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THE ROLE OF SEVERAL METHODS OF DRAINAGE AND FERTILIZATION LEVELS ON GROWTH AND YIELD OF OIL PALM PLANTS (*ELAEISGUINEENSIS* JACQ.)

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Abstract – Oil palm is a plantation commodity that requires sufficient nutrients and drainage management to produce high productivity requires the application of good cultivation technology. The cultivation technology that needs to be applied in oil palm plantations is the role of several drainage methods and the proper level of inorganic fertilization. This research aims to study the role of several drainage methods and appropriate levels of fertilization to improve soil physical and chemical properties, morphology and physiology, and increase oil palm productivity. The experiment was carried out from October 2014 to December 2016 at the IPB-Cargill Oil Palm Education and Research Garden, Jonggol, Bogor, using a two-factor separate plot design with three replications.The main plot is improvement of drainage consisting of natural conditions, biopore holes, drain ditches, and heap footprint. Subplots were fertilization doses consisting of 25, 50, 75, and 100% recommended doses. The recommended dosage is 500 g nitrogen (N) + 250 g phosphate (P) + 500 g potassium (K) plant^{-1} six months^{-1}. The fertilizer rate at 2nd Year of experiment were : 1,000 g nitrogen + 500 g P + 1,000 g K plant^{-1} six months^{-1}. The results showed that the biopore treatment and 100% recommended dose could increase the soil moisture content, the addition of fronds, the greenness of the leaves, and the stomata density. The interaction of biopore and 100% recommended fertilization rate was the best treatment combination to increase the productivity of oil palm which could produce 18.93 ton ha^{-1} year^{-1} fresh fruit bunch (FFB) at 46 months after planting.

INTRODUCTION

Oil palm (*Elaeis guineensis* Jacq.) As a plant originating from West Africa has grown rapidly in Indonesia and is currently a primadonna commodity for the country's foreign exchange earner from the agricultural sector. Palm oil has bright prospects in the world vegetable oil trade which has prompted the Indonesian government to spur the development of oil palm plantation areas. Lands that is economically suitable for use of the land for oil palm has had a positive impact on regional development and in improving people's lives. The total area of Indonesian oil palm plantations in 2016 reached 11.40 million hectares, about 41.23% or 4.70 million hectares cultivated by farmers, 51.75% or 5.90 million hectares were managed by private companies, and 7.02% or 0.80 million hectares owned by state plantation limited liability company. Palm oil production in 2016 reached 35 million tonnes of Crude Palm Oil (CPO), this amount controls 53.70% of world CPO production, with a composition of around 26 million tonnes being exported mainly to India, China, Russia and Europe GAPKI (2016).

Oil palm plants in order to be planted in wetlands to grow and produce well, a drainage channel must be made in the garden area. According to Suripin (2004), drainage is defined as a series of water structures that function to reduce and remove excess water from an area or land, so that the land can be used optimally. A drainage system, especially in oil palm plantations, is to hold water, then collect it, and remove excess water out of the area. Thus, drainage must be designed in the form of a network that utilizes topography (spot heigh) and drains excess water based on gravity and artificial channels that have been made (Dariah *et al*., 2013). The changes after making drainage are mainly changes from swampland conditions that were initially flooded and anaerobic to aerobic conditions due to drainage. Aerobic conditions lead to increased biological oxidation or mineralization of organic matter Imanudin and Bakri (2016).

The drainage improvement method is intended to control the water system in the plantation area by making biopore infiltration holes, water retention ditches, and hoarding sites. The biopore infiltration space is made in large quantities, so the ability of a plot of land to absorb water is expected to increase. According to the IPB team (2007b); (Susanto *et al.*, 2012); and Anggraeni *et al.* (2013), the presence of biopore infiltration holes is made with a diameter of 10-30 cm and within 50-100 cm, it can increase the ability of the soil to absorb water, reduce the chance of water flow on the ground, in other words it will reduce the danger of flooding that may occur, and groundwater storage techniques. Drainage on agricultural land is defined as the creation and operation of a system where water flow on agricultural land is created in such a way that both inundation and groundwater depth can be controlled so that it is beneficial for farming activities.

According to Arsyad (2006); (Rahutomo *et al.*, 2007); and Kalsim (2008) making drainage channels an attempt to remove "excess water" naturally or artificially from the soil surface, accelerate water regulation, limit inundation, in areas with a long dry season to improve groundwater reserves, as water storage, while in areas with a long dry season. Low land (flat) is more related to flood control, which will ultimately affect plant growth. The purpose of making a heap footprint is to raise the soil surface on the palm oil plate. Heap footprint is applied to an oil palm disc which has subsided soil (often occurs on peat soil) so that the roots are exposed. According to Balittra (2015), heap footprint is used on swamps, peatlands, tides, and land which is always inundated by water during the rainy season by elevating part of the plant plate, thereby facilitating maintenance and harvesting.

Fertilization aims to ensure the adequacy and balance of plant nutrients so that growth can be better. The need for nutrients for oil palm plants at each stage of its growth is different. The amount of nutrients added through fertilizers must take into account the nutrient losses due to leaching, evaporation, as well as the physical and chemical properties of the soil. Fertilization must be managed properly because it is one of the largest components of production costs in oil palm cultivation and about 60% of the maintenance costs of von Uexkull and Fairhurst (1991).

Nitrogen plays a role in stimulating vegetative growth of plants, a constituent of many compounds such as chlorophyll, amino acids, proteins, nucleic acids and organic acids as well as improving the quality of the leaves. Phosphorus is one of the essential nutrients needed for good growth and production for oil palm plants. Potassium plays a role in plant physiological processes including as an enzyme activator, regulating cell turgor, nutrient and water transport, increasing plant resistance, oil synthesis, the number and size of bunches.Potassium deficiency is usually found in plants growing on peat soils, sandy soils, and acid soils with low cation exchange capacity. This deficiency is due to the soil's low K exchange rate and the lack of K fertilizer application. Application of K can help meet the nutritional needs of plants and application time, dosage and type of fertilizer, must be based on plant age and soil characteristics. Sudradjat *et al*. (2018). The condition of some of the IPB research gardens in Jonggol is usually when the amount of rain is high (rainy season), especially the land in low areas, always inundated with water for 7-10 days so that the growth of oil palm plants is not normal which is marked by yellowing leaves.During the dry season the soil is cracked, 15-20 cm wide and 38-42 cm deep (field data 2014). When the rainfall is high, water flows to the lower part, causing inundation of the land. The research objective was to study the role of several soil drainage methods and fertilization doses in increasing growth and productivity of immature palm oil (*Elaeis guineensis* Jacq.) (IPO II).

MATERIALS AND METHODS

The research was conducted from October 2014 to

December 2016 at the IPB-Cargill Oil Palm Education and Research Plantation, Jonggol, Bogor. The plants used were oil palms 23 months after planting (MAP) (research blocks 3 and 4 were planted in November 2012). At the beginning of the observation, the Dami Mas variety was planted with a spacing of 9.2 mx 9.2 mx 9.2 m so that the population was 136 plants per acres.The fertilizers used are nitrogen, phosphate and potassium. The experiment used a separate two-factor plot design with three repeat. The first factor (main plot) is the soil drainage method (D) which consists of four levels of treatment, namely natural conditions, biopore holes (Figure 1a and 1b), drain ditches (Figure 2a and 2b), and heap footprint (Figure 3a and 3b) (implemented from July to September 2014).The second factor (subplot) is the fertilizer dose which consists of four levels of treatment, namely: 25% recommended (125 g nitrogen + 62.5 g phosphate + 125 g potassium (K) plant^{-1}six months^{-1}, 50% recommendation (250 g N + 125 g P + 250 g K plant^{-1}six months^{-1}), 75% recommendation (375 g N + 187.5 g P + 375 g K plant^{-1}six months^{-1}), and 100% recommendation (500 g N + 250 g P + 500 g K plant-1six months^{-1}). The doses used in the second year of the study were: 25% recommended (250 g N + 125 g P + 250 g K plant^{-1} six months^{-1}), 50% recommended (500 g N + 250 g P + 500 g K plant-1six months^{-1}), month), 75% recommendation (750 g N + 375 g P + 750 g K plant^{-1}six months^{-1}), and 100% recommendation (1,000 g N + 500 g P + 1,000 g K plant^{-1}six months^{-1}). According to Pamuji*et al.* (2006);

Fig. 1. Treatment plot of biopore holes 1a is being made, 1b biopore holes are finished.Each oil palm plant is treated with 4 biopore holes, the location of the biopore holes according to the direction of the wind with the size, namely the upper diameter of 14 cm, depth of 100 cm and distance from the stem of the oil palm plant 200 cm

Fig. 2. Treatment plot of disposal ditch 2a under construction, finished drain ditch 2b. Every 2 rows of oil palm plants are treated with 1 drain ditch, the dimensions are: top width 50 cm, depth 50 cm, bottom width (bottom hole) 40 cm, and length 72 m.

Fig. 3. Plot of 3a heap footprint treatment is making 3b of finished heap footprint. Each oil palm plant is given a treatment, with sizes, namely: radius (r) = 2 m, height 50 cm

Rahutomo *et al.* (2007), the fertilization dose used in oil palm plants 2 years after planting into the field are: 500 g nitrogen plant^{-1} (N), 250 g plant^{-1} phosphate (P), and 500 g potassium (K) plant^{-1} are given scatter on a plant plate. Each experimental unit consists of 8 observation units so that the number of plants observed is 384 plants. Fertilization is applied twice per year (six month intervals). Fertilization was carried out in October 2014, April 2015, October 2015, April 2016, and October 2016, each with ½ treatment dose.

The observed variables consisted of response variables to the physical and chemical properties of the soil (moisture content of 0-60 cm depth and *Bulk density* (BD), morphological and physiological responses (frond length, leaf greenness, and stomatal density), and fresh fruit bunches (FFB). (observed from November 2015 to October 2016). The length of the frond was observed by measuring the base of the midrib from the main stem to the tip. The level of greenness of the leaves was measured in the 17th midrib leaflets using the SPAD 502 plus chlorophyl meter [carried out in November 2014 (beginning of the study) and October 2016 (end of the study)]. Stomata density observations were carried out by taking stomata samples on the lower surface of the leaves using clear nail polish and tape [carried out in November 2014 (beginning of the study) and October 2016 (end of the study)]. The density of the stomata was observed using a microscope at a magnification of 40 times. Production was observed by weighing the average FFB weight in each treatment with a weight of more than 3 kg per FFB. Measurement of the weight of FFB per six months and a year by adding up the production every month. The data were analyzed using variance and continued with Duncan's Multiple Range Test (DMRT) and analyzed using orthogonal polynomials at the 5% significance level.

RESULTS AND DISCUSSION

Responsive to Physical and Chemical Properties of Soil

Soil Water Content at a Depth of 0-60 cm

The results of the analysis of the measurement of the soil water content of the treatment of the role of several drainage methods at a depth of 0-60 cm at 12 to 22 months of BSP observation are presented in Figures 4 (a and b). shows that the soil water content is 0-20 cm deep in the long dry season (mid-April to early November 2015) when the plants are 30 months old, the lowest is obtained in natural conditions, namely 9.02%, while the highest is with 16.40% biopore treatment. At a depth of 20-40 cm and 40-60 cm, the groundwater content is higher than the depth of 0-20 cm, respectively 9.71% natural conditions, 10.61% drainage ditch, and 18.21% biopore holes.

The long dry season (mid-April to early November 2015), causes the soil water content at a depth of 0-60 cm ranging from 9.02-17.20% has reached the critical limit of the permanent wilting point.In October 2015, the conditions in the field at the IPB-Cargill Jonggol oil palm education and research garden were all vegetation that grew leaves dried up and died. The oil palm plant leaves slightly yellowish, especially the natural condition of the leaves turning yellow more severely than other treatments. Oil palm plants with better leaf greenness, respectively: biopore holes, head footprint, drain ditch, and natural conditions.This is because plants are in a state of lack of water to meet

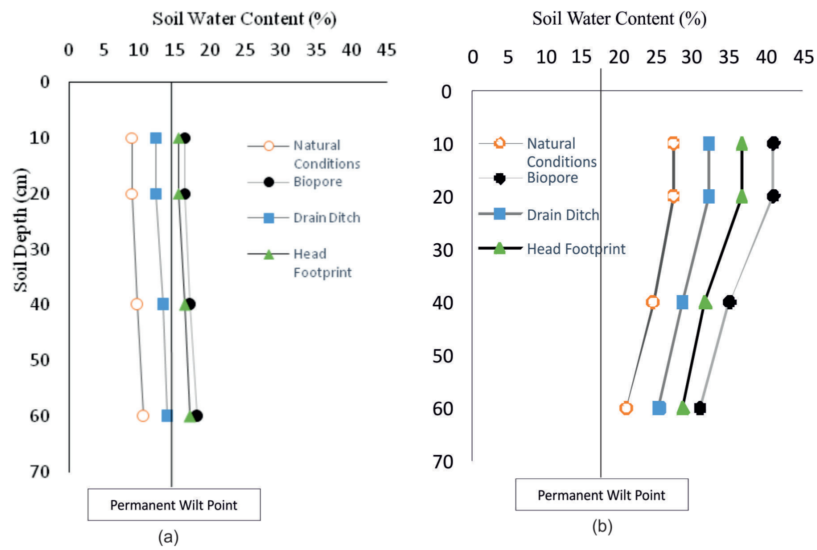

Fig. 4. Soil water content at 3 depths (0-20 cm, 20-40 cm, and 40-60 cm) (a) dry season (12 MAT) and (b) wet season (22 MAT).

their daily needs, causing metabolic processes to not run properly. The leaves of oil palm plants are normal green in the observation 18 months after the observation (April 2016), or the plants are 44 months old. Based on the plant leaves starting to turn green in a row, namely: treatment of biopore holes, heapfootprints, drain ditch, and natural conditions. Mid-November 2015 (12 BSP) has entered the rainy season, the soil water content and nutrients contained in the soil can be taken up by plant roots for plant development and growth

The biopore holes given weed biomass can store water well at a depth of 40-60 cm because Organic matter can save water, and reduce water evaporation from the biopore holes. Likewise, the presence of soil macroorganisms, especially worms, can help absorb water into the soil.

Bulk Density (BD)

Bulk Density (BD) is an indication of soil density, the denser the soil, the more difficult it is to continue water and the more difficult root penetration. The results of the analysis of BD values in the observation of 0 BSP of soil drainage improvement treatment and fertilization dose showed insignificant differences between treatments (Figure 5). The value of BD before the study was conducted was considered the same. There is no interaction combination between soil drainage improvement and fertilizer dose.

The BD value of soil drainage improvement treatment in 26 BSP observations was significant

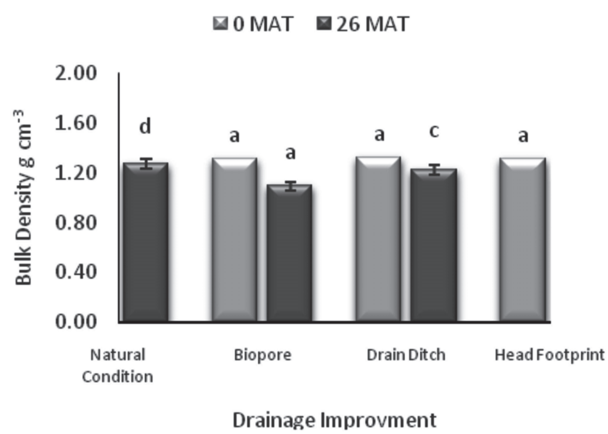

Fig. 5. Effect of soil drainage improvement treatment on Bulk density (BD), MAT; months after treatment, observations 0 MAT-26 MAT

(Figure 2). Natural conditions have a BD value of 1.27 g cm^{-3} (control) higher the other treatments. The BD value of the bioporehole treatment, namely 1.09 g cm^{-3}, decreased by 14.17% compared to natural conditions. Drainage treatment reduces BD, this means that improved drainage makes the soil looser due to improved soil structure. The treatment of the biopore holes in it is also given plant litter, able to hold more water infiltrating the soil layer through the natural holes that are formed so that water can spread widely to parts of the soil. Litter contained in the biopore hole can change the soil to become more crumbly (loose) and will improve (reduce) the bulk density of the soil. The results of research by Loso *et al.* (2020), which states that the biopore holes in it given weed litter can change the soil to become more crumbly and the soil pores are good, will reduce the Bulk Dencity value.

Responsive to Oil Palm Morphology and Physiology

Leaf Frond Length

The results of analysis of variance and orthogonal polynomial test, measuring the length of oil palm leaf midribs at 0 MAT to 20 MAT observations (Figure 6a). There is no interaction combination between soil drainage improvement and fertilizer dose administration. Figure 3b. presents the length of the leaf midribs of oil palm plants in the recommended fertilizer dose treatment as a subplot in a linear manner. Provision of the recommended fertilizer dosage produces a linear response curve for leaf midrib length with the equation y = 0.2816x + 306.21, R2 = 0.9111. So that the increase in the length of the leaf midrib from the application of 25% fertilizer dose to the highest 100% fertilizer dose according to the recommendation, shows a linearly increasing response curve.

The treatment of giving 25% of the recommended fertilizer dose resulted in a midrib length of 3.16 m, giving 50% of the resulting leaf midrib length of 3.17 m, which was 0.32% higher than the 25% dose of fertilizer. Giving 75% fertilizer dose resulted in leaf midrib length which was 3.27 m higher by 3.48% of the 25% fertilizer dose, increasing the fertilizer dose to 100% according to the recommended dose resulting in a leaf midrib length of 3.36 m, higher by 6.33% than 25% fertilizer dose. This means that the dose of fertilizer is increased linearly, increasing the length of the palm leaf midrib linearly.

Green Leaf Level

The results of the analysis of the measurement of the oil palm leaf greenness level are presented in Figures 7 (a and b). The leaves of the oil palm plants sampled for analysis were the 17th leaf midrib from the spear leaves (leaves that were still not open). Observations on 26 MAT showed that soil drainage improvement treatment had a very significant effect.

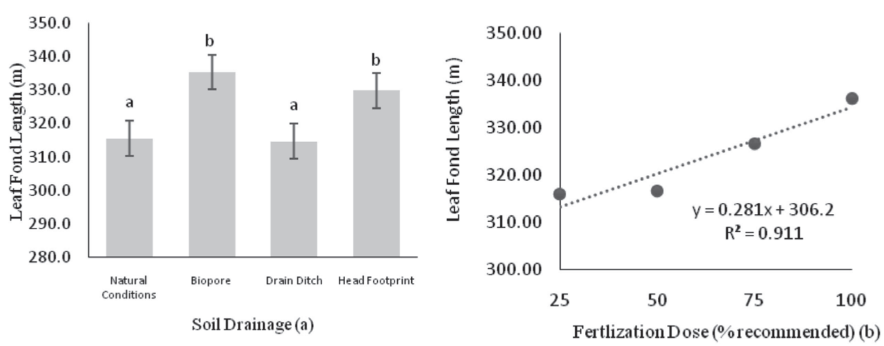

Fig. 6. Effect of (a) improved soil drainage (b) fertilization dose on leaf midrib length of 20 MAT

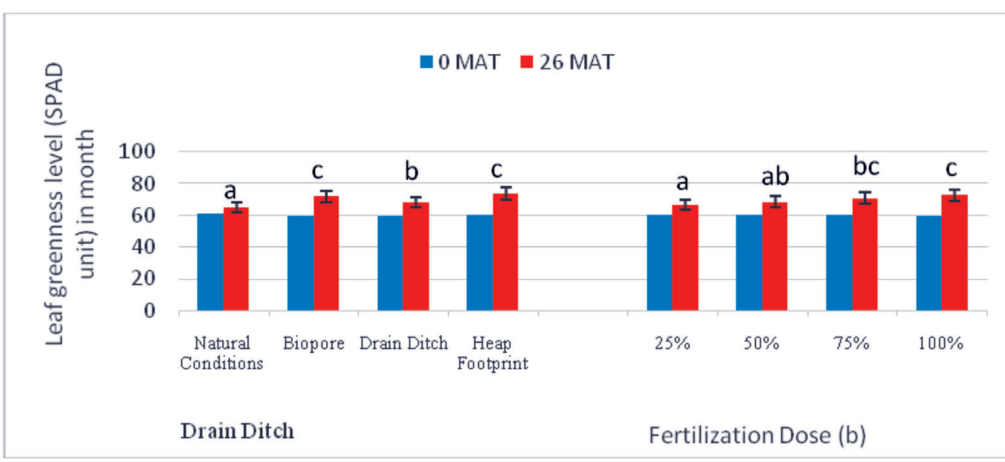

Fig. 7. Effect of improved drainage treatment and fertilization dose on the greenness level of oil palm leaves, 0 MAT-26 MATobservation

The level of greenness of the leaves with the treatment of pile and biopori sites showed the same results ranging from 71.94 - 73.72 SPAD units, higher between 10.29% - 13.02% compared to natural conditions. The drain ditch treatment shows the same results as the natural conditions treatment.

The leaves of the oil palm plants sampled for analysis were the 17th leaf midrib from the spear leaves (leaves that were still not open). Observations of 26 MAT soil drainage improvement treatment showed a very significant effect. The highest level of leaf greenness was obtained by pile site treatment, namely 73.72 SPAD units, 13.02% higher than natural conditions. The treatment of biopore holes with green leaf level is 71.94 SPAD units which are 10.29% higher and the treatment of sewage ditches with greenish levels is 68.17 SPAD units are 4.51% higher than natural conditions.

Stomata Density

Stomata density analysis on drainage repair treatment and orthogonal polynomial test analysis on the administration of fertilization doses observations are presented in Figures (a and b). Observations of 26 MAT showed that the stomatal density was significantly different between the drainage improvement treatments.The stomata density in natural conditions was 244.16 mm^{-2} (as control), the treatment of 320.17 mm^{-2} biopore holes was 53.56% higher. The stomatal density of the drain ditch treatment was 260.72 mm^{-2} and the heap footprint was 336.73 mm^{-2}, respectively 34.25% and 66.24% higher than the natural conditions. Heap footprint treatment produced the highest stomatal density compared to other treatments.

Heap footprint treatment can increase the greenness of the leaves and the highest stomata density compared to other treatments. This is due to the heap site of the treatment given to the oil palm plant, the bottom of the dish is raised 40 cm by taking the soil around the plant. The elevated section of the soil provides better aeration conditions, so the root environment is favorable for leaf greenness and stomata density compared to other treatments.

Nutrients and water donated from inside the biopore holes can be absorbed by plant roots, used for leaf midrib length growth, leaf greenness, and stomata density of oil palm plants. Biopore holes not only provide nutrients for plants, but also provide water that is stored in the soil (water reserves) during the dry season which can be used by plants. Heap footprint treatment by elevating the bottom (plate) of the plant as high as 40 cm, with a radius of 2 m, with the aim that the oil palm plants are not flooded during the rainy season. The excavation of the soil for the pile making is in the form of a basin, and filled with various types of biomass, this is also a source of nutrients for plants. The nutrients absorbed by plants are used for growth, development and production. The heap footprint also provides water stored in the basin, which the plants can use during the dry season.

The need for water for plants can be fulfilled from the reserves stored in the soil. Oil palm plants have sufficient nutrients and water so they can be used for growth, development, and supporting environmental factors. The results of research by

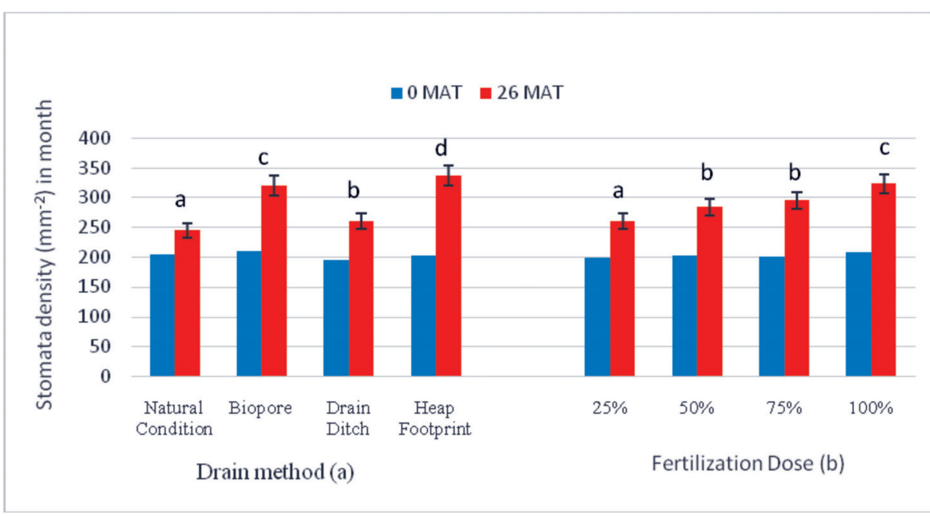

Fig. 8. Effect of improved drainage treatment and (b) fertilization dose on the stomata density of oil palm leaves 0 MAT-26 MAT observation

Brata (2007) show that the biopore holes can accommodate rainwater (as water reserves), and in the dry season it can be used by plants. The results of research by Darmosarkoro *et al.* (2008); Sumaryanto *et al.* (2015), which stated that an increase in leaf midrib length would also increase leaf stomata density and leaf greenness. According to Adnan *et al.* (2015), stated that the stem is an area of accumulation of plant growth, especially young plants, with the presence of nutrients it can drive the rate of photosynthesis in producing photosynthate, thus helping in the extension of leaf midrib and stomata to play a role in the photosynthetic process. The results of research by Loso *et al.* (2020), that the biopore holes in which litter are filled can increase the available nutrients, water, macroorganisms and soil microorganisms, so that nutritional needs are met for growth (leaf midrib length, leaf greenness, and stomata density) and the development of oil palm plants.

Palm Oil Production

The production of fresh fruit bunches (FFB) of 14 MAT-25 MAT observations in the highest drainage repair treatment was obtained by treating the biopore holes at 14.8 tons per ha per year, showing a very significant effect with other treatments. The administration of the highest fertilizer dose, namely 100% recommended fertilizer dose with a production of 15.1 tonnes ha^{-1} year^{-1}, showed a very significant effect with other treatments and the response curve was linear (Figure 9).

Treatment of soil drainage improvement and fertilization dose have a significant effect on the total productivity (FFB) of oil palm plants. The interaction in Table 1 shows that at the highest fertilizer dose (100%) and improved soil drainage compared to natural conditions, it has been able to

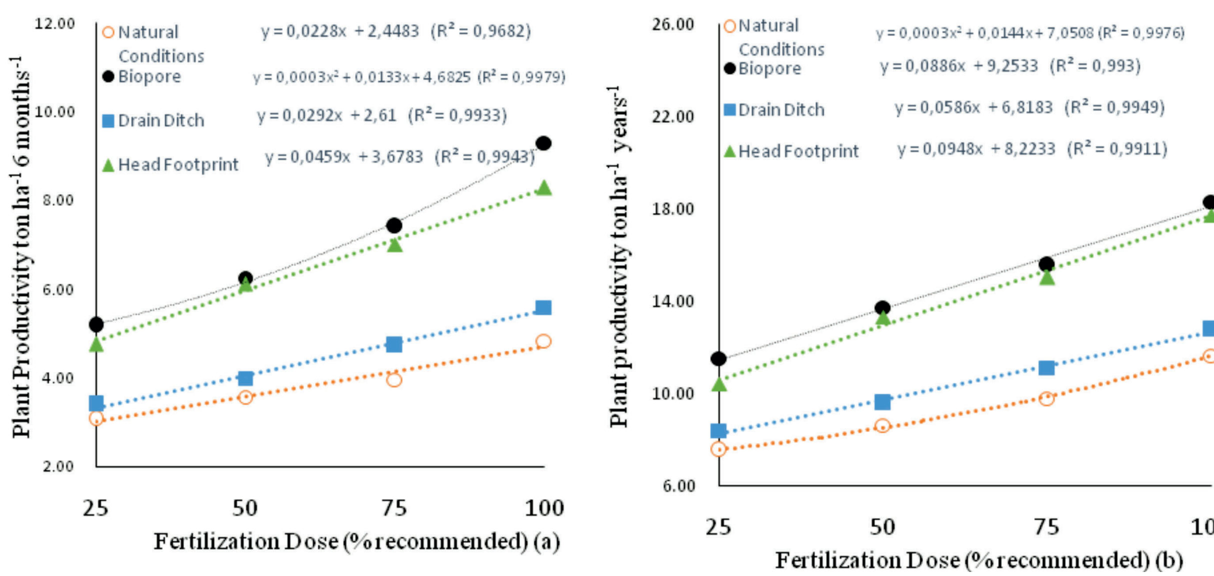

Fig. 9. The interaction effect of soil drainage improvement treatment and fertilization dose on (a) 6 months plant productivity (FFB) (14-19 MAT (b) 12 months (14-25 MAT)

Table 1. The interaction effect of soil drainage improvement treatment and fertilizer dose on total FFB production in one year

Drainage method	Fertilization Dose				Drainage average
	25%	50%	75%	100%	
	tonnes ha^{-1} year^{-1}				
Natural Conditions	7.57i	8.65h	9.80fg	11.66e	9.42
Biopore	11.55e	13.74c	15.56b	18.33a	14.79
Drain Ditch	8.41h	9.60g	11.14ef	12.78d	10.48
Head Footprint	10.43f	13.34c	15.06b	17.76a	14.15
Fertilizer average	9.49	11.33	12.89	15.13	

Note: The numbers followed by the same letter show the results are not significantly different based on the Duncan test at the 5% level.

significantly increase 53.32% and 57.20% in the heap footprint and biopore treatment, respectively. There was no difference between the biopore treatment and the pile site in producing plant productivity (FFB) at the highest fertilizer dose. According to Darmosarkoro *et al.* (2008), stated that oil palm plants require the provision of fertilizer doses according to recommendations to produce well. The results of research by Okoye *et al.* (2009) stated that the production of palm oil FFB is influenced by the dose of fertilizer applied and other environmental factors such as rainwater and sunlight.

The position of the biopore holes that are made vertically allows water to quickly enter and be absorbed into the soil and spread to all parts of the soil through the walls / sides of the biopore holes. Fertilization with the recommended 100% dose is used and absorbed properly by oil palm plants to produce high plant productivity. Other fertilizer treatments can also be well absorbed by oil palm plants but the dose given is still insufficient because it results in lower productivity. The heap footprint treatment gives the soil around the plate a looser condition and better aeration, allowing the plant roots to develop better in all directions to take up nutrients in the soil.

CONCLUSION

Biopore treatment can maintain and increase the highest water content at a depth of 0-60 cm in both the dry and rainy seasons and the lowest BD, midrib length, leaf greenness level, and the highest stomata density.Biopore treatment and fertilization with the recommended 100% dose is the best combination treatment to increase plant productivity (FFB) at six months and one year.The productivity of plants (FFB) produced at the age of 25 MAT [46 months after planting (MAT)] can reach 18.33 tonnesha^{-1}year^{-1} with a combination of biopore treatment and fertilization with the recommended 100% dose (1,000 g nitrogen + 500 g phosphate + 1,000 g potassium plant^{-1}year^{-1}).

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