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Agronomic Practices and Macronutrients Status of Different Age Groups of Smallholder Oil Palm (*Elaeis guineensis* Jacq.) Plantations in Dibombari Sub-Division, Cameroon

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Abstract

Oil palm is cultivated by agro-industries and smallholders for vegetable oil production. Good farm management practices with balanced soil and plant macronutrients are needed to attain optimum yields. Smallholder oil palm farmers of Dibombari Sub-Division, Cameroon, suffer from low on farm yields which could emanate from the agronomic practices implemented, which also has an influence on the soil and plant macronutrient status. This study provides information on the agronomic practices, soil and plant macronutrients status in smallholder oil palm fields. Structured questionnaires were administered to 200 farmers to collect data on their agronomic practices, using a stratified random sampling design. Soil and plants were sampled from plantations of different age groups (control, >0 - 4 years, >4 - 8 years and >8 - 15 years' plantations) in four locations of the Sub-Division (*i.e.* Dibombari-central, Bonamateke, Bomono and Nkapa) using a randomized complete block design. Data collected, was analyzed using descriptive and inferential statistics. The results showed that 65% of farmers planted Tenera variety, with majority of them below the standards for weeding (81%), fertilizer use (100%), pruning (62%), pest/disease control (90.5%) and harvesting (96%) practices. Soil macronutrients were low across the different plantations except P which was optimal at >0 - 4 years and >4 - 8 years' plantations but low at >8 - 15 years' plantation. Similarly, for plant macronutrients, N and P were optimal across the different plantations, while K and Mg were optimal at >0 - 4 years' plantation but low at >4 - 8 years and >8 - 15 years' plantations. Thus, agronomic practices and macronutrient status of soil and plants were below standards in smallholder oil palm plantations of Dibombari, leading to low yields of fresh fruit bunches.

Keywords

Smallholders, Oil Palm Plantations, Agronomic Practices,
Soil and Plant Macronutrients

1. Introduction

Oil palm (*Elaeis guineensis* Jacq) belongs to the family Palmae and is a perennial tree crop [1]. Oil palm is one of the most important vegetable oil crops grown in the past decades as a result of an increase demand in palm oil, leading to fast expansion and cultivation of the crop worldwide [2]. Oil palm has greater potential of productivity than other vegetable oil crops with less land area required and suppliers over one-third of vegetable oil globally [3]. Indonesia and Malaysia currently produce about 85% of global palm oil [4], while Africa produces just about 4%.

Many countries in Africa depend on agriculture (*i.e.* food, raw materials and livelihood) for economic growth and development and oil palm is no exception to this allusion [5] [6]. In Africa generally, oil palm plantations are managed and controlled by agro-industries that have their own industrial mills and by smallholders who either supply their fresh fruit bunches (FFB) to the industrial mills or process in small-scale artisanal mills [7]. Fresh fruit bunches from industrial farms are obtained over large uniform lands that range between 3000 and 5000 ha and are mainly for sale, as opposed to smallholders who produce for both home consumption and for sale with very low yields [8]. Smallholders are individual farmers or group of individual farmers that own oil palm plantations between 1 and 500 ha or more, as what is seen in Cameroon [9]. However, the Roundtable on Sustainable Palm Oil (RSPO) describes smallholders as farmers with less than 50 ha of oil palm estates [9] [10]. Previous studies by Nkongho *et al*., [10], distinguished oil palm farmers into different categories; native farmers, migrants and elite farmers and the farm holdings into small (0 - 5 ha), medium (5 - 20 ha) and large holdings (>20 ha).

Typically, Cameroon has so many smallholder production models which are based on different financing, land tenure, management, environmental and social factors, as well as livelihood benefits [11]. According to Hoyle and Levang [12], smallholders are categorized into two broad groups which include; independent farmers and scheme farmers or contract farmers (supervised smallholders). The first group of farmers manages their plantations without any government or private support, as such, they sell the FFB/palm oil to any buyer. On the other hand, the contract or supported farmers are given assistance either by the government or private sectors. In other words, they are provided with inputs/assistance like quality planting seeds or seedlings, fertilizers and pesticides; technical and managerial support and even financial support [11] and as such, they are supposed to supply their FFB to the nucleus estate mills.

Generally, high spatial variability in soil nutrients is due to the combine effects of physical, chemical and biological processes occurring in the soil [13]. Different age groups of oil palm account for the variation in soil and plant macronutrient contents. That is, nutrients are used up at different stages of growth and development in oil palm plantations and during harvesting [14] and crops (including oil palm) typically influence the changes in soil physicochemical properties and plant macronutrient contents. Moreover, nutrients depletion may result to a decline in soil fertility, if there is inadequate replenishment of mineral fertilizers and manure [13]. The management practices adopted in perennial crop culture differs across age groups. Meanwhile management practices like weeding decreases in frequency with age due to canopy coverage, management practices like fertilizer application increases with the age of oil palm. Within a given age group, the management practices are uniform and across age groups, the management practices differ.

Smallholder oil palm production improves the income levels and standards of living of farmers and remain a dominant production system in Cameroon with two-thirds of the plantations surface area in the hands of smallholders and just one-third in the hands of agro-industries [15] [16]. On the contrary, smallholders have been recording very low yields (less than 5 ton FFB/ha/year) far below the potential yield of 20 tons FFB/ha/year, compared to agro-industrial companies like SOCAPALM in Cameroon [17]. These poor yields are partly attributed to the agronomic practices implemented by farmers in their plantation, which many studies have decried the fact that these agronomic practices are far below standards. These low yields could have resulted to extensification strategies currently practiced by most smallholders. The question we are trying to answer is, what are the quality standards of management practices used by oil palm farmers and its influence on soil and plant macronutrients? Best agronomic practices entail using improved cultivars adapted to the agro ecological setting and the use of recommended types and rates of inputs amongst others [18].

The study was undertaken to better document management practices and their performances regarding reference or standard values across oil palm plantations age groups in Dibombari Sub-Division. The hypothesis of the study was as follows: Ho-Management practices implemented by farmers were below standard practices and Ha-Management practices implemented by farmers were within or above standard practices. The paper is structured into the following: Introduction, materials and methods, results, discussion and conclusion.

2. Materials and Methods

2.1. Study Site

Dibombari Sub-Division has a total surface area of about 150 square kilometers, with geographical coordinates: 4˚10'54"North, 9˚38'42"East and located some 18km from Douala, Littoral Region of Cameroon [17]. Dibombari Sub-Division is one of the 13 Sub-divisions in the Mungo Division (**Figure 1**). The climatic condition of the area is described as equatorial, with dry and humid seasons. The dry season runs from mid-November to late March, while the humid (rainy) season runs from late March to mid-November. The highest average temperature is 34˚C in January and the lowest is 28˚C in July. Thus, the average annual temperature and rainfall in Dibombari are 31˚C and 2402.8 mm, respectively. Generally, the Mungo Division comprises of alluvial soils, resulting from the weathering of sedimentary rocks. They are essentially sandy and commonly rich in quartz and clay minerals. These soils are very permeable in some areas. However, in other areas, the soils are very rich in clay to the extent that percolation of rainwater takes quite a long time [19]. The major source of livelihood for the local population is derived from agricultural activities, with most farmers involved in oil palm cultivation.

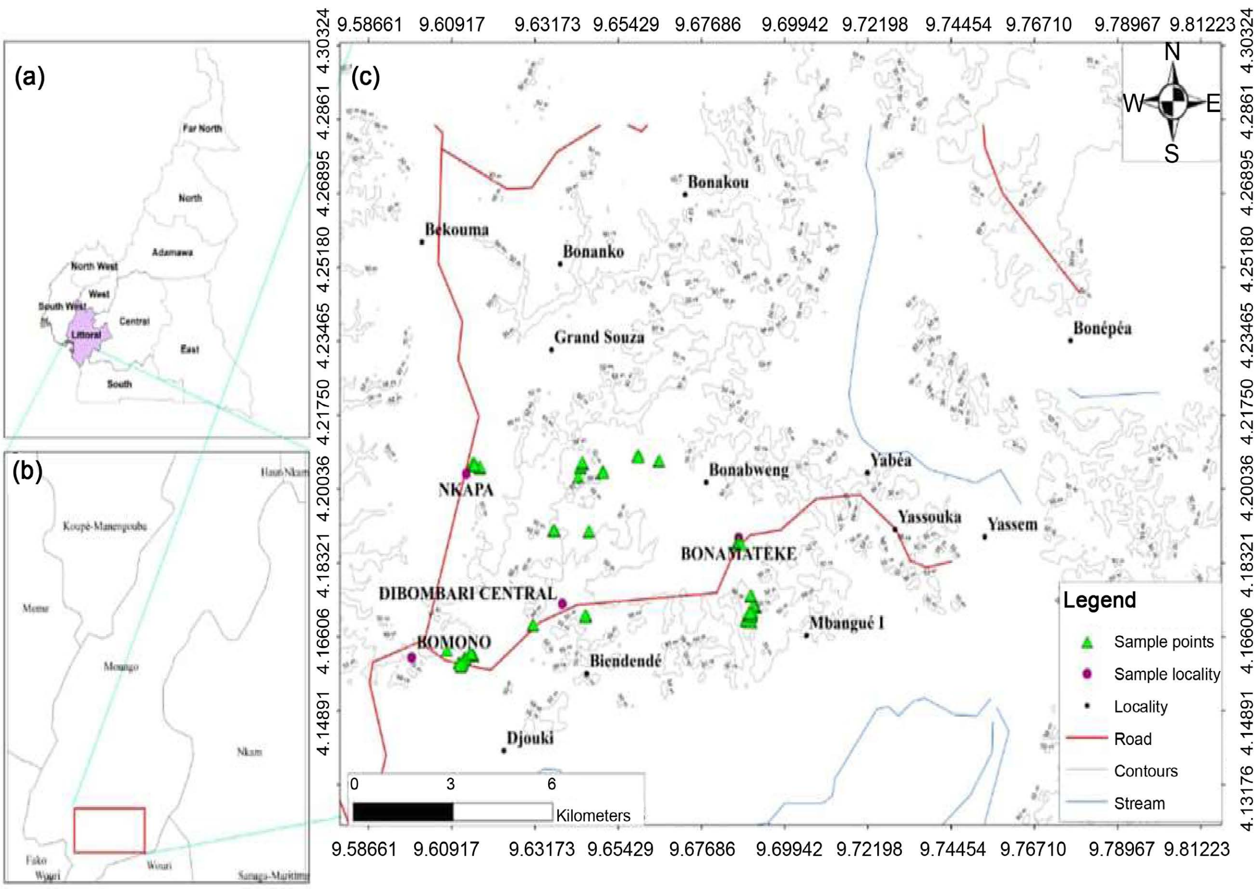

Figure 1. Map of study site with sample locality and sample points.

2.2. Research Design

2.2.1. Sampling Design for Field Survey

A field survey was carried out with farmers, in four different locations (*i.e.* Dibombari-central, Bonamateke, Bomono and Nkapa), of the study site. Two hundred (200) oil palm farmers were sampled through a stratified random sampling design (this involves the partitioning of farmers into different categories and a random sampling of each category of farmers in the sector), with structured questionnaires used to collect data on farmers' categories and the agronomic practices to achieve the first specific objective.

2.2.2. Sampling Design for Soil and Plant Analysis

Also, soil and plant leaf samples were collected in oil palm plantations of different age groups (*i.e.* 0 years, >0 - 4 years, >4 - 8 years and >8 - 15 years plantations), in a randomized complete block design experiment among independent farmers plots. We choose the different age groups because the nutrient needs of oil palm just like other perennial crops increases with age. Within a given age group, the nutrient needs and other management practices are stable, but as you leave from one age group to the other, the management practices will differ. It is also important to note that these management practices, especially fertilizers have an influence on the performance of oil palm.

The size of each plot was 3025 m^2, with 37 palms per plot. Sixteen (16) palms in each plot were sampled, giving a percentage sampling intensity of 43%. Specific criteria were used to select oil palm plantations for soil and foliar sampling. They included; the altitude of the plantation, past vegetation type, past utilization of the land before oil palm cultivation, cycles of oil palm cultivation, the cropping system used in oil palm cultivation, age group(s) of the oil palm plantations, cultivar of oil palm planted. This procedure for collecting soil and foliar samples was repeated in the different locations to achieve the second specific objective.

2.3. Description of Standards for Agronomic Practices and That of Soil and Plant Analysis

Standard management practices are locally, regionally or internationally recognized and accepted practices, which if implemented by farmers will optimize the performance of the crop. The evaluation of management practices implemented by farmers, is simply done by comparing these practices with standard practices for the crop in question, to know whether they are below, within or above standard recommended practices. The standards for best agronomic practices are shown in Table 1, while that for soil and plant nutrients are shown in Table 2 and Table 3 respectively.

2.4. Data Collection

2.4.1. Categorization of Oil Palm Smallholders

Structured questionnaires was used to categorize farmers according to some

Table 1. Standards for good agronomic practices in oil palm plantations.

Components	Good agronomic practices	>0 - 4 years	>4 - 8 years	>8 - 15 years
Weeding	-Establishing and maintaining clean weeded circles (weeding at least three times/year). -Establishing and maintaining harvesting paths, every other palm row. -Selective weeding of woody and noxious weeds. -Correct mixing of chemicals in relation to observed weed cover, and effective application.	-Manual weeding, four times/year -Chemical weeding, three times/year	-Manual weeding, four times/year -Chemical weeding, three times/year	-Manual weeding, three times/year -Chemical weeding, two times/year
Fertilizer application	-Application of proper and balanced quantities of Urea, Rock phosphate and KCl fertilizers in kg/ha/year or equivalent. -Application of Empty Fruit Bunches as organic fertilizer.	-Apply: N, 168 kg/ha/year P, 140 kg/ha/year K, 252 kg/ha/year -Apply empty fruit bunches	-Apply: N, 210 kg/ha/year P, 252 kg/ha/year K, 350 kg/ha/year -Apply empty fruit bunches	-Apply: N, 305 kg/ha/year P, 280 kg/ha/year K, 420 kg/ha/year -Apply empty fruit bunches
Pruning	-Pruning every six months to optimal number of fronds. -Placing pruned fronds in a U-box or along contour lines.	Every six months	Every six months	Every six months
Pest and disease control	-Integrated Pest Management (IPM), adopt cultural, biological, mechanical, physical or other less-hazardous strategies to minimize the use of pesticides.	Adopt IPM Methods	Adopt IPM methods	Adopt IPM Methods
Harvesting	-Timely harvesting of fruit bunches in the field to maximize quality (*i.e.* every 10 days). -Harvesting based on a loose fruit minimum ripeness standard. -Collection of all loose fruits.	Every ten days	Every ten days	Every ten days

Source: [20] [21]. Also based on knowledge of the authors, discussion with key informants in the oil palm sector and secondary data from agro-industries in Cameroon.

parameters like socio-demographic characteristics (*i.e.* age group, gender, marital status, level of education and number of children), plantation ownership (*i.e.* independent-self and independent-pledged owners), farm sizes (*i.e.* small, medium and large-scale plantations, with farm sizes of 0 - 5 ha, >5 - 20 ha and >20 ha, respectively), as well as the origin of the farmers (*i.e.* native, migrants and elites) [10] (Nkongho *et al.*, 2014b). This approach was employed because these groups of farmers may have different ways of establishing and managing their plantations that could influence the soil nutrient status, plant macro-nutrient

Table 2. Standards for soil macronutrients.

Nutrients	Low	Moderate	High	Very high
Total N (%)	0.08 - 0.12	0.12 - 0.15	0.15 - 0.25	>0.25
Available P (mg/kg)	10 - 25	25 - 40	40 - 60	>60
K (cmol/kg)	0.08 - 0.20	0.20 - 0.25	0.25 - 0.30	>0.30
Mg (cmol/kg)	0.08 - 0.20	0.20 - 0.25	0.25 - 0.30	>0.30

Source: [22]. Based on knowledge of the authors, discussion with key informants in the oil palm sector and secondary data from agro-industries in Cameroon, we considered the mean values of moderate for immature palms (>0 - 4 years); mean values of high for mature palms (>4 - 8 years) and values of very high for mature palms (>8 - 15 years).

Table 3. Sufficiency ranges of oil palm leaf nutrients.

Nutrients	Optimum critical value ranges
N (%)	2.4 - 2.97
P (%)	0.08 - 0.14
K (%)	0.78 - 0.91
Mg (%)	0.25 - 0.98

Source: [23]. Based on knowledge of the authors, discussion with key informants in the oil palm sector and secondary data from agro-industries in Cameroon, we considered the lower range of the critical range for immature palms (>0 - 4 years); the mean value of the lower and upper range for mature palms (>4 - 8 years) and the upper range for mature palms (>8 - 15 years).

uptake and oil palm production.

2.4.2. Assessment of Agronomic Practices

Similarly, the agronomic practices carried out by smallholder farmers within the plantations were assessed using structured questionnaires complemented by on-farm visits. These practices were assessed based on the seed variety used (Pisifera, Dura and Tenera varieties), frequencies of the weeding methods (*i.e.* the frequencies of manual or chemical weeding), fertilizer application (none, irregular, regular), pruning intervals (once or twice per year), pest and disease control (yes, no) and harvest cycles ("every" two weeks, three weeks and four weeks, respectively) for the 200 sampled farmers.

2.4.3. Determination of Soil and Plant Macronutrient Contents

1) Soil sampling, pretreatment and analysis/determination of available soil macronutrients

During the soil sampling process, 16 core samples (in 4 locations, with each location having oil palm plantations of 4 age groups), were collected at 0 - 20 cm depth, using an auger and bulked for each age group to give 4 composite samples of 1 kg each. The core soil samples were collected at distances between 0 - 2 m and 2 - 5 m from the base of the palm for immature (>0 - 4 years) and mature palms (>4 - 8 years and >8 - 15 years) respectively, in a zig-zag pattern for each age group within a particular location [24]. The soil samples were air-dried in a controlled room, mixed thoroughly and sieved properly using a 2 mm sieve. The four composite samples were later partitioned into two sets and one set of 500 g each was sent for soil physico-chemical analysis, while the other set was reserve, in case of any eventuality.

For C and N analysis, soils were further fine ground to pass through a 0.5 mm sieve. Soil pH in water and KCl was determined using a pH meter in a 1:2.5 (w/v) soil: water suspension [25]. Organic C (in %), was determined by chromic acid digestion with heating and spectrophotometric analysis [26]. Total N (in %) was determined from a wet acid digest [27] and analyzed by colorimetric analysis [28]. Exchangeable cations (Ca, Mg and K) (in cmol/kg), were extracted using ammonium acetate at pH 7 and analyzed by flame atomic absorption spectrophotometry (AAS) [29]. Available P (in mg/kg), was extracted by Bray-1 and determined using the molybdate blue procedure described by Murphy and Riley [30]. Particle size (in %) was determined using the rapid method of Arriaga *et al.* [31]. Parameters of interest in soil samples were analyzed at the International Institute of Tropical Agriculture (IITA), Yaounde.

2) Plant sampling, pretreatment and analysis/determination of available plant macronutrients

The plant samples were collected randomly from fronds 9 and 17 in the plantations for immature and mature oil palms, respectively in a zig-zag pattern for each age group within a particular location. The plant samples were collected after a count of 10 leaflets per frond on both sides of the rachis, with sampling done at the middle of each frond. These plant samples were then allowed to air dry at room temperature of 25˚C for some days. The leaflets were chopped into smaller pieces and twelve samples were prepared with three samples each from the different locations. The plant samples (100 g each) were sent for analysis, to determine the available macro-nutrients. Parameters of interest in plant samples were analyzed at IITA, Yaounde.

Basic cations; Ca, Mg, K, were determined by flame atomic absorption spectrophotometry to obtain their concentration at their different wavelengths. Total N and P were determined by wet acid digestion [27] and N analyzed by colorimetric analysis using a UV-VIS spectrophotometer [28], while P was measured by colorimetric analysis using Murphy-Riley reagent.

2.5. Data Analysis

This study employed both descriptive and inferential statistics to analyze the data collected from the field survey and on farm experiment, respectively.

Descriptive statistics included means, frequencies and percentages and was carried out for data collected from 200 farmers that were sampled during the field survey. For the comparison of farmer's agronomic practices with standard practices, we compared the frequency of farmers who respected standard practices with the frequency of farmers who did not respect standard practices, across age groups.

On the other hand, the inferential statistics included a two-way analysis of variance (ANOVA), to test for significance of soil and plant macronutrients, across oil palm age groups and Tukey pairwise comparison test, to separate treatment means that were significantly different at 95% confidence level ($P < 0.05$). For the soil and plant macronutrients, we compared the treatment means with standard or reference mean values documented in literature across age groups.

The statistical package used for the analysis was MINITAB version 2020 and Microsoft Excel 2016 to develop tables and graphs.

3. Results

3.1. Farmers' Information

3.1.1. Socio-Demographic Characteristics of Farmers

Out of 200 sampled farmers, 13 (6.5%) were between 21 and 35 years old, 104 (52%) were between 36 and 50 years, and 83 (41.5%) were between 51 and 65 years of age. 128 respondents (64%) were males, while 72 (36%) were females. 7 (3.5%) of the farmers were single, while the rest, 193 (96.5%) were married to either one or more wives. Eighty nine (44.5%) of the farmers had between 1 and 3 children, 77 (38.5%) had between 4 and 6 children, 30 (15%) had between 7 and 9 children, while 4 (2%) of these farmers had more than 9 children and the average number of children per household was 4. Finally, 122 (61%) of the sampled farmers had primary education, 48 (24%) had secondary education with Ordinary levels, 26 (13%) had secondary education with Advance levels, while 4 (2%) had university education, as shown in **Table 4**.

3.1.2. Plantation Ownership

Out of 200 sampled farmers in the area, 129 (64.5%) were independent (self-developed plantations), while 71 (35.5%) were independent plantations under pledge. This information indicates that a greater proportion of the farmers own and manage their plantations, unlike the pledged plantations. The resources to develop and manage the plantation are solely in the hands of the farmer, with little or no support, as shown in **Figure 2**.

3.1.3. Origin and Farm Sizes

Eighty-six (43%) of the farmers were native of the area, with 76 (38%) being small-scale, 10 (5%) being medium-scale, and none of them being large-scale producers. Also, 73 (36.5%) were elites with 20 (10%) being small-scale, 43 (21.5%) being medium-scale producers and 10 (5%) being large-scale producers. Finally, 41 (20.5%) of the farmers were migrants, with 33 (16.5%) being small-scale, 6 (3%) being medium-scale producers, and 2 (1%) large-scale producers. This indicates that oil palm cultivation is in the hands of different groups of

Table 4. Frequency distribution of smallholder farmers' characteristics.

Characteristics		Frequency	Percent
Age group	21 - 35	13	6.5
	36 - 50	104	52.0
	51 - 65	83	41.5
		200	100
Gender	Male	128	64.0
	Female	72	36.0
		200	100
Marital status	Single	7	3.5
	Married	193	96.5
		200	100
Level of education	Primary school	122	61.0
	Secondary school	48	24.0
	High school	26	13.0
	University	4	2.0
		200	100
Number of children	1 - 3	89	44.5
	4 - 6	77	38.5
	7 - 9	30	15.0
	>9	4	2.0
		200	100

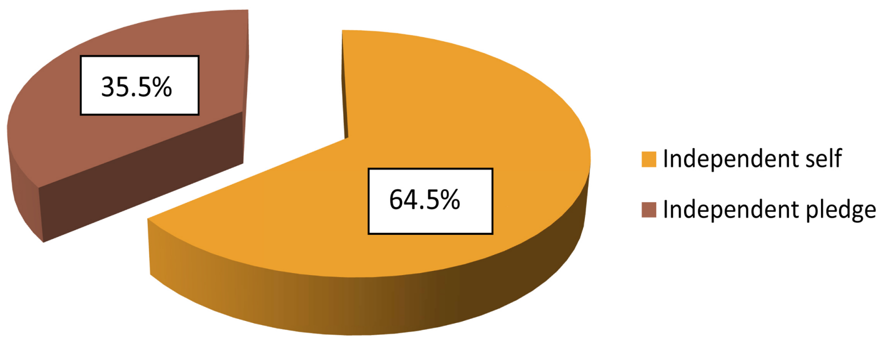

Figure 2. Percentage distribution of plantation ownership.

persons. Meanwhile, native and migrant farmers own smaller to medium-sized plantations, elites own more medium to large-scale plantations, as shown in **Figure 3**.

3.2. Agronomic Practices of Smallholders in Dibombari

Seventy (35%) out of 200 farmers planted the Dura variety, while 130 (65%)

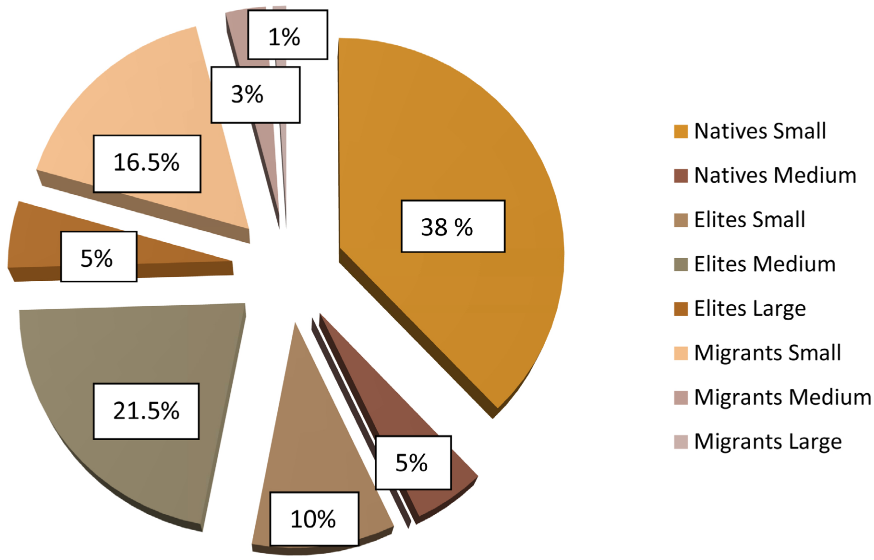

Figure 3. Percentage distribution of farmer's origin and size of plantation.

planted Tenera, the recommended variety in commercial plantations. 193 farmers weeded their plantations manually, with 38 respecting standards and 155 below standards. While 7 farmers weeded their plantations using chemical herbicides without respecting the standards for weeding in oil palm plantations. These indicate that a higher proportion of farmers (81%) weeding frequency were below standards recommended for manual and chemical weeding practices. One hundred and seventy seven farmers (88.5%) did not apply fertilizers, while 23 (11.5%) carried out irregular application, especially during the immature stage of their plantation. This indicates that all the farmers (100%) were below the standards for fertilizer application in their plantations. Also, 74 (38%) of the farmers pruned their plantations once a year, while 126 (62%) pruned twice a year, indicating that some farmers were below the standards for pruning, especially for mature plantations. Meanwhile, only 19 (9.5%) of the farmers carried out pest and disease control, and 181 (90.5%) did not, indicating that majority of farmers were below standards for pest and disease control. Eight (4%) of the farmers carried out harvesting every 2 weeks, 15 (7.5%) every 3 weeks, and 177 (88.5%) every 4 weeks, thus indicating that a higher proportion (96%) of the farmers were below standards for harvesting, as shown in Table 5.

There were major differences between farmers' practices and the standards for agronomic practices in all the different age groups and farm sizes of the oil palm plantations. This indicates that the farmers did not respect and follow the norms recommended for agronomic practices in their plantations.

3.3. Soil Properties and Plant Nutrients

3.3.1. Soil Physical Properties

The Sub-Division is dominated by sand particles with an average of 76.11% sandy loam texture. In addition, the average clay and silt contents of the soil

Table 5. Frequency distribution of standards for agronomic practices in smallholder plantations.

Activity		Standard	Oil palm plantation age group		
			(>0 - 4)	(>4 - 8)	(>8 - 15)
Variety	Dura		5	54	11
	Tenera	Tenera	29	85	16
Weeding	Manual	Standard	5	29	4
		No standard	25	108	22
	Chemical	Standard	0	0	0
		No standard	4	2	1
Fertilizer application	None		30	122	25
	Irregular		4	17	2
	Regular	Regular	0	0	0
Pruning	Once		18	93	13
	Twice	Twice	16	46	14
Pest/disease control	No		25	133	23
	Yes	Yes	9	6	4
Harvesting frequency	4 weeks		28	124	25
	3 weeks		4	9	2
	2 weeks	2 weeks	2	6	0

Standard for manual weeding; 0 - 4 years (4 times/year), 4 - 8 years (4 times/year), 8 - 15 years (3 times/year), Standard for chemical weeding; 0 - 4 years (3 times/year), 4 - 8 years (3 times/year), 8 - 15 years (2 times/year).

were 17.66% and 6.23%, respectively, which are lower compared to that of the sand particles, (Table 6).

3.3.2. Soil Chemical Properties

Apart from the soil pH which did not record significant results across age groups, other soil chemical properties like organic carbon, total N, C/N ratio, available P, Ca, Mg and K recorded significant results across oil palm age groups. O-years plantations recorded highest significant values, compared to the other age groups, while least values were recorded in >8 - 15 years plantations, with the exception of available P, as shown in Figures 4(a)-(h).

1) Comparison of soil macronutrients content with standard values

The soil macronutrient contents for N, K and Mg were low across the different age groups, while P was optimal at >0 - 4 years and >4 - 8 years' plantations but low at >8 - 15 years' plantation, compared to the recommended soil nutrient status, as shown in Table 7.

3.3.3. Plant Macronutrients Content

N, P and K recorded significant difference at >0 - 4 years age group, while Mg

Table 6. Texture of soil samples across age groups of oil palm plantations.

Age groups (in years)	Sand %	Silt %	Clay %	Textural class*
0	74.11	7.78	18.10	SL
>0 - 4	76.11	5.71	18.18	SL
>4 - 8	78.11	5.71	16.18	LS
>8 - 15	76.11	5.71	18.18	SL

*SL = sandy loam; LS = loamy sand.

Table 7. Comparison of soil macronutrient contents across the different age groups.

Age groups (in years)	N (%)	P (mg/kg)	K (cmol/kg)	Mg (cmol/kg)
>0 - 4	0.12 (0.15)*	47.54 (40.0)	0.04 (0.25)	0.21 (0.25)
>4 - 8	0.12 (0.20)	57.30 (50.0)	0.03 (0.28)	0.10 (0.28)
>8 - 15	0.08 (0.25)	52.00 (60.0)	0.03 (0.30)	0.10 (0.30)

*Recommended soil nutrient status in brackets, Source: [22] [23].

did not record any significant difference for treatment means as shown in Table 8.

The plant macronutrient contents of N and P were optimal across the different age groups of the plantations, while K and Mg were optimal at 0 - 4 years' plantation but low at 4 - 8 years and 8 - 15 years' plantations, as shown in Table 9.

4. Discussion

4.1. Socio-Demographic Characteristics of Farmers

Based on gender, oil palm plantations are in the hands of men, while women and youths own fewer plantations. This is probably because our tradition and customs favor men in land ownership more than women, and to an extent, farm operations in the plantation are labor-intensive, with men having more physical strength than women for farm upkeep [18]. More married persons own plantations than singles, which can cause farmers to adopt a sedentary lifestyle that could be beneficial in managing their plantations. Most plantations are owned by mid-age and aging populations, probably because they can easily afford the finance needed through personal savings, to develop and manage their plantations [12]. Smallholders, don't have collaterals and as such cannot easily solicit for bank loans, to enable them develop and manage their oil palm plantations and the structuring of farmers into cooperatives and linkages with other systems of production is very minimal. All the farmers are literate, meaning that they can easily adopt new techniques and methods to manage their plantations. With an average of four children per household, farmers cannot rely solely on family labor.

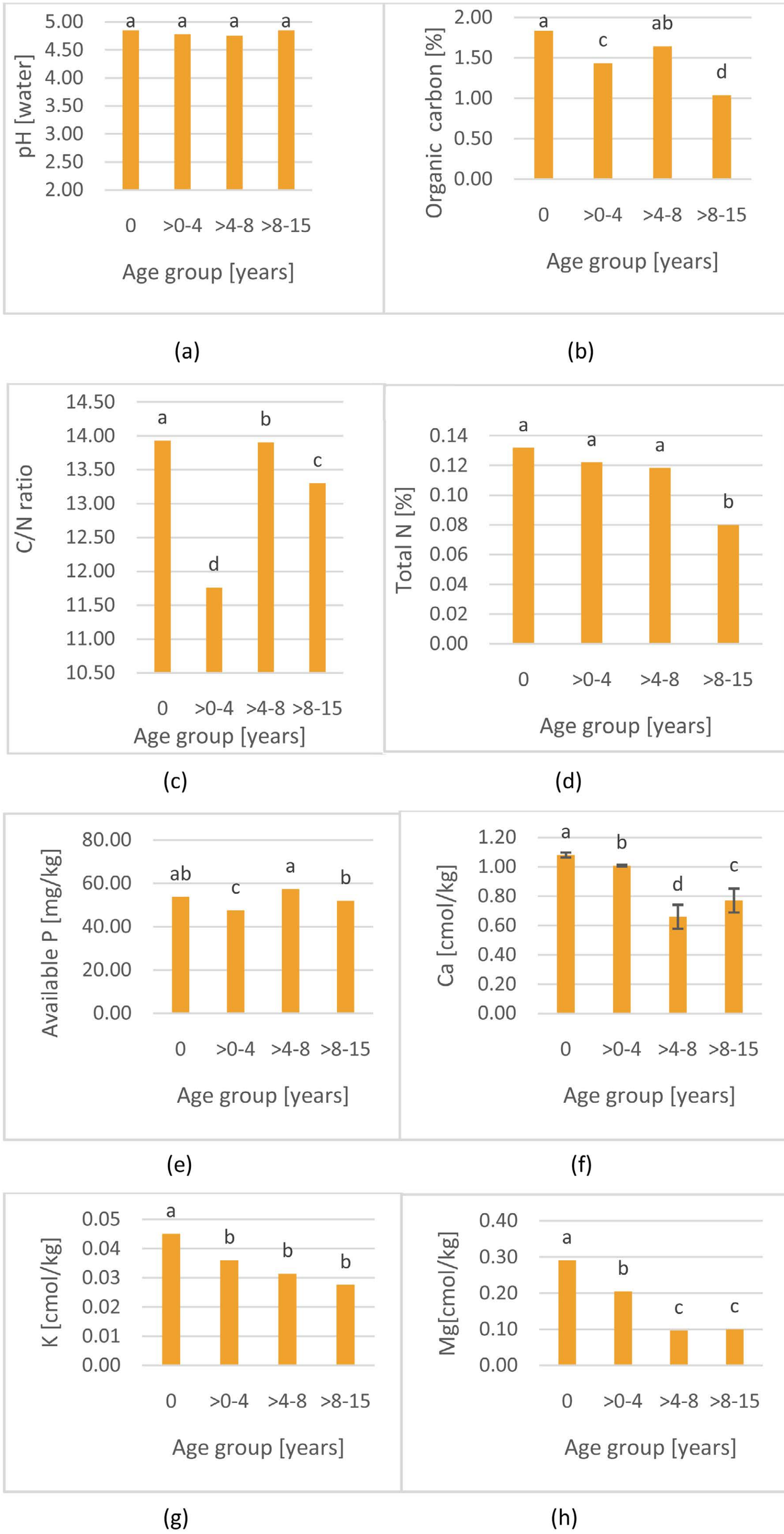

Figure 4. (a)-(h) Comparison of soil chemical properties across oil palm age groups.

Table 8. Comparison of plant macronutrient contents across the different age groups.

Age groups (in years)	N (%)	P (%)	K (%)	Mg (%)
>0 - 4	3.46 ± 0.0a	0.26 ± 0.0a	1.16 ± 0.0a	0.30 ± 0.0a
>4 - 8	3.18 ± 0.1b	0.21 ± 0.02b	0.70 ± 0.1b	0.41 ± 0.1a
>8 - 15	3.03 ± 0.2 b	0.20 ± 0.01b	0.69 ± 0.2b	0.30 ± 0.1a

Treatment means represented by the same letters are not significantly different under Turkey Test at 5% probability.

Table 9. Comparison of plant macronutrient contents with standard values.

Age groups (in years)	N (%)	P (%)	K (%)	Mg (%)
>0 - 4	3.46 (2.40)	0.26 (0.08)	1.16 (0.78)	0.30 (0.25)
>4 - 8	3.18 (2.69)	0.21 (0.11)	0.70 (1.16)	0.41 (0.62)
>8 - 15	3.03 (2.97)	0.20 (0.14)	0.69 (1.53)	0.30 (0.98)

Leaf nutrient critical levels in brackets, Source: [22] [23].

Thus additional cost is incurred to hire other sources of labor for farm upkeep, depending on the size of the plantation. Owners of plantations are self-independent and pledged-independent farmers. Both categories of farmers hardly benefit from any external assistance [10]. Meanwhile, self-independent farmers are interested in the sustainability of their plantation; this may not be the case for pledged-independent farmers, probably because they are more interested in the harvesting of FFB depending on the duration of their contract agreement with the owners of the plantation [32]. Although fewer women and youths own plantations due to cultural limitations and capital, they can enter into informal or formal contractual agreements with owners (pledge) to own and manage plantations together with the proceeds for a specific duration. In terms of plantation ownership, while native and migrant farmers are dominant in small and medium-scale plantations, the elites are dominant in medium and large-scale plantation ownership [32]. Compared to native and migrant farmers, elites have the resources and influence to initiate and implement agricultural development, especially in their region of origin. However, according to Nkongho *et al.* [9], the adoption of best agronomic practices amongst the different categories of farmers was not very different.

4.2. The Management Practices Used by Farmers

The introduction of standards for agronomic practices is significant for inclusive innovation that improves the technical and organizational changes of smallholders in the oil palm sector, which is in line with Chataway *et al.* [33]. Though most (65%) of the farmers planted Tenera seeds bought from research institutions to develop their plantations, some farmers still had a mixture of both tenera and dura palms in their plantations. The Tenera variety, with its thick mesocarp, has the potential to produce more palm oil though it is expensive compared to the Dura, with a thin mesocarp and less palm oil [8] [34]. The seed production and supply chain is distorted, with priority given to agro-industrial companies, who purchase in large quantities, compared to smallholders who purchase in smaller quantities. The institutions that produce certified oil palm seeds in Cameroon currently function below capacity and it takes time and resources to make available certified seeds to end users. When farmers buy seedlings from intermediaries, who claim to have bought from certified seed producers, the results are often questionable. The genetic potential of the planting material and it's adaptability to site specificity, together with other management practices, have an influence on the performance of the oil palm plantation.

The majority (77.5%) of the farmers used manual weeding, below standard practices for cycle and interline in the different age groups of oil palm, with minimal synthetic herbicides due to high cost. Though manual weeding is labor-intensive, it helps to protect the shallow feeder roots of oil palm, which could be destroyed due to the overuse of synthetic herbicides [20]. While heliophytic weeds dominate the immature growth stages of oil palm plantations, sciophytic weeds dominate the mature growth stages, especially after canopy coverage. Weeds, depending on their severity, compete with the crop for below ground resources like water and nutrients, as well as above ground resources like sunlight. If a good weed management strategy is not adopted, especially for immature palms, the palms will seriously be damaged by rodents.

The majority (62%) of the farmers' practices were below standards for pruning. According to studies carried out by Woittiez *et al.* [20], pruning could maintain optimal canopy, rationally use resources, and ease harvesting, but it depends on the age of the palms.

Majority (90.5%) of the farmers practices were below standards for pest/disease control though few farmers complained about the relevance, which could also be due to their low level of expertise in the area of identification of symptoms of pests and diseases, which is in line with reports by [20] [35] [36]. Though the Sub-division is not endemic to pests and diseases of economic importance, pests and diseases pose deleterious effect on the physiology of oil palm. Some pest/diseases cause root rot, leading to stunted growth and wilting, while others feed on the foliage, leading to challenges in the production and assimilation of food substances during photosynthesis.

Regarding harvesting, majority (96%) of the farmers harvested their plantations at 4 weeks intervals, below the standards for harvesting, but beneficial in terms of lower labor costs, though it has an effect on the quality of FFB [18]. The recommended harvesting interval is 14 days and the fresh fruit bunches need to be processed between 24 - 48 hours, so as to optimize the quality of the palm oil. Longer harvesting intervals and days of fermentation leads to increase in moisture content, free fatty acids, peroxide value, etc, which not only undermines the quality of the final product, but also reduces its shelf life.

All the farmers (100%) were far below standards for fertilizer application though fewer farmers did irregular application at the immature stages of the plantations, which is in line with studies carried out by Lim *et al*. [4]. The knowledge of the fertilizer types and application rates, in addition to the cost, could be problematic to farmers, and the consequences of these are lower FFB yields. This conforms with studies according to Comte *et al*. [37], which suggested that low FFB yields in smallholder plantations could partly result from limited fertilizer use. It is important for us to note that amongst the management practices listed above, the non-application of fertilizers by farmers has a major influence on soil and plant macronutrients and has been elaborated below.

4.3. Effect of Management Practices on Soil and Plant Macronutrients Content

The very low soil pH (H_2O) of the study site was also observed by Tening *et al*. [19]. These values are optimal for oil palm production, which is in line with studies carried out by [14]. The variation in pH values across the different age groups of oil palm could be attributed to the uptake of the basic cations at the early growth stages of oil palm. The high organic carbon content observed across the different age groups may have been due to the accumulation of organic matter over the years on the surface layer, which corroborates with similar works done by Ogeh and Ogwurike [38]. Total nitrogen (N) followed a similar trend with organic carbon, which is also in line with studies carried out by [14]. The high C/N ratio could be due to immobilization of nitrogen and hence not available for plant uptake. Tening *et al*. [39] also observed high C/N in soils of this agroecological zone. Cation exchange capacity (CEC) affects fertilization and liming practices. High CEC soils retain more nutrients than low CEC soils. Thus, sandy soils with low CEC will increase nutrient loss through leaching [40] and need to be limed more frequently but at lower application rates (split application) than clays soils. Ngane *et al*. [41], established that 2 tons ha^{-1} of lime was needed to ameliorate the acid condition of soils within this zone, to give optimum crop yield. Also, the basic cations (Ca, Mg, and K) were consistently low across the different plantations. This could be attributed to the effect of continuous uptake of nutrients by the plants overtime without replacement, which was not different from studies carried out by [42]. In addition, this could be due to the low content of organic matter and the presence of low activity clay in the area [43].

The plant macronutrient contents for N and P were optimal across the different plantations, while K and Mg were optimal at >0 - 4 years' plantations only, but low at >4 - 8 years and >8 - 15 years' plantations. This could partly be due to immobilization, leaching, runoff, and nutrient antagonism in the soil, as reported in studies conducted by [23]. In addition, K also plays a significant role in bunch production, and it is not surprising why smallholders in the sub-division are recording low yields.

Thus, the variation in soil and plant macronutrient contents from the standards may be attributed to the differences in management practices from the norm. This conforms to studies carried out by [44].

5. Conclusion

Majority of the farmers are indigenes of the area and their agronomic practices are poor and rudimentary compared to the standards for good agronomic practices. K and Mg are low in the soil and oil palm foliage. K is essential in bunch production, while Mg plays a significant role in chlorophyll production. These could partly be responsible for the low FFB yields within smallholdings in Dibombari Sub-Division. This study established a low level of adoption of the standards for agronomic practices, which also has influence on the soil and plant macronutrient contents.

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Conflicts of Interest

The authors declare that there is no conflict of interests regarding the publication of this manuscript.

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