humidity data of the study area can be seen in figure 3 and 4.
Based on Schmidt Ferguson climate classification [7], the study location has a climate type A which is very wet. Rainfall and humidity affect citrus productivity. The flowering phase of citrus plants is influenced by climate and requires stable water stress and humidity. High rainfall can lead to pest attacks, as a result of an increase in insect population [8]. Furthermore, the optimal humidity in oranges ranges from 70 to 95% [5].

Based on Figure 3 and 4, the study location has an annual rainfall of 2,745 mm year⁻¹ with 6 months of wet months, 3 months of humid months, 3 months of dry months, and 83 to 88% average humidity per month. This location is very suitable for planting RGL oranges. Citrus is ideal growing in areas that have rainfall between 1,000 to 3,000 mm year⁻¹, temperature 13 to 35°C and humidity 70 to 95%. Water stress that occurs during the dry months (July, August, September) will affect the formation of flower buds [9]. Furthermore, [10] added that the general growth requirements for oranges with soil

**Figure 3.** Rainfall data (2015-2019), Pal VII Village, Rejang Lebong District, Bengkulu Province.

**Figure 4.** Relative Humidity data (2015 to 2019), Pal VII Village, Rejang Lebong District, Bengkulu Province.
characteristics that have a pH of 5 to 6, can grow well on land that has a slope of up to 30° with an altitude of 800 to 1,500 above sea level. In tropical and subtropical areas (35° North Latitude to 35° South Latitude), with a temperature of 25 to 30°C, and 50 to 60% sun radiation (dislikes protected places), groundwater is found at a depth of 0.5 m during the rainy season and 1.5 m during the dry season.

The observations show that the lowest rainfall occurs during three months, namely July, August, September (<100 mm), while the highest rainfall occurs in April (> 500 mm). The amount of rainfall and its distribution greatly determines the availability of water in citrus plants, because water functions in the process of replenishing plant or fruit cells, solvent chemicals or solids needed by plants and as plant temperature control [11]. Furthermore, the high rainfall is wary of the development of pests and diseases in oranges. High rainfall has a major effect on pest populations [8]. Continuous rainfall causes moisture and high groundwater content so that the water content leading to the flowers is excess and causes hair loss. The chayote undergoes a flowering phase 2 to 3 times a year [12]. This loss is due to high rainfall which results in increased soil water content and in plants that is not optimal for fruit formation metabolism [13].

3.3. Soil characteristics
Judging from its geographical situation, Pal VII Village, Bermani Ulu Raya District consists of Andisol and Latosol land and is suitable for citrus cultivation. The soil characteristics can be seen in table 1.

| Parameter          | Value | Status   | Citrus growing requirements |
|--------------------|-------|----------|----------------------------|
| pH (H₂O)           | 5.27  | Acid     | 5.2 – 8                    |
| C-organik (%)      | 1.31  | Low      | 0.8 – > 1.2                |
| N (%)              | 0.84  | Very high| Very low – moderate        |
| P-Bray (ppm)       | 1.15  | Very low | Very low – high            |
| KTK (cmol kg⁻¹)    | 20.82 | Moderate | 5 - > 16                   |
| K-dd (cmol kg⁻¹)   | 0.04  | Very low | -                          |
| Na-dd (cmol kg⁻¹)  | 0.53  | Moderate | -                          |
| Ca-dd (cmol kg⁻¹)  | 2.61  | High     | -                          |
| Mg-dd (cmol kg⁻¹)  | 0.98  | Low      | -                          |
| Al³⁺               | 0.87  | Very low | -                          |
| H⁺                 | 1.75  | Very low | -                          |
| K (HCl 25%)⁺       | 51.63 | High     | -                          |
| P (HCl 25%)        | 51.53 | High     | -                          |
| KB (%)             | 20    | -        | > 20                       |

*Source:BBSDLP (2011).

The soil characteristics of Pal VII Village, Bermani Ulu Raya Subdistrict are very suitable to be developed as citrus planting areas. This can be seen by comparing several criteria and characteristics of the study land to citrus growth requirements. According to [14], the land characteristics required for citrus plantations are presented in table 1. It can be seen that the soil pH value is 5.27 and is classified as acidic. This condition is very suitable for the growth of citrus plants. Soil conditions with moderate or appropriate reactions are a good average atmosphere for plants, because the chemical and biological conditions are at the optimum level. In this condition, the availability of nutrients and microorganisms are very sufficient. To increase soil pH, dolomite 6 to 7 kg tree⁻¹ can be given.

The C-organic content is classified as low at 1.3%. According to Pakan [14], the organic C requirement of over 1.2% is very suitable to be used as an orange planting area. Organic C is used as an indicator in determining the fertility status of a soil. Information on the value of soil CEC is very
important in relation to the fertilization action that will be carried out, because it is an indicator of how much the ability of the soil concerned to hold the fertilizer given [9].

The available P content is very low. Under these conditions, fertilization is necessary. The P element is needed by citrus plants because it functions as a booster for root growth and the formation of a good root system, so that it can take up more nutrients and make plant growth healthier and stronger and increase plant resistance to pests and diseases. It would also accelerate the growth of plant tissues that form plant growth points and encouraging generative growth of plants, namely accelerating the formation of flowers and ripening of fruit / seeds, thereby accelerating the harvest period. Another function is increasing the percentage of flower formation into fruit and seeds.

Macro nutrients available at the study site range from very low to moderate. If the nutrient content is low, production can be guaranteed to be low as well. Phosphorus and potassium are included in a group of macro nutrients that are needed by plants in large quantities and their roles cannot be replaced by other nutrients. The amount of available phosphorus in the soil is less than nitrogen and potassium nutrients. The results of measuring the soil P2O5 content at the research location obtained a high criterion value, but it is necessary to know that although the total P content in the soil is high, it is not necessarily available for plants because in calcareous soils P is bound by clay minerals and Ca cations to become insoluble P. The quality of citrus fruits is significantly influenced by the low availability of P in the soil. Lack of phosphorus nutrients causes the skin of citrus fruit to become thick, pale, and the flesh of the fruit is foamy so that the water content is low and the taste is sour [15]. The P content in the soil have to be considered if we are going to fertilize P. On soils that have a high P content such as at the study site, P fertilization is intended only to fulfill or replace P transported by citrus plants.

The nutrient content in lime leaves is presented in table 2. It can be seen that the total K nutrient content in the leaves is high. Citrus plants require high amounts of potassium. As an illustration, to be able to produce 15 t of fruit ha⁻¹, the land will lose 143 t of K₂O ha⁻¹ plant⁻¹ life cycle because it is carried away during harvest. Therefore, potassium fertilization is needed depending on the amount of K-available content in the soil. Soil type must also have good drainage. Water must be completely permeable or stagnant and groundwater too shallow. Minimum groundwater depth is between 150 to 200 cm below ground level.

| Parameter | Value | Status |
|-----------|-------|--------|
| N (%)     | 3.29  | High   |
| P-Bray (%)| 2.17  | High   |
| Total K(%)| 1.91  | High   |
| Cu (me L⁻¹)| 0.62 | Low    |
| Zn (me L⁻¹)| 1.47 | Low    |
| Mn (me L⁻¹)| 21.69| Low    |
| Fe (me L⁻¹)| 19.51| Low    |

3.4. Plant pests and diseases

Pest and plant disease attacks are one of the limiting factors in increasing the productivity and quality of citrus yields. The application of control technology by farmers is one of the factors that distinguishes the presence and level of attacks between farmers’ gardens. The results of field observations show that the dominant pests and diseases that attack and have the potential to reduce yield are fruit flies, fruit borer, tryps, mites, sooty dew, fruit scab and dry fruit rot. There are three pests are potential to reduce the quantity and quality of citrus fruits, namely fruit fly pests, fruit borer and scurvy. The data is presented in figure 5.
Figure 5 shows the fluctuation in the severity of pests and diseases of citrus plants in each month of observation. It can be seen that the attack of fruit borer pests is very fluctuating, while the fruit fly pests at the beginning of the observation have a low level of attack. However, the two pests have a peak attack time at almost the same time. In the graph, it can be seen that the attack of fruit borer pests tends to be high when compared to fruit fly pests. This is because the phases of the attack of the two pests are different. Fruit borer pests can attack from the young fruit phase until they are ripe, while fruit fly pests only attack the fruit before it is ripe. The peak occurrence of fruit borer and fruit fly infestations at the same time indicates that food availability and climate influence are important factors. October to November is the peak of the harvesting. These months are still in the dry season. Climatic factors play an important role in the fluctuation of pest populations and disease epidemics, thus impacting the incidence and severity of attacks. If environmental factors are suitable, the population of pests and pathogens will develop rapidly, and vice versa. Both of these factors are factors in the high level of fruit borer and fruit fly infestation, the population of fruit borer and fruit fly will increase when the plants bear fruit [16].

The increase in C. sagittiferella attack was caused by the age of the fruit. According to Muryati [17], the level of borer attack is significantly influenced by the age of the fruit, where the increasing age of the fruit, the higher the attack rate. C. sagittiferella moths have a higher preference for the essential oil of orange fruit peels aged 6 months than the 2 month old citrus fruit peel essential oil. This is due to differences in the concentration and number of components of the essential compounds produced by aged orange peels 2 and 6 months [18].

Fruit fly pests seem to fluctuate from time to time. This is consistent with the research results by Manurung et al. [19] that the population dynamics of fruit fly pests are influenced by fruit ripening period, number of rainy days and rainfall. In the harvest period of May and June, fruit fly pests show very low intensity of attack. This is because in that months, the rainfall are still high enough so that the pest population decreases. Meanwhile, starting from July, August and September, the condition of the fruit were mostly young, so the attacks were small. The percentage of fruit fly pests starting in October and November has increased, because the fruit starts to enter the fruit ripening period and coupled with the long dry climate conditions, the development of the fruit fly population increases. Meanwhile, at the end of the observation in December, it was seen that the level of attack was drastically decreased because the ripe fruit had been harvested and only 3 months old fruit was left.
Figure 5 also shows an attack of scurvy which was quite high in intensity at the beginning of the observation. The rate of scurvy attacks is decreasing every month until the intensity is low. The decrease in the level of scurvy is predicted due to the intensive control by cooperator farmers by spraying a sulfur slurry solution and consistent pruning to reduce moisture in the plant canopy. This disease usually attacks citrus fruits starting from the fruit set phase and continues to develop until just before harvest [20]. If the young fruit (small size) has been attacked by scabies, the fruit will be difficult to develop, which in the end will fall. Scabies is a disease that falls into the dull dulled group on the fruit so that if there is a fruit that is ready to be harvested, it will reduce the interest of buyers because of the bad appearance of the fruit, although terms of taste it does not change the taste of the orange fruit. The fungus Spaceloma fawcetti Jenkins causes scabies not only attack the fruit, but also the leaves. Symptoms of a scabies attack include small, clear spots on the leaves or fruit, which then develop into a yellow / brown cork [14].

Based on the results of the collection of fallen fruit, it can be seen that the average fruit drop in five weeks in October is in the range of 8.3 to 10.2 with a weight of 1 to 2.1 kg. This shows that the percentage of yield loss ranged from 30.3 to 63.6% with three times harvests during the five weeks (figures 6 and 7).

**Figure 6.** Number and weight of fallen fruit for five weeks.

**Figure 7.** Average fruit weight three times harvest for five weeks.
Farmers can reduce the percentage of crop loss to below 30.3% by carrying out various efforts to control pests and plant diseases regularly and correctly such as garden sanitation \cite{21}. This garden sanitation does not only collect fallen fruit, but also pruning plant parts including fruit that are still on trees that are no longer healthy. This aims to reduce the level of damage to other healthy citrus fruits. Garden sanitation will run well if farmers are able to recognize the symptoms of orange trees that are attacked by pests that occur in their gardens. In order for pest control to be carried out effectively, each member of the Citrus Farmer Group must carry out their own garden sanitation with full discipline. Thus, garden sanitation which is supported by optimal maintenance of plants in the garden, can improve tree health, plant productivity and the quality of the fruit produced. It is included trimming the shape, pruning maintenance, tillage, fertilizing, watering, thinning fruit, controlling pests, diseases and weeds \cite{22}.

High rainfall greatly affects the development of pests and diseases in RGL citrus plants which can cause low productivity of RGL citrus plants. Therefore, it is necessary to do sanitation on a regular basis to reduce the impact of high rainfall \cite{11}.

4. Conclusions
The productivity of citrus orchards in Pal VII Village, Bermani Ulu Raya District is influenced by high rainfall during the fruit set period. Another limiting factor is the relatively low soil nutrients because farmers in general have not applied fertilization technology according to plant needs. Then the attack of fruit borer pests increased significantly in September, October and November, this was due to the fruit ripening period.

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