EVALUATION OF PESTS INCIDENCE ON MATURE CIRAD INDONESIA OIL PALMS AT THE DARU GOLDTREE CLONAL GARDEN , KAILAHUN DISTRICT EASTERN SIERRA LEO

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Abstract: A total of nineteen (19) clones of CIRAD Indonesia oil palm seedlings were planted in 2015 at the Goldtree clonal garden in Daru, Jawei chiefdom, Kailahun District, Sierra Leone. They were improved imported varieties from Indonesia.

These seedlings were nursed in January 2015 at the Goldtree nursery site at Daru and transplanted in June 2015. The aim of the research was to evaluate pests affecting mature CIRAD Indonesia oil palms planted in 2015 at the Goldtree clonal garden in Daru. The experimental design consisted of Randomized Complete Block Design (RCBD) with nineteen clones as the treatments. Three sets of five of the mature oil palm trees were randomly selected and tagged from each clone and formed the samples for three (3) replications used.

Data was collected on redpalm weevil (Rhynchophorus ferrugineus) incidence, Rhinoceros beetle incidence and Mammalian rats (Rattus rattus diardii) incidence. The data was subjected to statistical analysis. The results obtained showed significant differences among the clones. Further examination of the mean scores for each clone revealed various levels of the variables; some clones showed least and highest red palm weevil incidence, other clones showed least and highest rhinoceros beetle incidence whilst certain clones showed least and highest mammalian rats attack. This confirmed that there is variability among the clones. Moreover, the proper management practices on these clones could assure farmers and the company of having high yield and improved breeding materials for subsequent planting, and thereby contributing to the achievement of Food Security in Sierra Leone.

Keywords: INCIDENCE.

Introduction

Goldtree SL LTD, a subsidiary of Goldtree Holdings, is a Sierra Leone registered international oil palm company located in Daru, Kailahun District. Established in 2008, GTSL LTD is an integrated agro-industrial company specialized in the cultivation of oil palm, extraction of crude palm oil and palm kernel oil. GTSL LTD has about 2075 hectares of oil palm plantations at Daru, Tovaima, Lower Jawei and Malema estates in Kailahun District of Sierra Leone. Based on planting periods, GTSL LTD has plantation blocks of 2009, 2010, 2014, 2015, 2016 and 2017 with plant varieties of CIRAD Indonesia, CIRAD Côtedl'vore and Ghana Sumatra imported from Indonesia, Ivory Coast and Ghana respectively. The company has a processing facility comprises of 20mt/hr fresh fruit bunch oil mill. The company is a major employer in the eastern part of Sierra Leone. GTSL LTD supports the communities it operates in, through investment in education, health and the environment which are essential factors in social economic development.

The oil palms (Elaeis) belong to the Arecaceae, or palm family. Scientific classification Kingdom: Plantae Division: Magnoliophyta Class: Liliopsida Order: Arecales Family: Arecaceae Genus: Elaeis Jacq. Species: Elaeis guineensis Elaeis oleifera (Rione Drevale et all.2017)

It is generally agreed that the Oil Palm (Elaeis guineensis) originated in the tropical rain forest region of West Africa. The main belt runs through the southern latitudes of Cameroon, Côte d'Ivoire, Ghana, Liberia, Nigeria, Sierra Leone, Togo and into the equatorial region of Angola and the Congo. Processing oil palm fruits for edible oil has been practiced in Africa for thousands of years, and the oil produced, highly coloured and flavoured, is an essential ingredient in much of the traditional

West African cuisine. The traditional process is simple, but tedious and inefficient.(Kwasi Poku-FAO 2002)

During the 14th to 17th centuries some palm fruits were taken to the Americas and from there to the Far East of the world. The plant appears to have thrived better in the Far East of the world (Kwasi Poku-FAO 2002).

The wild oil palm groves of Central and West Africa consists mainly of a thick-shelled variety with a thin mesocarp, called Dura. Breeding work, particularly crosses between Dura and a shell-less variety (Pisifera), have led to the development of a hybrid with a much thicker mesocarp and a thinner shell, termed Tenera. All breeding and planting programs now use this latter type, the fruits of which have a much higher content of palm oil than the native Dura..(Kwasi Poku-FAO 2002)

Generally, oil palms can be grown on wide range of soils. However, they thrive best in well- drained deep loamy moist and alluvial soils rich in organic matter. Oil palm is a humid tropical crop and thrives best in the areas where temperature ranges from 22°C to 24°C (minimum) and 20°C to 33°C (maximum). Oil palms require at least 5 to 6 hours of bright sunshine per day and 80% of humidity for optimum growth. This crop requires annual evenly distributed rainfall of 2500 to 4000 mm or 150 to 150 mm monthly (AgriFarming 2018)

Indonesia is the world's largest producer of palm oil (33.4 million tonnes), surpassing Malaysia (19.9 million tonnes), Thailand (1.8 million tonnes), Columbia (1.2 million tonnes), Nigeria (0.94 million tonnes), Ecuador (0.53 million tonnes) and Guatemala 0.52 million tonnes). Both Indonesia and Malaysia

account for about 84% of the world's palm oil production (GreenPalm 2016; FAO 2019).

Oil palm is the richest source of vegetable oil production and is the most sustainable crop to feed the hungry mouths of the world as it is recognized universally as the most efficient, effective and highest yielding form of edible oil production. The eco friendliness is manifested as a perennial plantation crop, maintains its green canopy throughout 30 years of its economic life and does not cause soil erosion, river siltation etc. Its benefit Cost Ratio is 1.8 and can replace the other no remunerative crops that are poising threat (Kalidas P. 2012).

Sierra Leone is located on the West African coast between 7 and 10° N Latitude and 10 and 14° W Longitude. The country occupies a land area of 72,300 km square with a total population of over 7 million people.

Sierra Leone has a hot tropical climate with two pronounced seasons: a rainy season from May to November, and a dry season from December to April which are ideal for oil palm production (Dep. of Agric. and Forestry 1995). The soils are suitable for oil palm cultivation in Sierra Leone. Flat or gently sloping terrain is preferable for ease of harvesting and transportation and to minimize erosion hazards. Steep lands and rocky or stony soils should be avoided. Suitable soils are of loam to clay texture, depth greater than 100cm, good to moderately good drainage, slightly acidic (pH 4.5-6) alluvia soils are the best (Crop production guidelines for SL July 2005).

Palm trees are naturally present across the country (SL) but large scale industrial plantations are concentrated in Kenema and Kailahun Districts in the East,

Bonthe, Moyamba and Pujuhun Districts in the South and the Western parts of Kambia and Port-Loko Districts (Crop production guidelines for SL 2005).

Oil palm is a staple practices in Sierra Leone and has several roles as a food and cash crop; palm oil is a constituent of the daily diet and is a rich source of carbohydrates, fats and vitamin A; locally, palm oil is utilized in soap making, palm wine obtained from the tree is a valuable beverage, the trunk is used to construct bridges in rural areas, baskets and roofs for houses are constructed from the fronds, palm kernel cake is used as livestock feed. Palm kernel oil is used in industry for the manufacture of soap margarine and cosmetics (Crop production guidelines for SL 2005).

Though the crop is more sustainable to growers, processors and to the government, however in recent years, heavy incidence of pests population is observed causing defoliation and thereby yield loss. This warrant growers and companies to form an integrated pest management plan team which is an effective and environmentally sensitive approach to pest management that relies on a combination of common sense practices (Kalidas P 2012).

Many pests found on oil palms are specific pests of several species of wild palms. Many pests found on oil palms are potential polyphagous. The most harmful pests of oil palm are; Red palm weevil, Rhinoceros beetles, Mammalian rats, Grasshoppers, Ants etc. Which prevent crop yield in Sierra Leone.

Research on Nutrition of the oil palm

The oil palm is predominantly cultivated on tropical soils that belong mainly to the soil orders Ultisol, Oxisol, and Inceptisol. The soils are highly acidic and have low buffering capacities. Oil palm is unrivalled in its ability to convert solar energy into dry matter and vegetable (palm) oil. However, this process requires large amount of nutrients which may be supplied by the soil or fertilizers. Unfortunately, most soils grown with oil palm have low soil fertility and therefore, mineral fertilizers are usually necessary to achieve and sustain good palm nutritional status and large yield. Consequently, fertilizers are essential for economic production as attested by ample field experiments and growth in fertilizer usage in the oil palm sector. For good yields to be sustained, fertilizer inputs are necessary and typically constitute 40-50% of total field upkeep cost (S.K NG et al. pp 415-416).

Oil palms require a balanced and sufficient supply of micro, macro and secondary nutrients for high production of palm oil. In oil palm cultivation, fertilizers should be applied at every 3 months interval. Starting from the June or July, 4 equal split doses of fertilizer should be applied at 3 months interval. In case of newly planted trees, first dose of fertilizers should be applied after 3 months of planting. Farm yard manure (FMY) of 75 to 100 kg or 90 to 100 kg of green manure and 5 kg neem cake should be added per each oil palm tree along with 2nd dose of fertilizers. These fertilizers should be applied in the soil with the help of field fork at least 40 to 50 cm away from the palm base. Do not forget watering the palm trees after fertilization.(AgriFarming 2018)

The fertilization that can be mineral, organic or a combination of both should be better optimized. Organic matter including cow dung (CD) is also preferable. Palm

trees have high nutritional demands and the calciferous, sandy soils in which they are often grown cannot always accommodate these needs (Gardening known how 2021).To support its growth and yield, it requires large amounts of nutrients such as nitrogen(N), phosphorus (P), potassium (K) and magnesium(Mg)(Journal of oil palm research 2006 p:204-209)

If oil palm yields are to be improved, then the implementations of good agricultural practices (GAP) are required. The round table on sustainable palm oil (RSPO) considers GAP; including good management of soil fertility is usually required as most soils cannot supply sufficient nutrients to meet palm demand (Goh 2005). Ng et al. (1999) proposed that on tropical soils of poor fertility, the total demand of a mature plantation producing 20 tonnes fresh fruit bunches (FFB) per year is 129.5 kg N, 16.4 kg P, 236 kg K and 38 kg Mg per hectare. Some of these nutrients are supplied in the rainfall, so the total inputs requirements to sustain the yield of 20 tonnes FFB is 112.5 kg N, 14.0 kg P, 204.4 kg K and 33.2 kg Mg per hectare per year. From these inputs, 10-20% is lost through leaching and runoff especially during periods of high rainfall (Bananas et al. 2015) and after large nutrients application (Comte et al. 2015).

From the nutrients taken up by the oil palm, 30-50% is allocated to the palm trunk (Corley 2009b). These nutrients are mostly no longer available to the palm for other purposes and are considered as being removed from the balance although palms are able to re-mobilize some nutrients from the trunk when concentration in the reserve tissue are sufficiently high (Foster and Prabowo 2006). Nutrients allocated to the oil palm leaves and male inflorescences are recycled within the plantation after pruning and harvesting, and do not affect the nutrient balance.

Nutrients allocated to the bunches are removed from the plantation at harvesting (Corley 2009; Donough et al. 2016) and are considered as being removed from the bunches. The share of the total nutrients in the balance are removed in 20 tonnes of bunches are 51, 64, 37 and 58% for N, P, K and Mg respectively. The nutrient content of crude palm oil (CPO) is negligible 44g N, 18g P, <10g K and 3g Mg per tonne CPO (Donough et al. 2016). This means that most of the nutrients remain behind in the empty bunches and in the mill waste streams, which can be recycled in the plantation to meet part of the plant nutrient demand (Chiew and Rahman 2002; Comte et al. 2013). To maximize yield, nutrients must be applied in the correct balance (Goh et al. 2009). The growth rate of oil palm seedlings depend fundamentally on the quality of set up techniques adopted (Hossan et al. 2005). The best vegetative growth which is able later to induce higher productivity of the plant material is determined by an optimal mineral nutrition (Manna et al. 2005), which guarantees the coverage of the needs of the crop. Palm trees require a combination of N, P, K and micro nutrients for optimal growth (Gardening Known How 2021).

Generally, the initial dose of palm fertilizer would be applied in early spring. If only two feedings are required, the second dose of palm tree fertilizer would be applied in mid summary. Over-fertilizing can be more harmful than not fertilizing at all (Gardening Known How 2021).

Potassium is the most important nutrient in the oil palm production as it plays important role in the conversion of light into biochemical energy during photosynthesis, the flow of assimilate from leaves to other plant organs, also

promote the storage of assimilates and again utilize the soil moisture more efficiently.

Magnesium is the central of the chlorophyll molecule, the green pigment in leaves which captures the light energy required for photosynthesis and also in fixation of CO_2.

Phosphorus is an essential element for plant growth and is particularly important for root growth during the establishment and early growth stages.

Nitrogen is most useful to seedlings and young oil palms that are immature.

Oil palm in Traditional Farming system

Oil palm is a humid tropical crop and thrives best in the areas where temperature ranges from 22°C to 24°C (minimum) and 20°C to 33°C (maximum). Oil palms require at least 5 to 6 hours of bright sunshine per day and 80% of humidity for optimum growth. The crop requires annual evenly distributed rainfall of 2500 to 4000 mm or 150 to 150 mm monthly, well- drained deep loamy moist and alluvial soils rich in organic matter and cannot do well in highly saline, highly alkaline, coastal sandy and water stagnation soils (Agrifarming updated 2018).

In the traditional farming system, palm trees are part of the productive landscape. In many cases, natural palm groves are the result of long-term resource management, where forest areas have been cleared for agricultural production, but leaving a number of well-spaced palm trees. In some other cases, palm trees have been planted as community or family palm stands as part of agroforestry systems. The palm fruits are collected from the trees and are later processed locally into red palm oil. In some other cases, the process is totally manual while others include the

use of mechanical pressing units, operated manually. The palm kernels are converted manually into soap or other products, while the tree's sap is collected –both from standing or cut down trees- for the production of palm wine (World Rainforest Movement 2010)

Oil palms are wide spaced perennial trees and inter space can be utilized for intercropping during initial 3 years period. Thereafter, shade loving crops can be grown. The care should be taken with inter-crops so that it will not compete with oil palms in terms of water, light and nutrients. The most suitable inter-crops during initial 3 year period are any vegetables, flowers, chilies, banana , tobacco, ginger , turmeric, pineapple etc. (Agrifarming updated 2018).

Ruminant-oil palm plantation integration is also another recognized agricultural practice which is commonly introduced in the oil palm farming system (Maximilian Kapa et al. 2018).

Research on oil palm in Africa

Wherever it grows naturally, oil palm has for centuries provided local communities with a large number of benefits such as palm oil, sauces, soap, wine, fertilizer (ashes), roofing (leaves), building material (trunk), medicines (roots). All of these traditional uses are until today very much part of the African culture in oil palm countries. (AgriFarming 2018)

The oil palm has long been valued for its versatility. All parts of the plant, from the roots to the flowers to the by-products, are used for food, traditional medicine, and for their important sociocultural value. Palm groves and oil processing, along with the other services related to palm production, have contributed to the development of our local economies and still do today, since these products are used in our communities for food (palm oil, wine and alcohol) and traditional medicine (soaps made from palm and palm kernel oils, ointments derived from palm kernel oil) (GRAIN 2014).

Peasants who earn part of their livelihood from oil palms are careful to protect them at all times, trimming the surrounding vegetation to prevent bush fires or other phenomena from harming the trees. Throughout the regions of some African countries, small-scale palm oil extraction is a very important economic activity for nearly all families and peasant farms. The industry employs not only growers but also processors and merchants. There are mills in each region for processing the kernels into palm kernel oil, offering an income-generating opportunity for producers in rural communities and a source of soap for consumers (GRAIN 2014).

In addition to oil, the main products extracted from the palms are fibre from the leaves and a beverage from the sap. Brewed palm wine is sold in small containers or bottles along roads and in hotels and bars in most countries in Africa. This traditional beverage is often used in celebrations (weddings, customary or religious rites), most notably in sacred groves in forested regions. Fibres and kernels left over from oil extraction are dried in the sun to be used as fuel for the future batches of palm oil. The ash from the process is spread on fields as fertilizer. The oilcakes (fibre and nut chaff) produced as a byproduct of the process is used as feed for cattle, pigs, and poultry. Processing techniques for oil palm products (palm oil, palm kernel oil, palm wine, and distilled palm alcohol) are a common feature of the history and traditions of these regions (GRAIN 2014)

When the European powers invaded the continent, they quickly realized that they could profit from trading palm kernels and palm oil, initially from natural palm stands and soon followed by the establishment of large-scale plantations, in most cases based on either forced or slave labour and in the appropriation of communities' lands (World Rainforest Movement 2010).

Independence resulted in the further entrenchment of the plantation system –encroaching on local peoples' lands- now based on state-owned enterprises with attached large industrial processing units. World Bank and IMF-led structural adjustment policies imposed on African governments in the 1990s resulted in the privatization of most of those industrial complexes and in the return of control over industrial palm oil production to foreign corporations. During the entire process summarized above, the traditional system -based on the harvesting of fruits from natural or semi natural palm stands and their conversion into palm oil through manual techniques- managed to successfully coexist separately from the different centralized systems put in place by governments and corporations. During the period 2006-2010, there was a boom in the promotion and announcement of industrial oil palm plantations for agrofuels in Africa, led by a broad array of foreign corporations eager to invest in the region. However, several of these plans are still in their initial phase and it remains to be seen if the palm oil produced in future will be for agrofuel or other uses (World Rainforest Movement 2010).

Palm oil is one of the most important agricultural crops used for various goods, from edible to no-edible products in Africa (Corley and Tinker, 2008; Murphy, 2009).

As of 2018, Nigeria was the third-largest producer in the World and first in Africa with approximately 2.3 million hectares (5.7 million acres) under cultivation followed by Ghana. Congo RD, Guinea, Angola, Ivory Coast, Guinea Bissau, Togo, Cameron, Madagascar, Carbon, Sierra Leone are all high oil palm producers in Africa. While the industrial model employs relatively few workers in its plantations and processing units –in the order of thousands- the traditional system provides products and incomes to millions of people -particularly women- involved in harvesting, processing and trading palm oil, palm kernels and palm wine (World Rainforest Movement 2010).

In general terms, most African governments are currently establishing enabling environments for large-scale corporate investments in industrial palm oil production, in many cases within the broader framework of export-oriented agrofuels and agricultural commodities (Kwasi Poku-FAO 2002).

Oil palm Research in Sierra Leone

The wild oil palms grow in many parts of Sierra Leone. It is a staple food crop and it's cultivation provides small scale farmers with cash to move from semi assistance to more commercial farming. Large plantations can provide employment in rural areas. Areas of oil palm density are found in parts of Kailahun and Kenema districts in the East, Moyamba, Pujuhun and Bonthe districts in the South and the western parts of Kambia and Port-Loko districts. There are sparse plantings in the Northern Bombali and Koinadugu districts (Crop production guidelines for Sierra Leone 2005).

Agriculture accounts for almost half of Sierra Leone's GDP and is the largest source of employment, engaging more than three-quarters of the population.

The agricultural sector remains highly vulnerable to financial, economic and environmental shocks. Palm oil is one of the most important agricultural commodities in Sierra Leone and has recently seen an increase in foreign and private investments in the sector (Cécile Bessouet al. 2018).

Through the Technical Assistance Facility (TAF) of the African Agriculture Fund (AAF), the EU has financed since 2012 support programmes for out-growers with the aim of sustainably increasing their income, efficiency and access to market. This was pursued through replanting strategies, training in agricultural practices and the identification of a roadmap for the development of rural roads (Cécile Bessouet al. 2018).

Crude palm oil (CPO) is the oil extracted from the mesocarp of oil palm fruits through artisanal or industrial methods. In the artisanal extraction, fruits are mostly pressed by foot stomping, whereas industrial extraction is mechanized. Artisanal oil is mostly extracted from the fruits of wild dura palms tree. When extracted the artisanal way, CPO is decomposed into two types of oils: one rich in carotenoids locally called 'red oil', and a more saturated oil locally called 'masanke'(Cécile Bessouet al. 2018).

Palm oil is produced almost everywhere in Sierra Leone, but most of the production occurs in high rainfall regions, in the southern and eastern parts of the country. It is mostly produced at an artisanal scale.

The largest part of the palm oil production is used to manufacture soap, which is in great demand into the West-African regional market and therefore mainly exported. In a context of galloping inflation of the national currency, this sub-

sector is vital and has a crucial function as cash generator (including foreign exchange such as Guinean Francs). '(Cécile Bessouet al. 2018).

Despite the abundance of palm trees and the traditional use of red oil, the domestic production is not sufficient to cover demand, and Sierra Leone is importing about one fourth of its palm oil needs. The overall deficit of palm oil for food use is also due to the high volumes diverted to soap manufacturing.

Currently, industrial stakeholders produce palm oil that is destined for soap manufacturing for more than half of their current level of production. The plantations production cycle lasts for at least 25 years. Most of the industrial plantations are currently at early stages of development, between 2 and 8 years old, the companies are not yet achieving their full production potential. Difficulties in transporting palm oil to Freetown, in particular during the rainy season, are a major bottleneck in the development of the sector (Cécile Bessouet al. 2018).

There are two main models of investments in the palm oil sector used by the industrial mills to ensure fruit procurement: the out-growers scheme and the concession scheme. In an out-growers scheme, a company provides a contract to a landowner for them to grow palm trees during a given period. In some cases, the company pays an annual fee to the landowners to get the exclusive right to purchase the fruits. The company does not directly take care of the palm trees, but provides improved material and training to the owners, and subsequently buys their production. In the concession scheme based on compensation (fee paid at the beginning), a company leases land under a contract with landowners. The company itself takes care of the husbandry, carrying out all the production activities. It compensates the landowner for the duration of the concession, and employs

preferentially the landowners' family and other inhabitants within the concession with a fixed salary. soap palm oil value chain in Sierra Leone is relatively stable and independent from most economic shocks and from the international palm oil markets. The value added of the whole palm oil value chain represented around 14% of the Sierra Leonean GDP, which is relatively high. 20% of the production is self-consumption by families, and the surplus is shared between sales for local consumption of traditional oil, and soap manufacturing for the regional market (Cécile Bessouet al. 2018).

Studies on Pests of oil palm

Oil palm is the richest source for vegetable oil production with a capacity of 4-6 tons of oil per ha per year. It is the most sustainable crop to feed the hungry mouths of the world as it is recognized universally as the most efficient, effective and highest yielding form of edible oil production. Though the crop is more sustainable in many ways to growers, processors and to the government, however in the recent years, heavy incidence of pest population is observed causing defoliation and thereby yield loss (Kalidas November 25, 2012).

Many pests found on oil palms are specific pests of several species of wild palms. Some insect pests are polyphagous. There are at least 80 species of arthropods that are potential pests on oil palms. As the plants grow, the plantation becomes a more favorable environment for pests (Kalidas November 25, 2012).

Palm oil is one of the most important agricultural crops used for various goods in the world, from edible to no-edible products (Corley and Tinker, 2008; Murphy, 2009). The main benefits of the crop are its high productivity compared to other oil producing crops (Basiron, 2007; Murphy, 2009; Wahid et al., 2005) and it is a

much more economic crop in terms of production input and cost (Carter et al., 2007; Murphy, 2009).

Great expansion of oil palm plantations transformed from natural habitat (Phalan et al., 2013) results in huge biodiversity losses and alteration of species communities, especially of higher trophic group structures (Chung et al., 2000; Donald, 2004; Fitzherbert et al., 2008). Even though worldwide environmental groups are highly concerned about the adverse effects of the transformation on the global ecosystem (Phalan et al., 2013; Wilcove and Koh, 2010), it seems that the oil palm expansion still continues, leading to even greater expansions in the future (Fitzherbert et al., 2008). Most studies on biodiversity loss due to oil palm generally proposed conservation strategies and mitigation processes which might not have direct economic benefit for the growers (Foster et al., 2011a; Savilaakso et al., 2014a). Investigating the effect of biodiversity loss due to oil palm expansion on ecosystem functions such as pest control, pollination, and soil processes might draw the grower's attention via their income if plantation sustainability might be affected by the reduction in ecosystem functioning (Foster et al., 2011a; Savilaakso et al., 2014a).

Similar to other monoculture, oil palm plantations suffer from attacks by insect pests (Gestablishmentch 2016;Corley and Tinker, 2008; Foster et al., 2011b). Data about their economic importance is still limited (Cooper and Rusli, 2014; Darus and Basri Wahid, 2001; Kamarudin and Wahid, 2010; Priwiratama et al., 2014; Ruf, 2000), but severe impacts on yield have been reported. For instances, bagworms (Lepidoptera: Psychidae) can cause 33-50% yield losses at high infestation levels (Kamarudin and Wahid, 2010), nettle caterpillars (Lepidoptera:

Limacodidae) cause about 30% yield reduction after the first and second year of infestation respectively (Potineni and Saravanan, 2013), rhinoceros beetles (Oryctes rhinoceros (L.)) reduce yield by about 25% (Göttingen 2016); high abundance of rats destroy around 5 - 10% of the yield (Wood and Fee, 2003)

Management of monoculture plantations often creates unfavorable condition for biological control agents such as predatory birds, ants, and beetles (Foster et al., 2011a; Senior et al., 2013). Compared to pesticide applications, biological control (short: biocontrol) is known as a sustainable and ecofriendly solution to reduce pest numbers below economic levels by using natural enemies (Hajek, 2004; Norris et al., 2003).

However, despite the decline in use of broad spectrum-long residual contact-insecticides (bslrcs), pest numbers have still continued to reach detrimental numbers in many locations (Kamarudin and Wahid, 2010).

Defoliating pests, in particular bagworms (Psychidae) and nettle caterpillars (Limacodidae), play the most important roles in reducing crop yield due to their high reproduction and mobility (Wood, 2002). Significant pest attacks can be related to an imbalance between pests and their natural enemies (Igbinosa, 1992; Wood, 2002). Studies on the biocontrol of pests have mostly focused on the introduction of exotic biocontrol agents to the field or on the assessment of potential agents (Bakeri et al., 2009; Kamarudin and Wahid, 2010; Zeddam et al., 2003), rather than on evaluating factors influencing native enemy populations. There has been no comprehensive study that links pests to native biocontrol agents in oil palm plantations (Fosteret al., 2011a; Savilaakso et al., 2014b).

However, substantial yield losses from pest attacks are becoming major threats to the oil palm industry, while the potential role of conservation biological control, a sustainable and environmentally friendly solution for pest control, is still largely unknown

Studies on oil palm Yield

Palm oil is the world's highest yielding oil crop, with an output 5–10 times greater per hectare than other leading vegetable oils. It is a highly productive crop with a yield far greater than other vegetable oils, meaning that less land is needed to grow it (WWF 2013).

Oil palm, currently the world's main vegetable oil crop, is characterised by a large productivity and a long life span (≥25 years). Peak oil yields of 12 t per ha per yr have been achieved in small plantations, and maximum theoretical yields as calculated with simulation models are 18.5 t oil per ha per yr , yet average productivity worldwide has stagnated around 3.9 t oil per ha per yr . With an overview of the available data on yield-determining, yield-limiting, and yield-reducing factors in oil palm; the effects of these factors on yield, as calculated using computer models; and the underlying plant-physiological mechanisms, four production levels are distinguished: the potential, water-limited, nutrient-limited, and the actual yield. The potential yield over a plantation lifetime is determined by incoming photo synthetically active radiation (PAR), temperature, atmospheric CO_2 concentration and planting material, assuming optimum plantation establishment, planting density (120–150 palms per hectares), canopy management (30–60 leaves depending on palm age), pollination, and harvesting. Water-limited yields in environments with water deficits >400 mm year can be less than one-third of the potential yield, depending on additional factors such as temperature, wind speed, soil texture, and soil depth. Nutrient-limited yields of less than 50% of the potential yield will be recorded when nitrogen or potassium were not applied. Actual yields are influenced by yield-reducing factors such as unsuitable ground vegetation, pests, and diseases, and may be close to zero in case of severe infestations (Elsevier. B et al. 2016).

Smallholders face particular constraints such as the use of counterfeit seed and insufficient fertilizer application. Closing yield gaps in existing plantations could increase global production by 15–20 Mt oil per yr , which would limit the drive for further area expansion at a global scale. To increase yields in existing and future plantations in a sustainable way, all production factors need to be understood and addressed. (European Journal Of Agronomy 2017 pp 57-77).

Oil palm trees start to bear fresh fruit bunches (FFBs) after three years of planting, each tree can produce 10 tonnes of fresh fruit bunches per hectare, each individual Pierce of fruit on fruit bunch contains 50% oil, and an average 3.9 tonnes crude palm oil and 0.5 tonnes of palm kernel oil can be extracted per hectare (GreenPalm 2016).

A new variety of oil palm developed using traditional plant breeding techniques will increase crude palm oil yield by up to double current levels, says SMART Tbk, a subsidiary of Green-Agri Resources (GAR). The two clones of oil palm planting materials called Eka1 and Eka 2 have been registered in Indonesia catalogue of seeds and were approved for use by the country's ministry of Agriculture. Eka1 are seedlings are expected to yield 10.8 tonnes of crude palm oil (CPO) per hectare at the palms' prime age (between 10 and 18 years), with extraction levels of 32%. Eka2 seedlings meanwhile are expected to yield 13 tonnes per hectare and to generate extra levels of 36%. This is an increase of around one-fifth from oil palm's current capacity of between 7.5 and 8 tonnes per hectare per year under optimal conditions and significantly more than Indonesia's industry average which sits at less than 4 tonnes (GAR 2017).

Higher yields are not necessarily associated with proportionally higher quantities of agrochemicals; organic fertilizers and improved management can also play important roles in reducing the yield gaps (Darras et al. 2018).

Breeding research could also contribute to increasing oil palm productivity (Zulkifli et al. 2018).

Development of oil palm Industries in Africa

Palm groves and oil processing, along with the other services related to palm production, have historically contributed to the development of our local economies Africa and still do today, since these products are used in our communities for food (palm oil, wine and alcohol) and traditional medicine (soaps made from palm and palm kernel oils, ointments derived from palm kernel oil) (GRAIN 2014)

In Africa, the oil palm industry is characterized by various types of agro-systems ranging from large agro-industry plantations to all scale farmers, who may or may not be recognized into cooperatives. Several supply models also co-exist, from fully integrated agro-industry companies with oil mills which procure from their own plantations to out growers' scheme, to small scale producers. The local industry contends with a number of constraints, including little demand-driven research, limited access to land and finance, high production cost, low levels of technology, low extraction rates and poor quality CPO, and lack of adequate government support Some African governments are targeting oil palm as a key sector for agricultural growth and to address rural poverty (Ofosu- Budu, K. and D. Sarpong 2013).

However, the sector current expansion is driven largely by large-scale agro-industry and favours large plantations for economies of scale, which raise the question of whether and to what extent small-scale farmers, including women, can successfully compete, capture a share of the value addition of the growing sector and improve their incomes (Ofosu-Budu, K. and D. Sapong 2013).

Although the oil palm boom has been a driver of economic growth in producing countries in Africa, it has also led to substantial critics due to negative environmental and social effects (Pye 2019) and the expansion of the oil palm areas has contributed to tropical deforestation and associated biodiversity loss, greenhouse gas emissions, land degradation (Clough et al. 2016; Dislich et al. 2017).

From the social perspective, local rural communities are often claimed to suffer from the oil palm expansion driven by large companies due to conflicts over land and worker right (Hiduyal et al. 2018; Pye 2019). More recently, industries with large mills that produce refined palm oil have also gained in importance i n Africa (Runl and Qaim 2019)

Many West African countries (and countries in other parts of Africa) have plans to expand and develop oil palm plantations. Bouyed by rising producer prices, strong international demand from biofuel markets, and several Africa countries have formulated national programs to encourage both national and foreign investment in new oil palm plantations (Ofosu-BUDU and D. Bruce SARPONG 2013).

Statement of Problem

In the cultivation of oil palm, whether in large plantations or small farms, pests prevent the healthy growth and cause significant reduction in growth and crop yield. This decrease in yield may sometimes be attributed or cause by wide range of variability among clones. Other variation may result to differences in susceptibility or resistance of certain clones. Identifying such clones will make better crosses to produce resistance hybrids and improved planting materials.

Aim

The aim of this research is to evaluate pests affecting mature CIRAD Indonesia oil palms planted at the Goldtree clonal Garden in Daru.

Objectives

The main objectives of this research are:

1. To assess Redpalm weevils (Rhynchophorus ferrugineus) incidence on mature CIRAD Indonesia oil palms

2. To assess Rhinoceros beetles incidence on mature CIRAD Indonesia oil palms

3. To assess Mammalian Rats (Rattus rattus diardii) incidence on mature CIRAD Indonesia oil palms

Justification of the Study

Research on the incidence of pests on mature CIRAD Indonesia oil palms planted at the Goldtree clonal Garden in Daru is of relevance several in several ways .

Firstly, identifying such clones that are resistant to such pests is suitable for breeding programs.

Secondly, crosses among them can give suitable hybrids which farmers could grow to alleviate poverty thus promoting food security in the country.

Thirdly, youths that are unemployed can easily gain employment in the locality.

Also, acquiring skills in the growing oil palms can make them become self-reliant.

Finally, this piece of work can serve as a reference material for who so ever that may want to go into such a related work or field.

METHODOLOGY

Location and Climate of the Study area: The research area is located in Daru Goldtree clonal garden, Jawei chiefdom Kailahun district Eastern Sierra Leone. It lies on Lat. 7° 59'23.14" N and Long -10°50'32.03" W in the Eastern part of Sierra Leone. The research area is approximately 25 miles (40 kilometers) away from Kenema and approximately 167 kilometers from the capital city- Freetown.

The study area is characterized by two tropical seasons; the wet season which starts from May to November and the dry season which starts From December to April.

The study area has a tropical monsoon climate with moderate to little rainfall from December to February and heavy to very heavy rainfall starting from late March to November. Annual rainfall ranges between 100 and 120 inches and about 85 percent which falls between May and November (Climate-Data-Org. 2020).

Soils of the Study Area: The research area is characterized by granite, acid gneiss and weathered and leached lateritic soils which exhibits reddish to yellowish brown colour. It is moderately well drained, fertile with good water holding capacities and has a productivity potential (International Course on Soil Science-x1v pp: 18)

Description of the Clones: The oil palms were planted in plots, with each clone occupying approximately 150 oil palm trees per hectare.

Treatment and Experimental Design: The number of mature oil palms forms the population. Each clone was planted in an identified plot. A set of five (5) mature oil palms were randomly selected from each clone and marked with White paper that formed a sample for the treatment in replication one (1). Another set of five (5) mature oil palms were randomly selected from the same clone and marked with white cards that formed a sample for the treatment in replication two (2). A third set of five (5) mature oil palms from the same clone were randomly selected and marked with white cello tape that formed a sample for the treatment in replication three (3).These mature oil palms were subjected to scoring for pests incidence; where 1 is clean-no infection or highly tolerance/resistance and 5 is severely damage or highly susceptible. This depicts that the research was carried out in a Randomized Complete Block Design (RCBD).

Population and Sample Size: The mature oil palms were assigned into plots. Each plot contains a clone containing approximately 150 oil palm trees per hectare which forms the population.

The five (5) randomly selected oil palm trees from the experimental plot. Each clone forms a treatment unit. The nineteen (19) clones therefore mean that there are nineteen treatments. The total land area for the entire oil palms is 263.17 hectares.

Time of Planting: A mature virgin bush was brushed and cleared. The immature oil palms (seedlings) were transplanted in June 2015 to ensure that all the oil palms take off at the same time.

Data Collection: Data were collected on the following;

Invertebrate-Redpalm weevil (Rhynchophorus ferrugineus)

- ✓ Holes in the crown or trunk accompanied by oozing brown viscus liquid
- ✓ Withered bud/crown
- ✓ Fallen empty pulpal cases and death of infested palms
  27
- ✓ Chewed plant tissues in and around opening of tunnels with a typical fermented odour
- ✓ Breaking of trunk or toppling of the crown
- ✓ Drying of off- shoots in the middle of the trees
- ✓ Crunching noise produced by feed grubs which become pronounced and leads to the destruction of the trunk and fronds

1- Clean; no infection or highly resistant

5- Severely damage; highly susceptible

Invertebrate- Rhinoceros beetle

- ✓ Adults feed in the crown region of the oil palms
- ✓ Bore the oil palms through the petiole bases into the central leaves
- ✓ Tissue maceration and fibrous grass inside the feeding hole
- ✓ Fronds have wedge- shape gaps or characteristic aerated cut (fan shaped fronds)

1-clean; no infection or highly resistant

5-severely damage; highly susceptible

Mammalian rats (Rattus rattus diardii)

- ✓ Rats gnaw through the lower fronds through holes around the base of the palm
- ✓ Rats cut the raw and ripened fruits and hoard them in burrows

1-Clean; no infection or highly resistant

5-Severely damage; highly susceptible

Statistical Analysis: The research was done in Randomized Complete Block (RCB) design with nineteen (19) clones as the treatments.

RESULTS AND DISCUSSION

So far, detailed work has not been done and reported on pests on mature oil palms at the Daru Goldtree clonal garden. Therefore, little is unknown or known about pests' incidents at the Daru clonal garden and the country as a whole.

The result reported here were obtained during the dry season in March 2021 at the Daru Goldtree clonal garden. Furthermore, the results to be presented here shall be done according to the objectives of this research.

- ✓ To assess red palm weevil incidence mature CIRAD Indonesia oil palms
- ✓ To assess Rhinoceros beetle incidence on mature CIRAD Indonesia oil palms
- ✓ To assess Mammalian rats incidence on mature CIRAD Indonesia oil palms

Assess Red palm weevil Incidence on Nineteen Clones of mature CIRAD Indonesia oil palm trees

Figure 1 illustrates the percentage distribution of mature CIRAD Indonesia oilpalm trees scored in the field.

Three categories of red palm weevil attack were observed; least infested, moderately infested and highly infested.

The least infested category had mean score ranging from 1.10-1.31, the moderately infested category had mean score ranging from 1.32-1.52 and the highly infested category had mean score ranging from 1.53-1.73.

There were significant differences among the varieties as far as scoring were concerned. Variety 9 (D5G) with a mean score of 1.73 showed the highest score for red palm weevil attack and therefore highly susceptible to redpalm weevil attack. Also, variety 16 (D7C) showed the lowest score of 1.10 for red palm weevil attack on oil palm trees and therefore highly resistant to redpalm weevil attack.

Rating of the nineteen varieties of CIRAD Indonesia in terms of percentage basis, the least infested category had a percentage of 42.00, which include variety 2 (D4D), variety 7 (D5E), variety 10 (D5H), variety 15 (D7B), variety 16 (D7C), variety 17 (D7D), variety 18 (D7E) and variety 19 (D7G) CIRAD Indonesia. The moderately infested category had a percentage of 32.00, which include variety 1 (D1C), variety 3 (D5A), variety 4 (D5B), variety 8 (D5F), variety 12 (D5J) and variety 13 (D6G) CIRAD Indonesia. The highly infested category had a percentage of 26.00 which include variety 5 (D5C), variety 6 (D5D), variety 9 (D5G), variety 11 (D5I) and variety 14 (D7A) CIRAD Indonesia.

The overall picture on the percentage distribution for redpalm weevil attack for nineteen clones of mature CIRAD Indonesia oil palm trees is summarized in figure one (1).

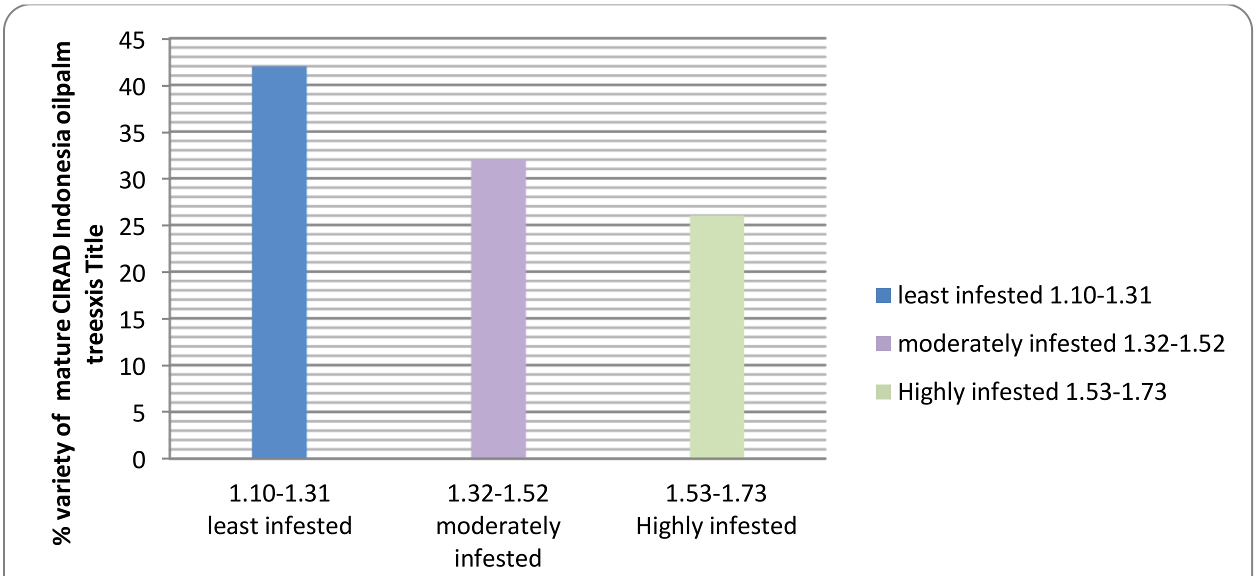

figure 1 percentage distribution of mature CIRAD Indonesia oilpalm trees scored in the field

Assess Rhinoceros beetle Incidence on Nineteen Clones of mature CIRAD Indonesia oil palm trees

Figure II illustrates the percentage distribution of mature CIRAD Indonesia oil palm trees scored in the field.

Three categories of rhinoceros beetle attack were observed; least infested, moderately infested and highly infested.

The least infested category had mean scores ranging from 1.07-1.18. The moderately infested category had mean scores ranging from 1.19-1.29 and highly infested category had mean scores ranging from 1.30-1.40.

There were significant differences among the varieties as far as scoring were concerned. Variety 9 (D5G), variety 11 (D5I), and variety 13 (D6G) recorded the highest mean score of 1.40 and therefore highly susceptible. Also, variety 3 (D5A), variety 15 (D7B) and variety 16 (D7C) recorded the lowest mean score of 1.07 each and therefore highly resistant to rhinoceros beetle attack.

Rating of the nineteen varieties of CIRAD Indonesia interns of percentage basis, the least infested category had a percentage of 16.00, which include variety 3 (D5A), variety 15 (D7B) and variety 16 (D7C) CIRAD Indonesia. The moderately infested category had a percentage of 47.00, which include variety 1 (D1C), variety 2 (D4D), variety 4 (D5B), variety 5 (D5C), variety 7 (D5E), variety 10 (D5H), variety 17 (D7D), variety 18 (D7E) and variety 19 (D7F) CIRAD Indonesia. The highly infested category had a percentage of 37.00, which include variety 6 (D5D), variety 8 (D5F), variety 9 (D5G), variety 11 (D5I), variety 12 (D5J), variety 13 (D6G) and variety 14 (D7A) CIRAD Indonesia oil palm trees.

The overall picture on the percentage distribution for rhinoceros beetle attack for nineteen clones of mature CIRAD Indonesia oil palm trees is summarized in figure two (2).

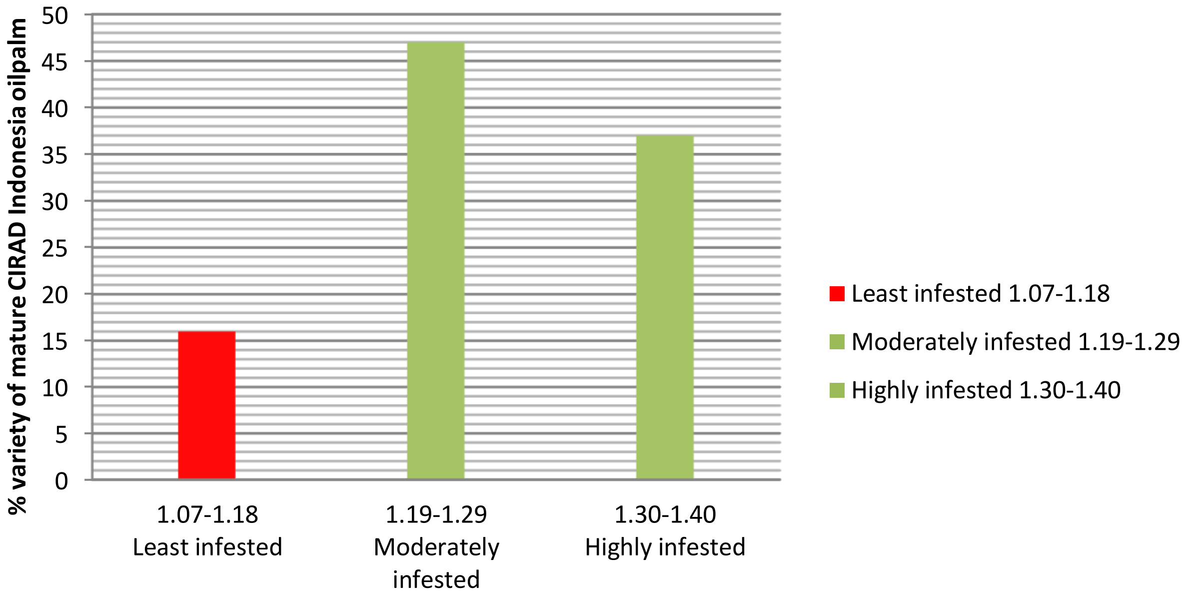

figure II illustrates the percentage distribution of mature CIRAD Indonesia oilpalm trees scored in the field

Assess Mammalian rats Incidence on Nineteen Clones of mature CIRAD Indonesia oil palm trees

Figure III illustrates the percentage distribution of mature CIRAD Indonesia oilpalm trees scored in the field.

Three categories of mammalian rats attack were observed; least infested, moderately infested and highly infested.

The least infested category had mean scores ranging from 1.13-1.42. The moderately infested category had mean scores ranging from 1.43-1.71 and the highly infested category had mean scores ranging from 1.72-2.00.

There were also significant differences among the varieties as far as scoring were concerned. Variety 6(D5D) with a mean score of 2.00 showed the highest score of mammalian rats attack and therefore highly susceptible. Also, variety 16 (D7C) showed the lowest score of 1.13 for mammalian rats attack on oil palm trees and therefore highly resistant to mammalian rats attack.

Rating of the nineteen varieties of CIRAD Indonesia interms of percentage basis, the least infested category had a percentage of 21.00, which include variety 1 (D1C), variety 4 (D5B), variety 15 (D7B) and variety 16 (D7C) CIRAD Indonesia. The moderately infested category had a percentage of 42.00, which include variety 3 (D5A), variety 7 (D5E), variety 10 (D5H), variety 12 (D5J), variety 13 (D6G), variety 17 (D7D), variety 18 (D7E) and variety 19 (D7F) CIRAD Indonesia oil palm trees.

The overall picture on the percentage distribution for mammalian rats attack for nineteen clones of mature CIRAD Indonesia oil palm trees is summarized in figure three (3).

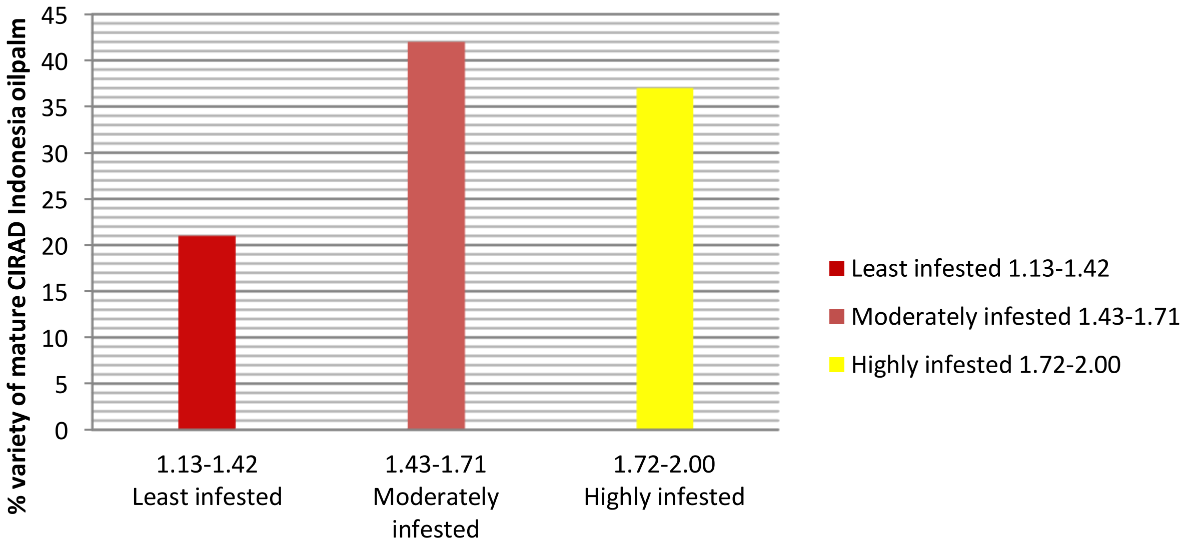

figure III illustrates the percentage distribution of mature CIRAD Indonesia oilpalm clones scored in the field

SUMMARY, CONCLUSION AND RECOMMENDATIONS

Based on the methodology of this research, findings are summarized, conclusions drawn and recommendations made according to the objectives of the research.

Summary

The research revealed a number of key and relevant issues on the evaluation of pests' incidence on mature CIRAD Indonesia oil palm varieties in the Daru clonal garden.

There were nineteen (19) clones of mature CIRAD Indonesia oil palms established in nineteen (19) different plots. These were assessed for Redpalm weevil incidence, Rhinoceros beetle incidence and Mammalian rats attack incidence. Adequate results from the analysis of variance table at 5% level of probability based on the Least Significant Difference (LSD) and the mean score for each clone were recorded accurately and accordingly.

Red palm weevil incidence

The analysis of variance for the red palm weevil incidence showed significant variation among the treatments at 5% level of probability. The highest and lowest scores for the redpalm weevil incidence were 1.10 and 1.73 respectively. In percentage basis, the least infested mean score category was 42.0%, the moderately infested category was 32.0% while the highly infested category was 26.0%.

Rhinoceros beetle incidence

The analysis of variance for the Rhinoceros beetle incidence showed insignificant variation among the treatments at 5% level of probability . The highest and lowest mean scores for the Rhinoceros beetle incidence were 1.40 which indicates high susceptibility and 1.07 which indicates high resistance. The slowest mean score category was 16.0%, moderately infested mean score category was 47.0% while the highly infested mean score category was 37.0%.

Mammalian rats attack

The analysis of variance for the mammalian rats attack showed highly significant variation among the treatments at 5% level of probability. The lowest and highest mean scores for the mammalian rats attack were 1.13 and 2.00 respectively. The least mean score category recorded 21.0%, the moderately infested mean score category recorded 42.0% while the highly infested mean score category recorded 37.0%.

Conclusion

Based on the research summary, the following conclusions are drawn.

Red palm weevil incidence

The research revealed that the redpalm weevil incidence on the nineteen (19) clones are least infested by 42.0%. This means that clones that belong to this category are mildly infested and therefore do not suffer immensely from redpalm

weevil attack. The moderately infested category showed 32.0% of the total palms indicating that the clones that fell in this category are destroyed by pests but not to a greater extent. The highly infested category showed 26.0% of the total treatments indicating that they are highly susceptible to redpalm weevil attack and their destruction is higher as compared to the other categories of clones. The weevils severely damaged the trees by creating holes in the trunk leading to the destruction of the tree sap which contain glucose and which is essential for plant growth. The holes created in the trunk by the weevil may also destroy the reservoir capacity of the palm that contributes to transpiration. Also, holes on the fronds of the palms may serve as entry sites for insects and diseases. Activities of the weevils on the fronds, crowns or bud of the trees will lead to the destruction of the leaves and hence minimizing the photosynthetic site and rate of the trees.

On a whole, a greater percentage of the nineteen (19) clones showed resistant characters and therefore accounted for appreciable yield.

Rhinoceros beetle incidence

The study revealed that the Rhinoceros beetle incidence on the nineteen (19) clones had a least infested category of 16.0% meaning that only few treatments were clean and therefore highly resistant to Rhinoceros beetle attack. The moderately infested category showed 47.0% of the total palms of the treatments indicating that the trees are infested by the pests but not to a higher degree. This also revealed that the beetles attack the trees but not severely damaging the trees.

Furthermore, the highly infested category showed 37.0% of the total number of the treatments which means that the trees were highly susceptible and therefore severely damaged the trees; the pests feed greatly in the crown region of the oil palm tree leading to the destruction of the leaves which are responsible for photosynthesis, evaporation and transpiration processes, hence leading to low yielded.

Mammalian rats attack

Finally, the mammalian rats attack showed division of categories. The least infested category had 21.0%, indicating that clones within this category are least infested and therefore highly resistant to mammalian rats attack. The moderately infested category had 42.0% indicating that the clones found in this category are not severely damaged and therefore resistant to mammalian rats attack. The highly infested category had 37.9% of the total number of palm trees of the nineteen (19) clones indicating that clones that fall in this category are highly susceptible to mammalian rats attack and therefore severely damaged.

It could be concluded that the establishment of the underground galleries around the base of the palm trees serve as a source of food for the trees and increase the activities of the microorganisms. Contrarily, the galleries also serve as harbouring site for rats leading to the destruction of fruits and roots of the trees. This detard nutrient uptake, fruit formation and anchorage and will sometimes result to low yield.

RECOMMENDATIONS

In considering the conclusions of this research, the following recommendations on mature CIRAD Indonesia oil palm trees are made based on the objectives of the research.

Red palm weevil incidence

The mean score for the red palm weevil incidence on mature CIRAD Indonesia oil palm varieties was appreciable and seems suitable for further production.

The following are also recommended.

- Highly susceptible varieties to redpalm weevils attack such as variety 5 (D5C), variety 6 (D5D), variety 9 (D5G), variety 11 (D5I) and variety 14 (D7A) should be treated by the use of insect collector (D) and should be half filled with diesel, kerosene or paraffin to minimise redpalm weevil incidence.
- Destroy beetles by putting up mercury-vapour light traps at regular intervals in infested plantations.
- Use hooked wire to extract larvae that are boring into young crown.
- Introduce pest's surveillance to destroy the pests in the plantation.
- Highly resistant varieties such as variety 2 (D4A), variety 7 (D5E), variety 10 (D5H), variety 15 (D7B), variety 16 (D7C) variety 17 (D7D), variety 18 (D7E) and variety 19 (D7F) should be maintained for subsequent breeding programmes.

Rhinoceros beetle incidence

The high infestation rate of 37.0% showed high rate of susceptibility of palm trees of certain clones.

The following are recommended.

- Use sanitary measures such as pruning or removal of dead palms or palms beyond recovery are essential as they will create ideal breeding places for the pests.
- Wounding the palms like making cutting steps to facilitate climbing should be avoided as this will facilitate entry points for pests.
- Use potassium cyanide and carbon bisulphate on cuts and holes on trees to prevent pest's invasion.
- Treat infested tree trunks with phostoxin tablets and then sealed with gypsum or cement in order to prevent further damage on the trees.
- Use correct management practices on highly susceptible varieties; variety 6 (D5D), variety 8 (D5F), variety 9 (D5G), variety 11 (D5I), variety 12 (D5J), variety 13 (D6G) and variety 14 (D7A) as continuous beetle epizootic can accumulates which may sometimes lead to the loss of the whole plantation.
- Kill adult beetles inside the palms by injecting insecticides into the trunk or fumigate the trees infested.

Mammalian rats attack

The rats infestation rate of 37% need intensive control measures to combat such clones that are infested

The following are recommended.

- Use physical control methods such as setting traps, hunting, alarms and caricature to minimise rats' infestation.
- Use poison baits even though environmental unfriendly but should be done with care; a mild dosage mixture of zinc phosphate at 30 - 50g with 1kg of flour and 3% of cooking oil, paste the mixture around the palms at the entry point of the galleries. This will minimise rats' infestation.
- Use active anticoagulant such as "finale" (chemical product) as an active ingredient to control pests is also recommended.
- Finally, this research will serve as a guide in planning for the Ministry of Agriculture, Forestry and Food Security (MAFFS) to alleviate poverty and food security in Sierra Leone.

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